ARUP

BOSTON HOUSING AUTHORITY

Decarbonizing Boston’s Affordable Housing

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What this plan is and is not

The BHA decarbonization study is a data-driven strategic implementation plan that provides BHA with an actionable approach and clear next steps to accelerate the decarbonization process.

This plan is:

- Provide a strategic roadmap for decarbonization across BHA portfolio, prioritizing developments as near and mid term candidates for electrification.
- Identify systems requiring for electrification in representative typologies of buildings and suitable technologies for replacement
- Collate resources to aid in decision making when implementing an electrification project including procurement
- Estimate rough order of magnitude costs for implementation
- Acknowledge known uncertainties and outlines next steps to solidify the data supporting the recommendations

This plan is not:

- A detailed implementation plan. This plan sets the course, but many details need to be worked out soon to put it into motion.
- Serve as a proxy for building audit reports or for detailed cost estimates

This plan includes:

- Electrification prioritization by BHA development
- Electrification intervention points and decision trees
- Decarbonization strategies and technologies
- Potential energy and carbon savings from efficiency and decarbonization measures
- Potential capital costs by phase and measure
- Potential incentives by phase and measure
- Indicates potential procurement pathways for consideration
- Indicates priority next steps

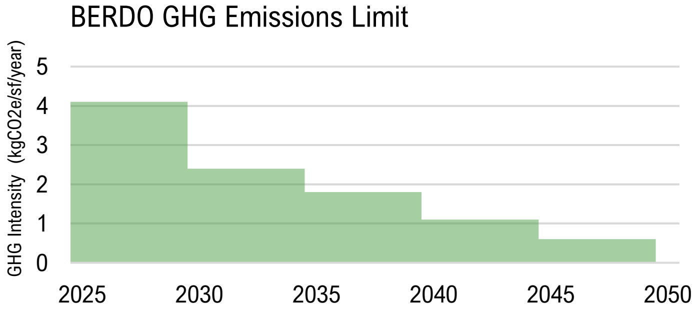
Why decarbonize?

To meet BHA's fossil-fuel free mandate, all BHA developments will be electrified by 2030.

Regulatory drivers of change

Fossil Fuel Free Public Housing target for 2030 set by Boston Housing Authority and City of Boston is an ambitious driver of change. The BHA aims to achieve full electrification by 2030.

Building Energy Reporting and Disclosure Ordinance (BERDO 2.0) BHA also must meet or exceed relevant City of Boston emissions requirements and other relevant climate action targets by 2030.


BERDO GHG Emissions Limit

Resident health and wellbeing

Reducing or eliminating carbon emissions associated with energy use in residential buildings, can have several positive impacts on the health and well-being of the residents, including the following:

Indoor Air Quality and Health Equity Vulnerable populations, including low-income individuals who often reside in public housing, are disproportionately affected by environmental hazards. By decarbonizing BHA can reduce exposure to environmental pollutants and providing cleaner, healthier living conditions for all residents.

Thermal Comfort Maintaining a comfortable indoor temperature can positively impact mental well-being and physical health, particularly among vulnerable populations such as the elderly and young children.

Other drivers of change

The energy system is undergoing rapid transformation: Reducing carbon emissions by eliminating fossil fuels from the grid and buildings is a global imperative. But decarbonization is not the only force of change.

Other drivers of change:

- Climate-driven impacts and other hazards (heat, floods, cyber, etc.)
- Moving energy generation away from fossil fuels towards renewable sources
- Building and transportation electrification
- Aging infrastructure seeing increasing energy demands
- Sociodemographic, economic, and political forces like population growth, migration, and war can impact energy demand, availability and cost

2.0 The current state

BHA’s building stock
  Building characteristics
  Portfolio emissions by end-use
  EUI and CEI

BHA's building stock

Development, building, and unit snapshot

Comprised of over 500 buildings, the BHA portfolio is scattered around the City of Boston. The recommendations within the scope of this study therefore have the potential to touch over 9,000 residential units.

There are multiple angles from which this portfolio and its characteristics may be considered: on a development basis, a building-by-building basis, a unitary basis, or a square footage basis. Our analysis takes a two-pronged approach - building level characteristics that are most pertinent when considering decarbonization technologies and unitary analysis to best understand any inherent characteristics that inform decarbonization modeling and recommended actions.

Portfolio snapshot

Developments
59 in scope developments

Units
9,476 in scope units
Over 50% of all units in Walk Up buildings

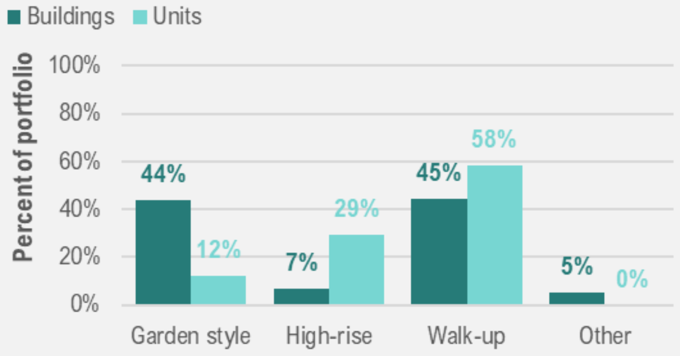
Buildings
519 in scope buildings
Walk-up: most common typology

Key Features
Though numerous, garden style buildings comprise a relatively smaller total unit count and portfolio area

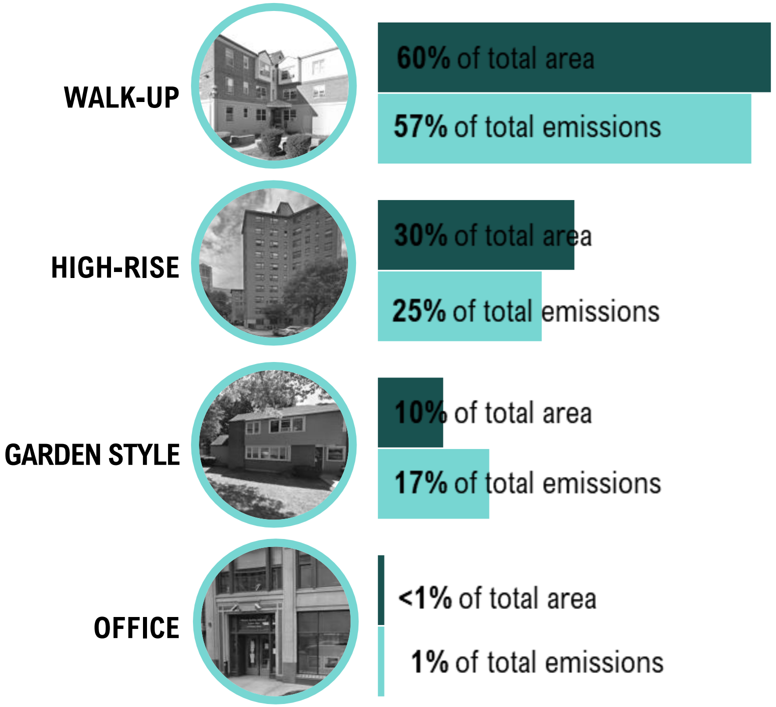
The **Walk Up** is the dominant typology within the BHA portfolio: it represents the majority of portfolio square footage, buildings, and units. Consequently, it also accounts for the majority of portfolio carbon emissions.

Portfolio analysis revealed that while the garden style typology accounts for a large number of buildings, it actually accounts for a relatively smaller proportion of units and portfolio square footage. Conversely, though fewer in number, the high-rise typology represents a proportionally larger amount of unit and portfolio square footage. This is unsurprising as a high-rise building is more spatially efficient than a garden style unit. Though accounting for a smaller number of units (12%) and portfolio square footage (10%), the garden style typology accounts for an elevated ratio of portfolio carbon emissions (25%), due to the typology's higher façade area-to-volume ratio.

Buildings and units by typology



Four building types were selected for this study, representing 100% of the BHA building stock by floor area. A description of the four archetypes is provided below and detailed in the Pathways section.



WALK-UP
60% of total area
57% of total emissions

HIGH-RISE
30% of total area
25% of total emissions

GARDEN STYLE
10% of total area
17% of total emissions

OFFICE
<1% of total area
1% of total emissions

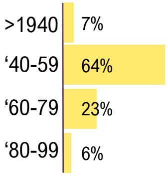
A portfolio represented by 4 archetypes

60% of total area
57% of total emissions

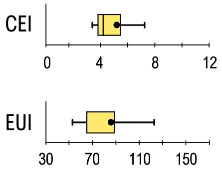
WALK-UP

Developments	28
Buildings	226
Dwelling units	5,741
Area (sf)	5.6M
Typical Floors	3
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Tenant A/C
Ventilation	Passive
Cooking	Gas Stove

VINTAGE
% of buildings



EUI in kBtu/sf/yr
CEI in kgCo$_2$e/yr

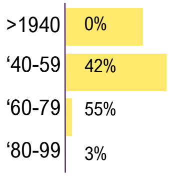


30% of total area
25% of total emissions

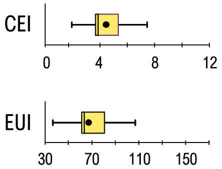
HIGH-RISE

Developments	21
Buildings	34
Dwelling units	2,753
Area (sf)	2.8M
Typical Floors	6-20
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Tenant A/C
Ventilation	Make-up air unit
Cooking	Gas Stove

VINTAGE
% of buildings



EUI in kBtu/sf/yr
CEI in kgCo$_2$e/yr

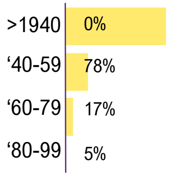


10% of total area
17% of total emissions

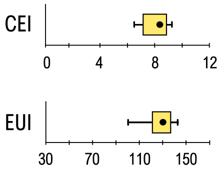
GARDEN STYLE

Developments	12
Buildings	234
Dwelling units	1,272
Area (sf)	1.5M
Typical Floors	2
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Tenant A/C
Ventilation	Passive
Cooking	Gas Stove

VINTAGE
% of buildings



EUI in kBtu/sf/yr
CEI in kgCo$_2$e/yr

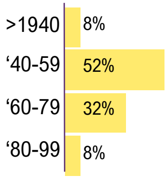


<1% of total area
1% of total emissions

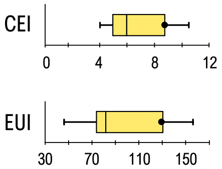
OFFICE

Developments	20
Buildings	25
Dwelling units	0
Area (sf)	70,240
Typical Floors	1
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Window Unit
Ventilation	AHU
Cooking	NA

VINTAGE
% of buildings



EUI in kBtu/sf/yr
CEI in kgCo$_2$e/yr



1. The energy-use values represent the average typology characteristics.
2. The energy and carbon emission statistics are the average for the typology. Both energy use intensity (EUI) and carbon emissions intensity (CEI) are area-normalized values. The latter metric, CEI, is one of the carbon emissions reporting factors used by the City of Boston via its BERDO protocol.

THE CURRENT STATE

BHA’s building stock

Building Characteristics

Three-quarters (75%) of all BHA buildings are 60 years old or older.

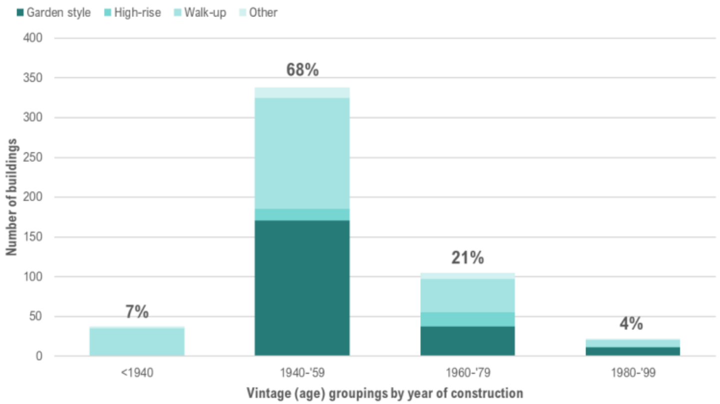
	**Walk-up**	**140 buildings** were built in 1940-’59 Only **4%** are from 1980-’99 (or later)
	**High-rise**	The **“newest”** typology **58%** of buildings from 1960-’99
	**Garden style**	**171 buildings** were built in 1940-’59 Only **5%** are from 1980-’99 (or later)
	**Office**	**52%** were built in 1940-’59 Only **25 buildings** in this typology
	Portfolio	**375 buildings** were building built before 1980

Assumptions & Notes

1. Considers only “in-scope” buildings.
2. Building typologies are based on classifications derived during building characteristic analysis (i.e.: elevator buildings that are 4 stories or fewer are considered to be “Walk Ups” in the context of this study).

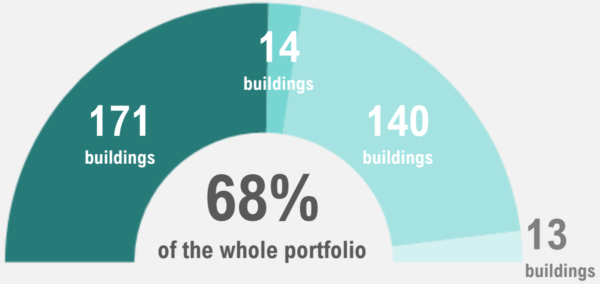
VINTAGE

Distribution of BHA buildings by age



1940-1959 Vintage Group

■ Garden style ■ High-rise ■ Walk-up ■ Other



68% of the entire BHA portfolio falls into this vintage group. Consequently, over two thirds of all BHA buildings are at least 60 years old. When combined with the 1940s and earlier vintage grouping, this percentage jumps up to 75%. Furthermore, except for the high-rise typology, the majority of each typology is comprised of buildings in this vintage group: garden style (78%), Walk Ups (62%), and all other/office buildings (52%).

DEMOGRAPHICS

Representing a diverse group of occupants, BHA nonetheless houses some occupants at elevated risk of heat and cold stress as a result of their age.

Overall, 16% of the total BHA population is age 5 or less, and 9% of all BHA households contain at least one child under the age of 5.

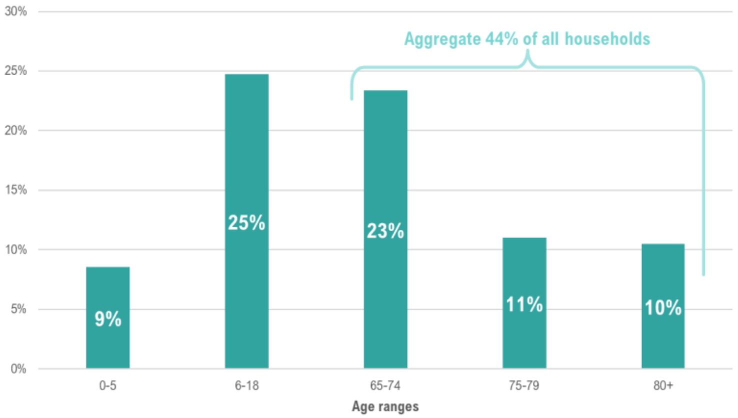
This means that children are concentrated within households (i.e.: families are more likely to have multiple children than there are families with just one child).

34% of the total BHA population is aged 65 and older, while 45% of all BHA households contain at least one resident aged 65 and up.

This means that the elderly population is dispersed across a proportionally larger number of households.

The very young and the very old are more are risk from extreme temperatures. Consequently, efficient and effective heating and cooling equipment can help this demographic group combat heat and cold stress risks.

Percentage of total households with at least one occupant in sensitivity age group



BHA's building stock

Portfolio emissions by end-use

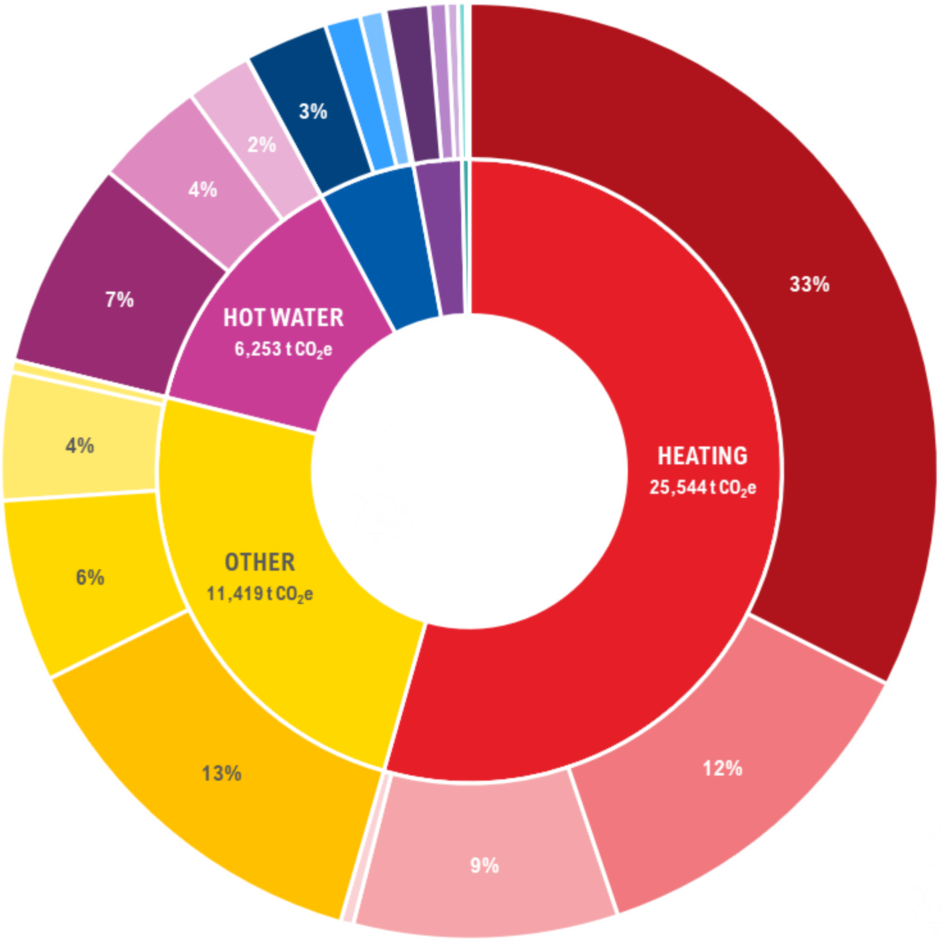
Key Stats

Over half of all portfolio emissions are associated with providing space heating.

Space heating	**54%** of total portfolio emissions **93%** of which are Scope 1
Hot water	**13%** of total portfolio emissions **93%** of which are Scope 1
Cooking	**3%** of total portfolio emissions **59%** of which are Scope 1
Laundry	**<1%** of total portfolio emissions **10%** of which are Scope 1
Cooling	**5%** of total portfolio emissions **0%** of which are Scope 1
Other	**24%** of total portfolio emissions **0%** of which are Scope 1

Assumptions & Notes

1. All emissions are calculated with a 2023 grid carbon emissions factor. See *Appendix: Carbon Emissions Factors* for additional information.
2. Scope 1 emissions describes emissions from the onsite burning of fossil fuels. Natural gas is the primary fossil fuel consumed in the BHA portfolio.
3. Scope 2 emissions refers to emissions resulting from the consumption of electricity. The BHA portfolio will still have Scope 2 emissions until either the grid is sourced from 100% renewables or BHA installs on-site renewables to 100% of portfolio electricity use.
4. "Other" emissions describes emissions coming from end-uses including indoor and outdoor lighting, plug loads, and miscellaneous equipment.
5. Emissions shown to the right are combined Scope 1 and 2 emissions.



Heating	**25,544 t CO_2e**
Walk-up	15,249 t CO_2e
High-rise	5,798 t CO_2e
Garden Style	4,279 t CO_2e
Other	218 t CO_2e
Hot water	**6,254 t CO_2e**
Walk-up	3,382 t CO_2e
High-rise	1,802 t CO_2e
Garden Style	1,063 t CO_2e
Other	7 t CO_2e
Cooking	**1,153 t CO_2e**
Walk-up	683 t CO_2e
High-rise	295 t CO_2e
Garden Style	174 t CO_2e
Laundry	**192 t CO_2e**
Walk-up	47 t CO_2e
High-rise	133 t CO_2e
Garden Style	12 t CO_2e
Cooling	**2,351 t CO_2e**
Walk-up	1,362 t CO_2e
High-rise	565 t CO_2e
Garden Style	366 t CO_2e
Other	58 t CO_2e
Other	**11,419 t CO_2e**
Walk-up	6,208 t CO_2e
High-rise	2,963 t CO_2e
Garden Style	2,060 t CO_2e
Other	188 t CO_2e

BHA's building stock

EUI and CEI

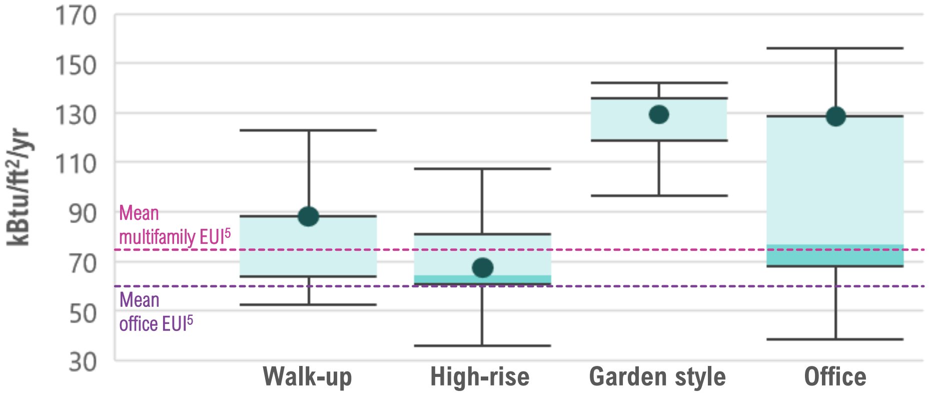
Key Stats

 **Walk-up**	**65.0 kBtu/ft2/yr** median EUI **4.21 kg CO_2e/ft^2/yr** median CEI
 **High-rise**	**63.5 kBtu/ft2/yr** median EUI **3.87 kg CO_2e/ft^2/yr** median CEI
 **Garden style**	**136.9 kBtu/ft2/yr** median EUI **8.87 kg CO_2e/ft^2/yr** median CEI
 **Office**	**81.8 kBtu/ft2/yr** median EUI **5.96 kg CO_2e/ft^2/yr** median CEI
Portfolio	**43.7 kBtu/ft2/yr** median EUI **3.83 kg CO_2e/ft^2/yr** median CEI
BERDO	**4.1 kg CO_2e/ft^2/yr** CEI (residential) **5.3 kg CO_2e/ft^2/yr** CEI (office)

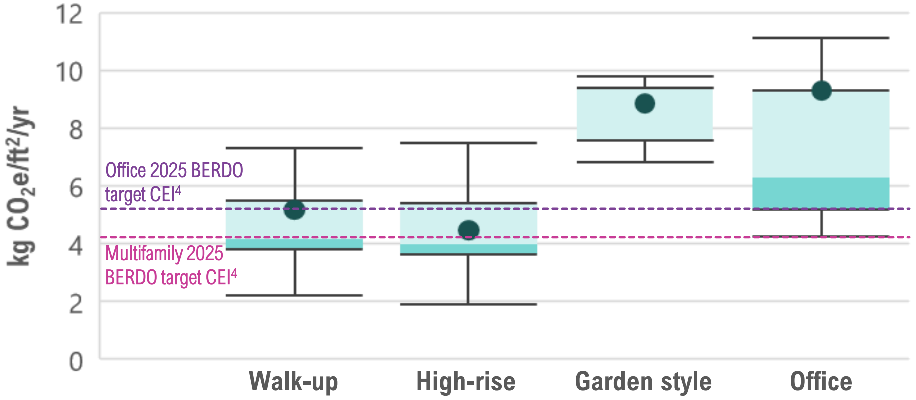
Assumptions & Notes

1. All emissions are calculated with a 2023 grid carbon emissions factor. See *Appendix: Carbon Emissions Factors* for additional information.
2. EUI refers to the energy use intensity of a property: this is an area normalized energy consumption.
3. CEI refers to the carbon emissions intensity of a property: this is the area normalized Scopes 1 and 2 emissions for a property.
4. The BERDO reference CEI thresholds are in-force for the years 2025 through 2029. The full timeline of thresholds is available within the *Ordinance Amending City of Boston Code, Ordinances, Chapter VII, Sections 7-2.1 and 7-2.2, Building Energy Reporting and Disclosure (BERDO)*; BERDO Ordinance (Final) (boston.gov)
5. Peer building energy and carbon emissions benchmarks are based on the 2021 BERDO reporting data, with peer buildings controlled based on year of construction and program typology.

EUI performance ranges for each BHA building typology



CEI performance ranges for each BHA building typology



Typical Existing Building Energy and Carbon Emissions Performance

Most BHA buildings are more energy intensive than peer residential (or office, where applicable) buildings of the same vintage.[5] The most efficient BHA buildings, i.e.: those that meet or outperform peer buildings, are a selection of high-rise and Walk Up typology buildings, owing in part to a reduced façade area-to-volume ratio (v. a garden style typology, which has a larger façade area relative to the enclosed volume).

As pertains to carbon emissions intensity (CEI), the Walk Up and high-rise typologies have median and mean performance at or below peer residential buildings.[5] The garden style typology, in contrast, is the more carbon emission-intensive property in the portfolio. However, when compared to the 2025 CEI target set in BERDO for multifamily residential projects, roughly half of the buildings in the Walk Up and high-rise typologies have a CEI higher than the BERDO target, while all of the garden style properties are more carbon intensive than the 2025 BERDO target. Roughly 75% of the "office" (or "other") typology buildings perform worse than the 2025 BERDO target.[4]

Electrification is essential to operate fossil fuel-free

What is Building Electrification?

Building electrification is the removal and replacement of any equipment that combusts fossil fuels (e.g., natural gas, oil, propane) with all-electric equivalents. The goal of building electrification is to reduce carbon emissions, improve energy efficiency, and promote renewable energy integration.

This plan addresses the electrification of the four fossil fuel-based systems:

Space heating

Domestic hot water

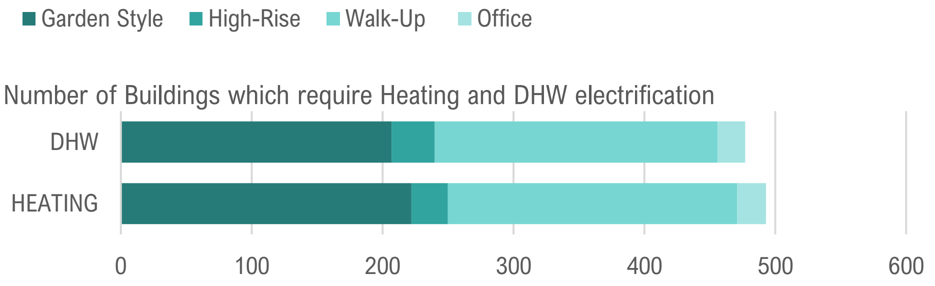
Cooking

Clothes washing & drying

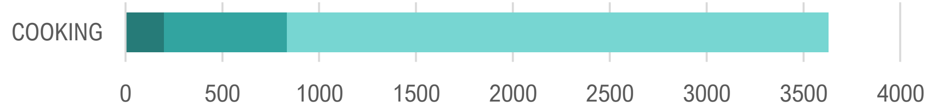
Electrification Status Today

The charts below identify the quantities for each end use that need to be electrified. Currently, only 16 buildings out of 519 in the portfolio are fully electric. These buildings were still included in our analysis for efficiency upgrades related to BHA's commitment to be Net Zero by 2050.

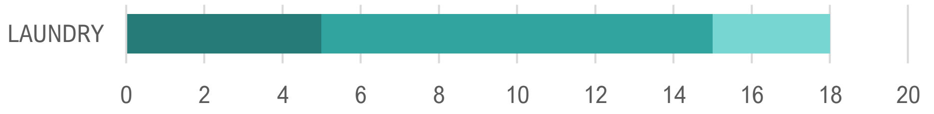
Building End Uses to be Electrified



Number of Buildings which require Heating and DHW electrification



Number of Dwelling Units which require cooking electrification



Number of Dryers that require electrification

3.0 BHA’s pathways to decarbonization

- A roadmap to 2030
- How were the pathways developed?
- A portfolio represented by 4 archetypes
- Prioritization of assets
- Archetype drill down: Walk Up
- Archetype drill down: High Rise
- Archetype drill down: Garden Style
- Archetype drill down: Office

How were the Pathways developed?

Baseline database creation

Existing building and equipment inventory was collected to create a baseline dataset. Historical utility data was not available, so the energy consumption over time was based on NREL databases and normalized to development-level energy consumption.

Typology Definition

Given the baseline data, four typologies were determined for analysis across the portfolio:

- Walk-Up Buildings
- High-Rise Buildings
- Garden Style Buildings
- Office Buildings

Technology Analysis

Existing space heating, domestic hot water, cooking, and laundry equipment for each building typology was matched with recommended replacement technologies. This was based on existing equipment, fuel type, installation complexity, efficiency, and building typologies.

Decarbonization Approaches

Distinct decarbonization measures were bundled into seven packages:

- **Weatherization**
- **Efficiency Upgrades**
- **Electrical Upgrades**
- **Heating Electrification**
- **DHW Electrification**
- **Cooking Electrification**
- **Laundry Electrification**

Modeling energy and emissions calculations

Parametric energy & carbon modeling allowed for each decarbonization package to be applied as applicable to each building. Energy and carbon savings were calculated for electrifying each energy end-use.

Prioritization Exercise

The priority criteria provided a way to compare the development characteristics, such as carbon reduction potential and occupant sensitivities, against each other to determine which developments would be the most impactful to decarbonize first. The exercise resulted in four priority groupings (P1-P4).

Cost Estimating

Cost estimating was conducted across the four different building typologies for each of the seven decarbonization packages.
The cost estimating analysis summarized the average costs for each building typology and total cost for each priority grouping.

Incentives Analysis

Incentives analysis provides information on available incentives and programs for each typology across the seven different decarbonization packages.

Phasing Analysis

The phasing analysis considered the requirements, carbon reduction impact, and level of effort for each decarbonization package.
The prioritization exercise was used for phasing of heating and DHW electrification. Given the enabling characteristics of weatherization and electrical upgrades these packages must happen before new electric equipment is installed. Given the smaller quantity of gas stoves and gas dryers, these packages were considered separately.

Decarbonization Pathways

The decarbonization pathways provides the recommended course of action across the 7-year timeline based on the phasing analysis. The pathway intertwines the cost and incentive data to understand the estimated cost per year and phase.

Prioritization Criteria

Prioritization criteria were determined to identify which developments in the BHA portfolio to address first. The structured approach considered various factors related to occupants, building conditions, and development context. This method ensures a systematic and objective approach to identify the most suitable buildings for decarbonization efforts that will yield the greatest overall benefit.

The process considered occupant factors to help address quality of life for more vulnerable occupants, including elderly population, young children, and occupants with limited mobility. Occupant factors had a lower impact on the overall scoring of buildings; however, the factors were taken into account to ensure that decarbonization efforts contribute positively to social well-being and inclusivity.

The building factors were chosen to allow for a nuanced understanding of each building's characteristics and potential for successful decarbonization. These factors help identify buildings where interventions can yield the most impact in terms of energy efficiency and carbon reduction in a way that considers equipment end of life and timeline of potential envelope or electrical upgrades unique to each development.

Contextual factors of flood risk and the urban heat island (UHI) effect were also included in the prioritization criteria. By considering flood risk and the UHI effect in the prioritization matrix, the decarbonization efforts become more robust, adaptive, and aligned with broader environmental and community goals.

	HIGHEST PRIORITY				LOWEST PRIORITY
OCCUPANT FACTORS					
ELDERLY POPULATION	80+	75+	65+	60+	NONE
FAMILIES WITH CHILDREN	YES				NO
OCCUPANT SENSITIVITIES	> 50%		< 50%		NONE
BUILDING FACTORS					
NATURAL GAS END USES	4 END USES	3 END USES	2 END USES	1 END USE	NONE
EQUIPMENT STATE OF REPAIR	BY 2025		BY 2030		BEYOND 2030
ENVELOPE CONDITION	POOR		FAIR		GOOD
ELECTRICAL UPGRADES	EXTENSIVE		REQUIRED		NONE
EUI	HIGH (100+)		MEDIUM (50+)		LOW (<50)
CARBON REDUCTION POTENTIAL	HIGHEST	3rd QUARTILE		2nd QUARTILE	LOWEST
PERCENT ELECTRIFIED	80%+		30%+		< 30%
BERDO REGULATED	FINED BY 2025		NON-COMPLIANCE BY 2025		NON-COMPLIANCE BY 2030
CONTEXTUAL FACTORS					
FLOOD RISK	CURRENT		FUTURE		NONE
URBAN HEAT ISLAND INDEX	HIGH		MEDIUM		LOW

Prioritization Criteria

Each factor was given a weight to reflect the relative importance in achieving portfolio decarbonization. This process enabled the team to compare the criteria against each other and rank them based on their perceived or quantified importance. Through an iterative process, the team identified which criteria have a more significant impact on the overall success of the decarbonization initiative.

The results of the prioritization exercise revealed a heavier weighting of building factors compared to occupant and contextual factors. Building factors represent the technical aspects that directly influence the feasibility and impact of decarbonization efforts. This outcome suggests that, in the context of decarbonization efforts, the conditions and characteristics of the buildings themselves are considered to be more influential in achieving the overall goals of the initiative; however, the occupant and contextual factors serve as differentiators between developments.

The results of the prioritization exercise, with a heavier weighting of building factors, indicate a strategic emphasis on technical feasibility, resource efficiency, and addressing potential barriers within the existing portfolio to achieve meaningful and lasting decarbonization outcomes.

OCCUPANT FACTORS	WEIGHT	% OF SCORE	
ELDERLY POPULATION	5	9%	23%
FAMILIES WITH CHILDREN	4	7%	
OCCUPANT SENSITIVITIES	4	7%	
BUILDING FACTORS			
NATURAL GAS END USES	5	9%	68%
EQUIPMENT STATE OF REPAIR	2 - 4 by end use	14%	
ENVELOPE CONDITION	3	5%	
ELECTRICAL UPGRADES	2	4%	
EUI	5	9%	
CARBON REDUCTION POTENTIAL	5	9%	
PERCENT ELECTRIFIED	5	9%	
BERDO REGULATED	5	9%	
CONTEXTUAL FACTORS			
FLOOD RISK	2	4%	9%
URBAN HEAT ISLAND INDEX	3	5%	

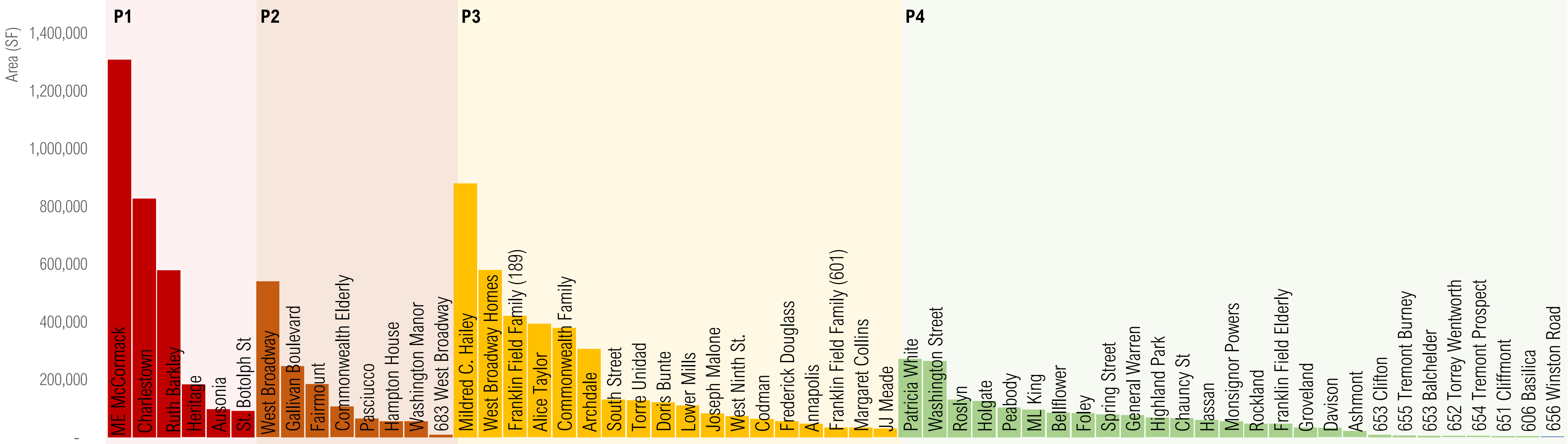
1. A sensitivity analysis of the priority groupings can be found in *Appendix: Sensitivity analysis of prioritization groups*.

Prioritizing BHA developments

Each development was individually scored against the priority criteria and then grouped into four priority buckets. P1 developments represent the highest tier in the prioritization matrix, indicating that they possess characteristics and conditions that make them prime candidates for immediate and impactful decarbonization efforts.

The 8 developments categorized as Priority 2 constitute a substantial number of buildings, that, while not immediately requiring the same level of urgency as Priority 1, still hold considerable potential for impactful decarbonization. These 202 buildings possess characteristics like moderate energy inefficiency, a mix of outdated and modern equipment, and notable carbon reduction opportunities.

The priority groupings established through the prioritization exercise serve as the foundation for a phased approach to decarbonization efforts, allowing for a strategic implementation of heating and domestic hot water electrification across the portfolio. A timeline of 4 years is assumed to make buildings electric ready and decarbonize end-uses.



Priority Score Range	145+	140 -145	120 - 140	< 120
Total Area (SF)	3.1 M	1.3 M	3.9 M	1.8 M
Number of Buildings	111	202	146	60
% of Portfolio CO2 emissions	29%	27%	30%	14%

A roadmap to 2030

The graphic to the right shows a 7-year timeline starting 2024. Initiatives are laid out in order of recommended prioritization from top to the bottom. The width of each initiative indicates implementation timeline. Initiatives, along with costs are detailed out on the next few pages.

Key Takeaways

Eliminate on-site fossil fuel usage by 2030

Phased-in continuous implementation based on prioritized and opportunistic interventions.

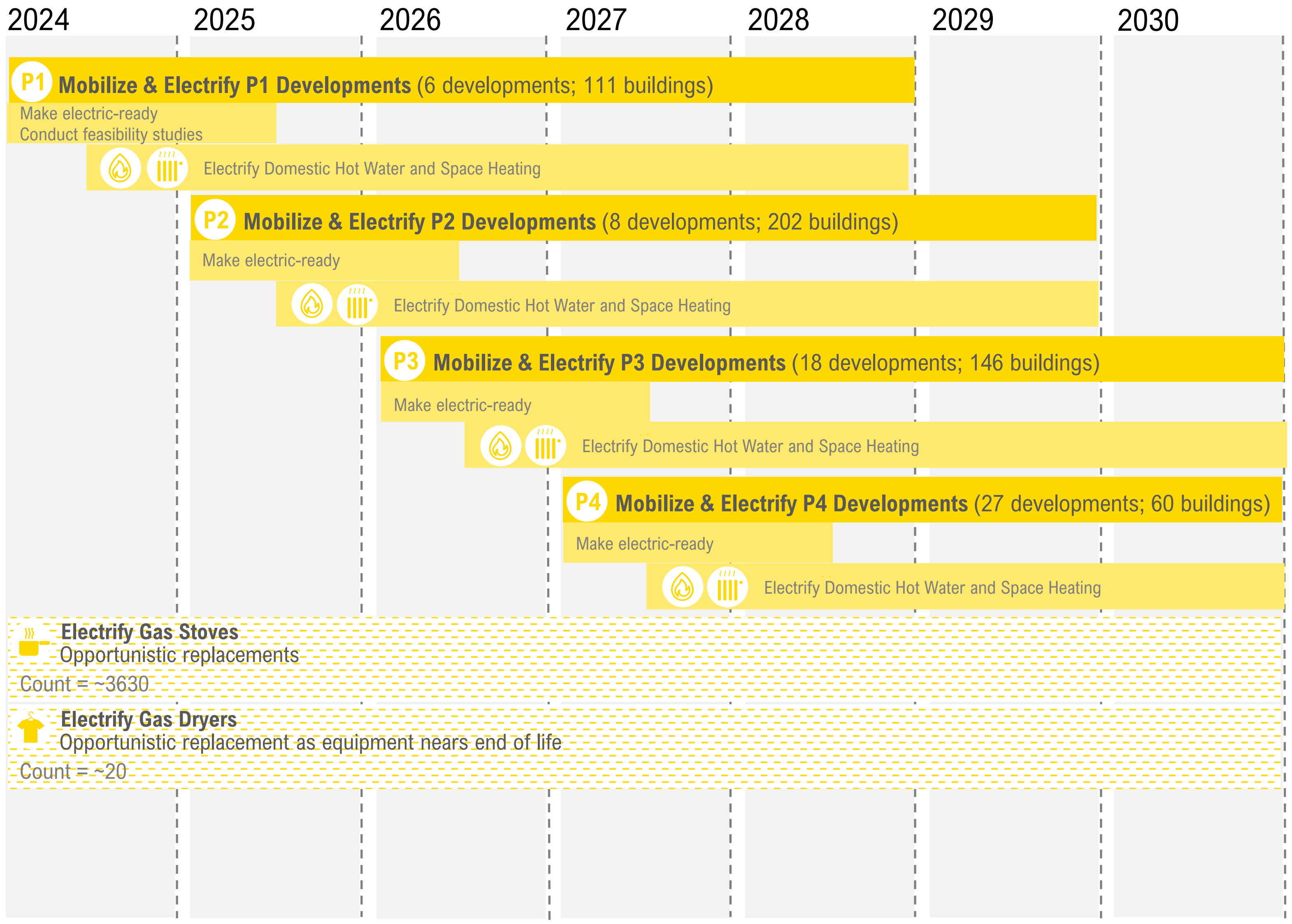
Average retrofit rate of 14% each year between 2024 and 2030 across 10M sf and average 75 buildings per year.

This plan optimizes for cost and impact and recommends improvements across capital and operational expenses and savings.

Includes efficiency, electrification, and indicates next steps analysis for demand flexibility and solar/storage.

Assumptions & Notes

1. Retrofit rate is based on total square footage across the 519 buildings in scope.



2024 2025 2026 2027 2028 2029 2030

P1 **Mobilize & Electrify P1 Developments** (6 developments; 111 buildings)

Make electric-ready
Conduct feasibility studies

Electrify Domestic Hot Water and Space Heating

P2 **Mobilize & Electrify P2 Developments** (8 developments; 202 buildings)

Make electric-ready

Electrify Domestic Hot Water and Space Heating

P3 **Mobilize & Electrify P3 Developments** (18 developments; 146 buildings)

Make electric-ready

Electrify Domestic Hot Water and Space Heating

P4 **Mobilize & Electrify P4 Developments** (27 developments; 60 buildings)

Make electric-ready

Electrify Domestic Hot Water and Space Heating

Electrify Gas Stoves
Opportunistic replacements
Count = ~3630

Electrify Gas Dryers
Opportunistic replacement as equipment nears end of life
Count = ~20

A roadmap to 2030

Key Actions

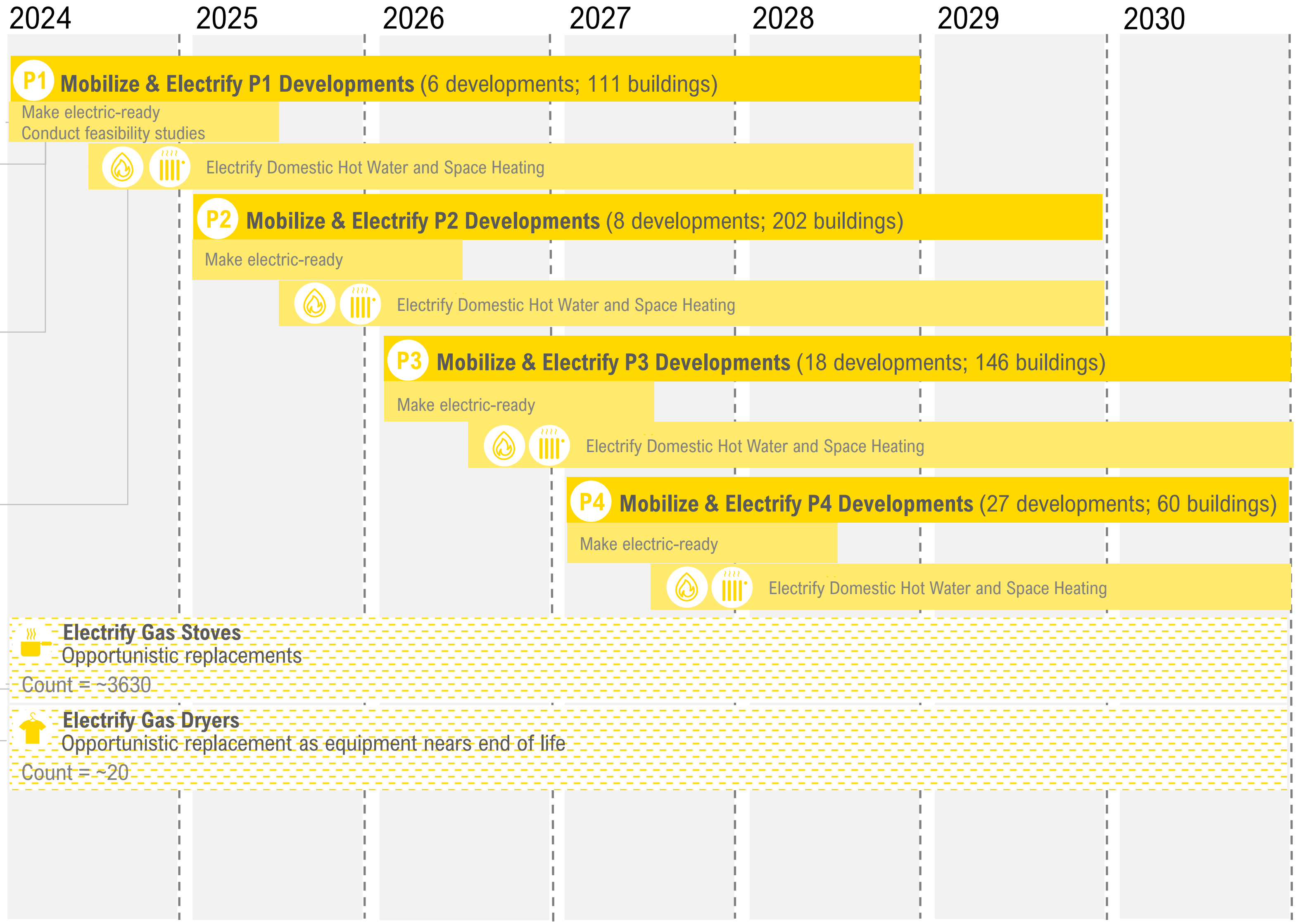
Make Electric Ready: A prerequisite for electrification of heating and hot water systems
Weatherization: air seal, insulate walls and roof
Efficiency upgrades: install LEDs and EnergyStar appliances (refrigerators and dishwashers)
Upgrade electrical capacity: upgrade in-unit panels and building as needed.

Conduct feasibility studies: Conduct electrification feasibility studies to determine electrification options, cost and schedule. This plan assumes a minimum of 1 feasibility study for typical building in a development.

Electrify Domestic Hot Water and Space Heating: Electrifying DHW is less intrusive and doesn't require apartment access so should be prioritized before electrifying space heating. Solutions vary with building type. See typology section for details. Properties with electric resistance systems should electrify as the existing equipment nears/reaches end of life.

Electrify Gas Stoves: A quick win with big returns in terms of resident safety, health and wellbeing. Many BHA developments have electric resistance stoves but the few that have gas stove should be prioritized for replacement with induction stoves.

Electrify Gas Dryers: Gas dryers in shared laundry facilities should be replaced with heat pump dryers as the existing equipment nears/reaches end of life.



2024 2025 2026 2027 2028 2029 2030

P1 Mobilize & Electrify P1 Developments (6 developments; 111 buildings)

Make electric-ready
Conduct feasibility studies

Electrify Domestic Hot Water and Space Heating

P2 Mobilize & Electrify P2 Developments (8 developments; 202 buildings)

Make electric-ready

Electrify Domestic Hot Water and Space Heating

P3 Mobilize & Electrify P3 Developments (18 developments; 146 buildings)

Make electric-ready

Electrify Domestic Hot Water and Space Heating

P4 Mobilize & Electrify P4 Developments (27 developments; 60 buildings)

Make electric-ready

Electrify Domestic Hot Water and Space Heating

Electrify Gas Stoves
Opportunistic replacements
Count = ~3630

Electrify Gas Dryers
Opportunistic replacement as equipment nears end of life
Count = ~20

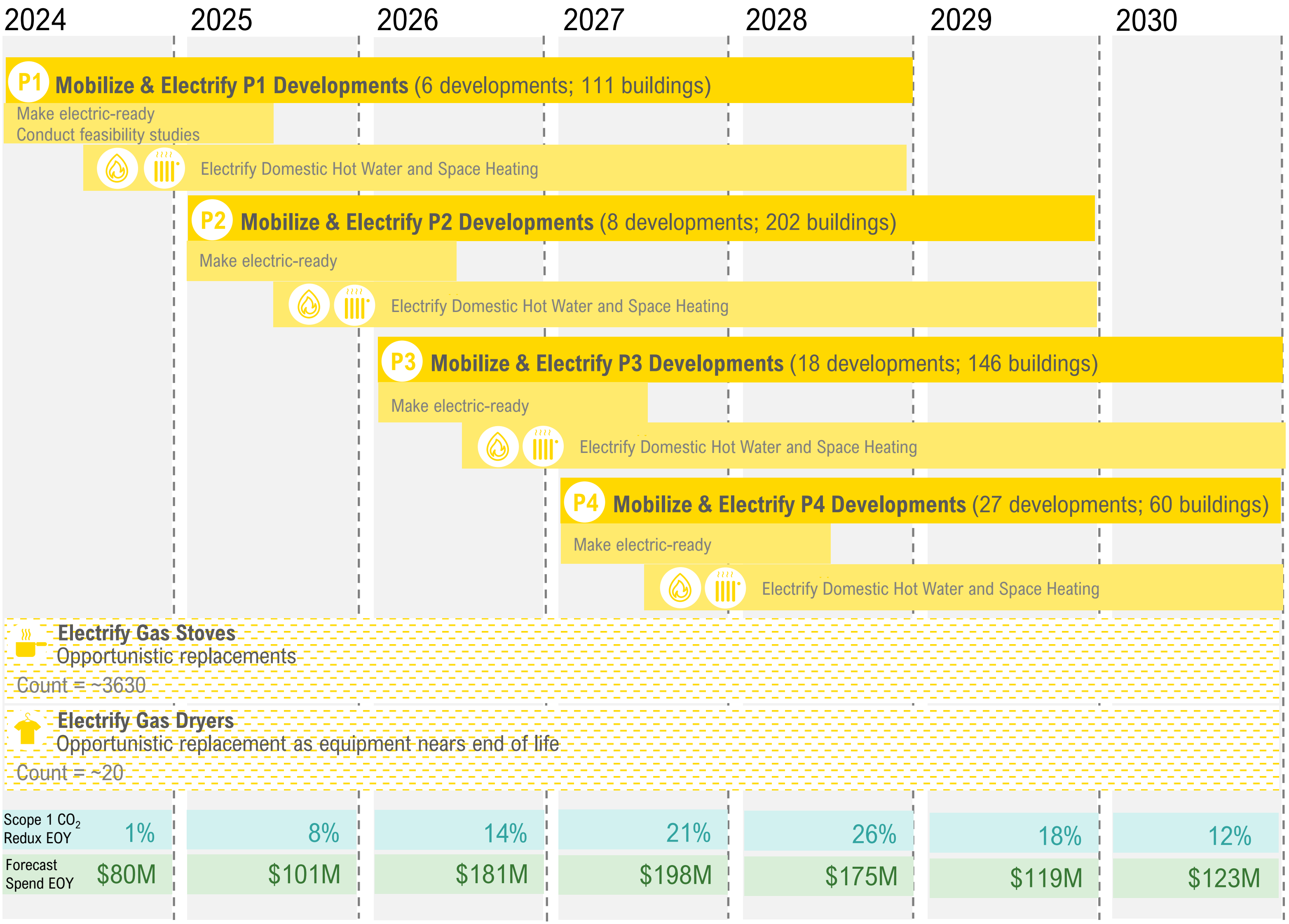
A roadmap to 2030

Key Stats

- $978M to decarbonize 9,476 in-scope dwelling units over seven years
- Average cost $105.5k per unit to decarbonize
- 100% reduction in scope 1 carbon emissions by 2030
- 43% reduction in total carbon emissions (Scope 1 + 2) by 2030 with 2023 carbon emissions factor
- 49% reduction in total carbon emissions (Scope 1 + 2) by 2030 with 2030 carbon emissions factor
- 53% reduction in energy use across the portfolio by 2030

Assumptions & Notes

1. Analysis includes 519 in-scope buildings across 59 developments.
2. Prior approved capital projects excluded.
3. Scope varies by building; Feasibility studies will refine cost/schedule by building.
4. 36 months for execution from full funding allocation (30% design + 70% construction)
5. Costing is based on Class 4 AACE and represents most likely scenario. Full costing methodology and assumptions here.
6. In addition to energy and carbon modeling, a summary of utility cost calculations can be found in *Appendix: Utility cost reduction modeling*.



Forecast Spend	Scope 1 Emissions ▼	
$ 284 M	29% from ’23 BAU 8,748 t CO_2e	**P1 Mobilize & Electrify P1 Developments** (6 developments; 111 buildings) Make electric-ready Conduct feasibility studies Electrify Domestic Hot Water and Space Heating
$ 128 M	27% from ’23 BAU 8,238 t CO_2e	**P2 Mobilize & Electrify P2 Developments** (8 developments; 202 buildings) Make electric-ready Electrify Domestic Hot Water and Space Heating
$ 375 M	29% from ’23 BAU 8,581 t CO_2e	**P3 Mobilize & Electrify P3 Developments** (18 developments; 146 buildings) Make electric-ready Electrify Domestic Hot Water and Space Heating
$ 150 M	13% from ’23 BAU 3,293 t CO_2e	**P4 Mobilize & Electrify P4 Developments** (27 developments; 60 buildings) Make electric-ready Electrify Domestic Hot Water and Space Heating
$ 40 M	2% from ’23 BAU 648 t CO_2e	**Electrify Gas Stoves** Opportunistic replacements Count = ~3630
$ 0.5 M	<1% from ’23 BAU 18 t CO_2e	**Electrify Gas Dryers** Opportunistic replacement as equipment nears end of life Count = ~20
$ 978 M	100% from ’23 BAU 30,155 tCO_2e	

	2024	2025	2026	2027	2028	2029	2030
Scope 1 CO_2 Redux EOY	1%	8%	14%	21%	26%	18%	12%
Forecast Spend EOY	$80M	$101M	$181M	$198M	$175M	$119M	$123M

A roadmap to 2030

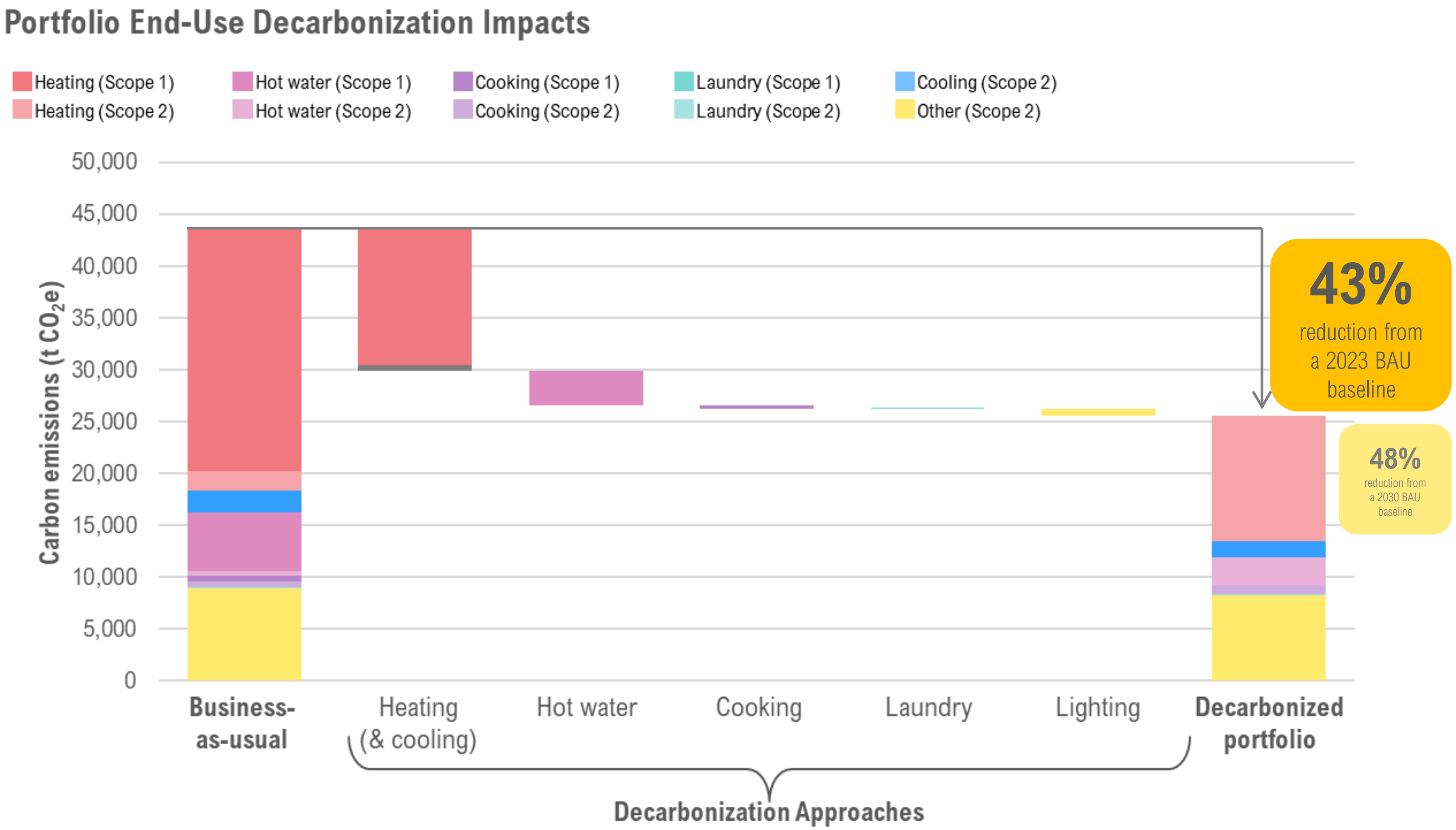
Carbon emissions reductions

Key Stats

Space heating	**100%** reduction in Scope 1 emissions **41%** reduction in Scope 1+2 emissions
Hot water	**100%** reduction in Scope 1 emissions **49%** reduction in Scope 1+2 emissions
Cooking	**100%** reduction in Scope 1 emissions **22%** reduction in Scope 1+2 emissions
Laundry	**100%** reduction in Scope 1 emissions **6%** reduction in Scope 1+2 emissions
Cooling	**0%** reduction in Scope 1 emissions **25%** reduction in Scope 1+2 emissions
Other	**0%** reduction in Scope 1 emissions **7%** reduction in Scope 1+2 emissions
Portfolio	**100%** reduction in Scope 1 emissions **44%** reduction in Scope 1+2 emissions

Assumptions & Notes

1. All emissions are calculated with a 2023 grid carbon emissions factor. See *Appendix: Carbon Emissions Factors* for additional information.
2. Scope 1 emissions describes emissions from the onsite burning of fossil fuels. Natural gas is the primary fossil fuel consumed in the BHA portfolio.
3. Scope 2 emissions refers to emissions resulting from the consumption of electricity. The BHA portfolio will still have Scope 2 emissions until either the grid is sourced from 100% renewables or BHA installs on-site renewables to 100% of portfolio electricity use.
4. Cooling emissions are projected to decrease even when accounting for a projected increase in future cooling load as more units have access to air-conditioning. This decrease results from more efficient cooling systems.
5. “Other” emissions reductions are via application of LED light bulbs across the entire BHA portfolio.



Portfolio End-Use Decarbonization Impacts

43% reduction from a 2023 BAU baseline

48% reduction from a 2030 BAU baseline

Phasing Analysis

Typical recommended loading order for each building*

LOAD REDUCTION		ELECTRIFICATION OF DOMESTIC HOT WATER AND HEATING			RENEWABLE AND RESILIENT ENERGY STRATEGIES		OPPORTUNISTIC STRATEGIES INDEPENDENT OF LOADING ORDER	
1	2	3	4	5	6	7		
Envelope Weatherization	**Efficiency Upgrades**	**Electrical Capacity Upgrades**	**Electrify Domestic Hot Water**	**Electrify Space Heating**	**Install Solar PV**	**Energy Storage**	**Electrify Gas Stoves**	**Electrify Gas Dryers**
Includes air sealing, roof insulation, wall insulation & targeted window upgrades	Includes lighting and appliance upgrades, controls, energy recovery & ductwork sealing and insulation	Includes panelboard upgrades, new utility supply lines & electrical distribution	Includes upgrading to heat pump water heaters (HPWH).	Includes ASHP units, terminal units, and refrigerant piping	Includes Solar PV installation, structural upgrades & electrical wiring.	Include battery storage systems along with the necessary inverters and control systems	Includes induction cooktop & induction-ready cookware set	Includes upgrading to heat pump dryers
BHA has experience with WAP and with securing funding. Opportunity for building staff to be trained on typical weatherization issues and solutions	Opportunity for BHA to implement the integration of more efficient and smart technologies for energy management.	At a high-level BHA has studied electrical upgrade requirements. Electrical upgrades are necessary to enhance capacity for electrification of end-uses.	BHA mostly provides Domestic Hot Water through onsite combustion of natural gas. Opportunity to remove natural gas by upgrading to HPWH.	BHA has experience with procuring and securing funding for heat pumps. Opportunity to study design requirements using building typologies.	BHA has conducted preliminary solar-PV analysis across their portfolio. Opportunity to install on properties with solar-availability.	Opportunity to store renewable energy generated on-site, providing a reliable and sustainable source of power when needed.	BHA mostly provides electric resistance stoves. Opportunity to electrify the small portion of gas stoves and change electric resistance to induction.	BHA provides primarily electric dryers at 36 developments. Opportunity to replace gas dryers and upgrade electric ones to heat pump dryers.
-Improves building's thermal performance and resident comfort -Reduces peak heating loads and helps the building retain heat -Enhances passive survivability during power outage	-Reduces energy consumption - Provides technology integration allowing better monitoring and control of energy usage. -Improves maintenance procedures	-Increases power availability and ensures a more robust power supply -Accommodates the use of high-capacity appliances, such as heat pumps for heating and domestic hot water -Facilitates integration of renewables.	-Reduces carbon emissions and increases energy efficiency -Improves temperature control and reliability of hot water supply -Requires simple installation process	-Provides greatest reduction in carbon emissions -Enhances energy efficiency -Decreases fossil-fuel use on site -Capitalizes on available financial incentives.	-Generates clean energy on-site - Reduces carbon emissions and operational energy expenses -Enables integration with smart technologies and storage	-Optimizes energy utilization of renewable energy sources -Provides opportunities for load shifting -Enhances passive survivability during power outage	-Improves indoor air quality and resident health -Enhances kitchen safety by eliminating risk of gas leaks and open flames -Requires simple installation process	-Reduces carbon emissions and increases energy efficiency -Requires simple installation process
Typically, intrusive and expensive $/sf	Typically, intrusive	Typically, intrusive and expensive $/sf	Typically, intrusive and expensive $/sf	Typically, intrusive and expensive $/sf	Relies on available space on-site	Typically, expensive $/sf	Transition of cooking habits and techniques for residents	Small portion of overall portfolio emissions
EASY MED. ▼ HARD	▼ EASY	▼ HARD	▼ MED.	▼ HARD	▼ MED.	▼ HARD	▼ EASY	▼ EASY

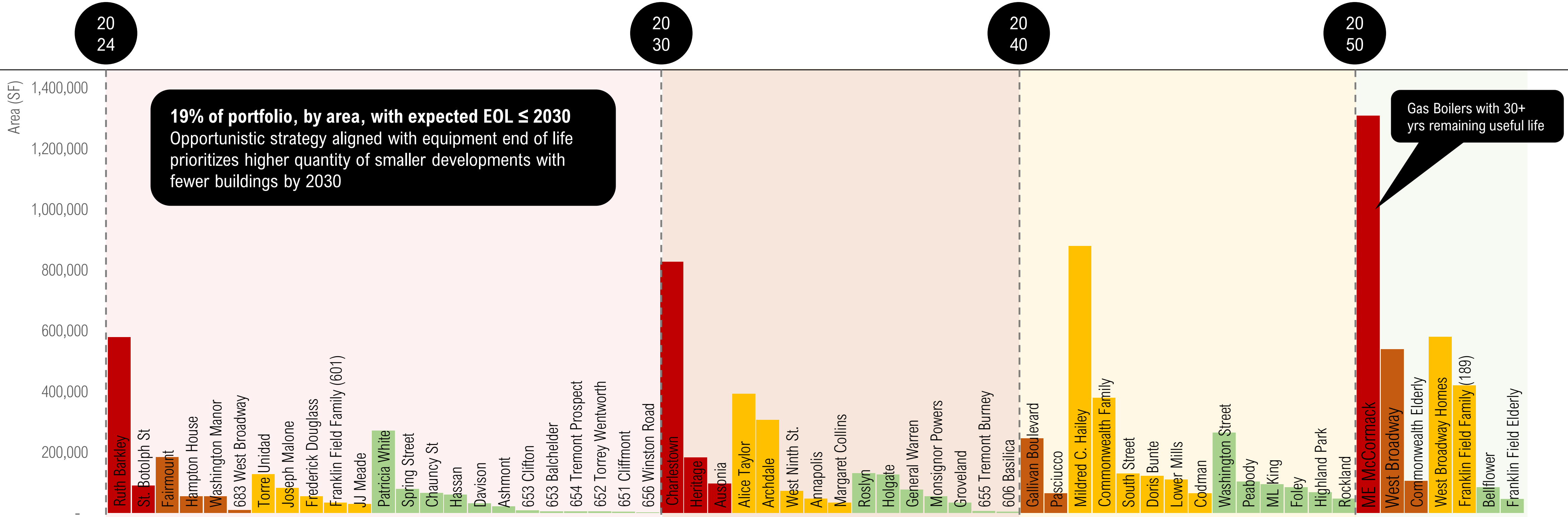
*typology specific recommended loading order is discussed further down in the report

Roadmap to 2050+ (Alternate Timeline)

What if time wasn't a constraint? The alternate timeline analyzes a scenario where buildings are decarbonized as fossil fuel equipment reaches the end of useful life. This approach prioritizes buildings in a way that is synergistic with BHA's maintenance program and physical needs assessments (PNAs). In the original prioritization matrix, the equipment end of life was a secondary factor as shown through the sensitivity analysis (refer to Appendix A for sensitivity analysis details).

By following this approach, BHA can systematically decarbonize properties with older, less efficient equipment and optimize resource allocation. However, when looking at the opportunistic replacement of fossil fuel equipment, there is less emphasis on developments with high-energy use and greater carbon emission reduction potential that were originally prioritized as P1 and P2 (highlighted in red and orange).

Using the equipment end of life as the framework for the timeline extends the decarbonization timeline beyond 2030. It is recommended that both approaches, one driven by the prioritization matrix and this alternate timeline driven by development's physical needs assessments, are considered as decarbonization opportunities are further studied.



19% of portfolio, by area, with expected EOL ≤ 2030
Opportunistic strategy aligned with equipment end of life prioritizes higher quantity of smaller developments with fewer buildings by 2030

Gas Boilers with 30+ yrs remaining useful life

Equipment EOL	≤ 2030	2031 – 2040	2041 – 2050	2050+
Total Area (SF)	1.86 M	2.39 M	2.66 M	3.09 M
Number of Buildings	101	119	200	103
% of Portfolio CO2 emissions	22%	25%	28%	25%

Roadmap to 2050+ (Alternate Timeline)

Synergistic with Heating and DHW Replacements

Key Stats

18% reduction in scope 1 carbon emissions by 2030

10% reduction in total carbon emissions (Scope 1 + 2) by 2030 with 2023 carbon emissions factor

44% reduction in scope 1 carbon emissions by 2040 with 2023 carbon emissions factor

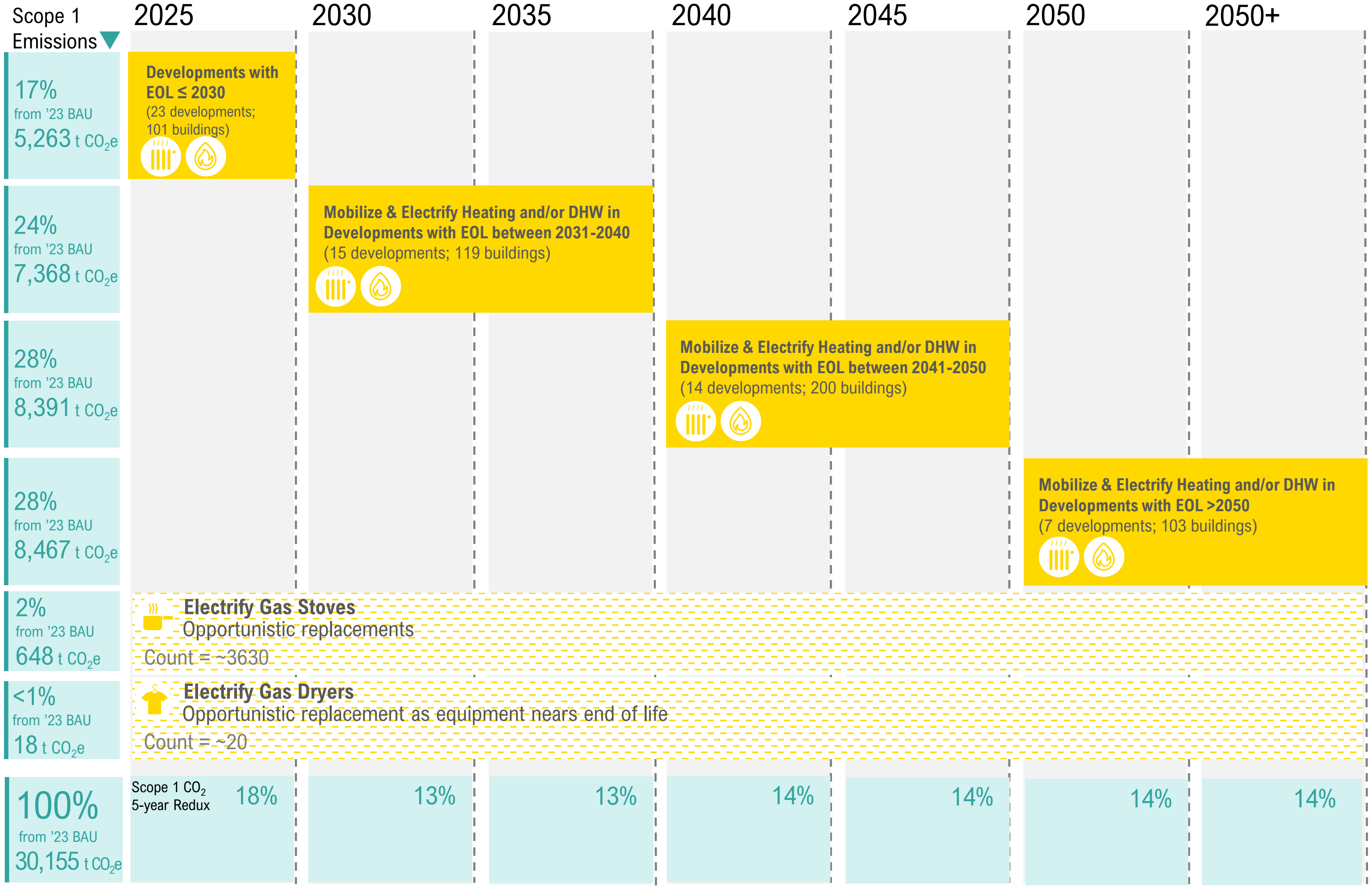
72% reduction in scope 1 carbon emissions by 2050 with 2023 carbon emissions factor

32% reduction in total carbon emissions (Scope 1 + 2) by 2050 with 2023 carbon emissions factor

11% reduction in energy use across the portfolio by 2030

Assumptions & Notes

1. Analysis includes 519 in-scope buildings across 59 developments.
2. Prior approved capital projects excluded.
3. Scope varies by building; Feasibility studies will refine cost/schedule by building.
4. 36 months for execution from full funding allocation (30% design + 70% construction)
5. Costing is not included for extended timeline due to variability of future cost.



Scope 1 Emissions ▼	2025	2030	2035	2040	2045	2050	2050+
17% from '23 BAU 5,263 t CO_2e	**Developments with EOL ≤ 2030** (23 developments; 101 buildings)						
24% from '23 BAU 7,368 t CO_2e		**Mobilize & Electrify Heating and/or DHW in Developments with EOL between 2031-2040** (15 developments; 119 buildings)					
28% from '23 BAU 8,391 t CO_2e				**Mobilize & Electrify Heating and/or DHW in Developments with EOL between 2041-2050** (14 developments; 200 buildings)			
28% from '23 BAU 8,467 t CO_2e						**Mobilize & Electrify Heating and/or DHW in Developments with EOL >2050** (7 developments; 103 buildings)	
2% from '23 BAU 648 t CO_2e	**Electrify Gas Stoves** Opportunistic replacements Count = ~3630						
<1% from '23 BAU 18 t CO_2e	**Electrify Gas Dryers** Opportunistic replacement as equipment nears end of life Count = ~20						
100% from '23 BAU 30,155 t CO_2e	Scope 1 CO_2 5-year Redux 18%	13%	13%	14%	14%	14%	14%

Roadmap Comparison

2030 Roadmap

Prioritization Criteria
The 2030 Roadmap scores buildings based of multiple factors. The most influential factors which ranked building's higher were, Natural gas end uses, EUI, Carbon reduction potential, and percent of electrified energy. Therefore, the buildings with the most natural gas use and highest energy consumption are prioritized.

Timeline
The 2030 roadmap aligns with the fossil-fuel free by 2030 mandate. In order to meet BHA's 2030 goal's the priority groups which resulted from the prioritization exercise overlap. This would require 519 buildings to be decarbonized within a 7-year timeline.

Decarbonization Outcomes
This timeline results in 100% reduction of Scope 1 emissions by 2030.

2050+ Roadmap (Alternate)

Prioritization Criteria
The alternate timeline considers opportunistic replacement of fossil fuel-based equipment as the systems reach the end of their useful life. This strategy aligns with current project needs assessments and maintenance practices.

Timeline
The alternate timeline suggests that equipment is replaced at the time of it's estimated end of life. With this criteria, 101 buildings will need to decarbonize by 2030, 319 buildings would need to replace equipment between 2030 and 2050, and 103 buildings with newer equipment would not need to replace systems until after 2050

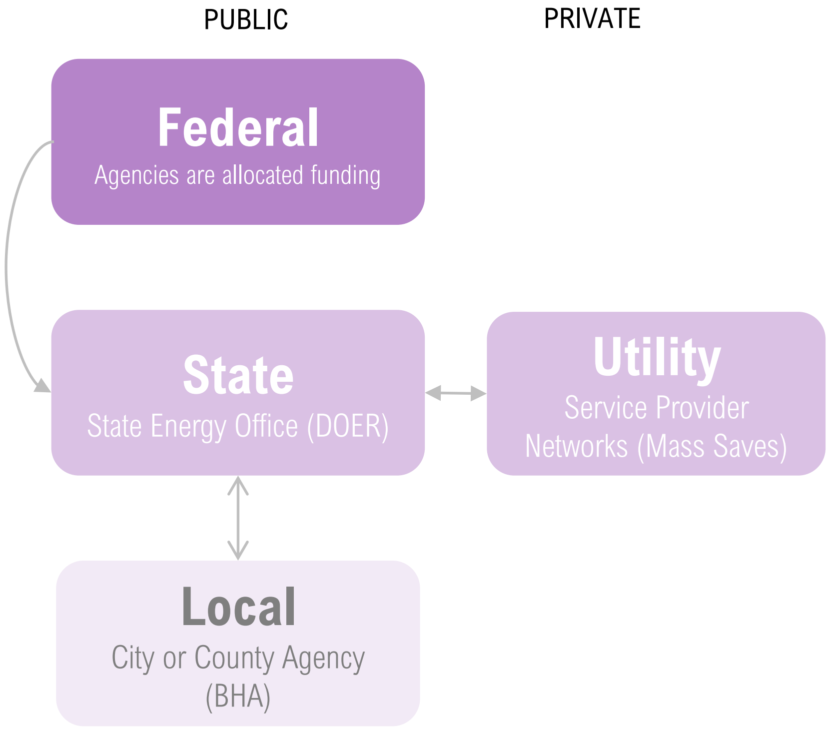
Decarbonization Outcomes
This timeline results in 22% reduction in Scope 1 emissions by 2030, 47% by 2040, and 100% reduction beyond 2050.

Pathway to Funding Decarbonization

This analysis focused on three funding mechanisms across four sources: federal, state, local, and utility service providers.

Federal decarbonization funding is typically managed by State Energy Offices. For Massachusetts, DOER and Mass Saves manage most programs. Forthcoming IRA funding may flow through either DOER or Mass CEC.

FUNDING SOURCES



PUBLIC

PRIVATE

Federal
Agencies are allocated funding

State
State Energy Office (DOER)

Utility
Service Provider Networks (Mass Saves)

Local
City or County Agency (BHA)

FUNDING MECHANISMS

Below outlines the most common funding mechanisms and their respective pros and cons.

Grants	Grants are typically competitive without guarantee of award. Grants often require significant time, costs, and effort to develop applications. Additionally, while grants do not require repayment, some may require a local cost-share or ‘match’ which can be cost-prohibitive.
Loans	Loans make it easier for entities to bear the upfront costs of certain interventions that might otherwise be cost prohibitive despite providing co-benefits. Loans require structured repayments over time.
Rebates	Rebates are paid once upon proof the entity has fulfilled a certain requirement. The amount is typically a percentage of the cost of the system installed or a price per square foot.

Assumptions & Notes

1. Other financing mechanisms, such as Energy as a Service, were included in this analysis. See *Appendix C* for additional information.

Recommended Incentive Packages

Comprehensive - Whole-Building Deep Retrofits

Portfolio Wide Deep Retrofits

I want to: fund holistic deep energy retrofits across an entire typology, neighborhood, or priority level.

Ex: Weatherize, upgrade appliances, electrify DHW and heating for all P1 buildings.

Building Scale Deep Retrofits

I want to: fund one or a few holistic deep energy retrofits building by building.

Ex: Weatherize, upgrade appliances, electrify DHW and heating for Mildred C, Haley.

Rebates:

IRA Home Efficiency Rebates
Home Energy Rebate Programs Requirements & Application Instructions

Low-Income Energy Affordability Network (LEAN) Multifamily Deep Energy Retrofit Rebates
Deep Energy Retrofit | LEAN Multi-Family (leanmultifamily.org)

Prescriptive & Direct Install - System-Specific Interventions

Portfolio Wide System-Specific Upgrades

I want to: fund one or a few system upgrades across an entire typology, neighborhood, or priority level.

Ex: Electrify all DHW across all Walk-ups.

Building Scale System-Specific Upgrades

I want to: fund one or a few system upgrades building by building.

Ex: Upgrade lighting and appliances in West Broadway Homes.

Rebates:

IRA Home Electrification and Appliance Rebates
Home Energy Rebate Programs Requirements & Application Instructions

LEAN Multifamily Direct Install Rebates
Home | LEAN Multi-Family (leanmultifamily.org)

Mass Save Residential Rebates
Residential Rebates & Incentives | Mass Save

Recommended pathway:

1. Prioritize the highest need buildings to complete whole-building deep energy retrofits.
2. Use system-specific ‘direct install’ rebates to complete upgrades in properties with less immediate need and/or appliance upgrades.

Incentive Pathways by Residential Typology

Walk Up

Pathway: Prescriptive approach using **multiple prescriptive & direct install programs** for different interventions.

Average Incentives per building:

Direct install weatherization + direct pay heat pump rebate = average **$451,360** per building

Inflection point where a **Comprehensive Deep Energy Retrofit path would be more cost-effective** = **1,289.6 MMBTU**

Programs:

IRA Home Electrification and Appliance Rebates
Home Energy Rebate Programs Requirements & Application Instructions

LEAN Multifamily Direct Install Rebates
Home | LEAN Multi-Family (leanmultifamily.org)

Mass Save Residential Rebates
Residential Rebates & Incentives | Mass Save

High Rise

Pathway: The most cost-effective pathway is a **comprehensive program** like Deep Energy Retrofit, especially when decommissioning central heating plants and building energy efficiency to offset the increase in kWh via electrification.

Average Incentives per building:

Direct install weatherization + direct pay heat pump rebate = average **$1,458,240** per building

Inflection point where a **comprehensive Deep Energy Retrofit path would be more cost-effective** = **4,166.4 MMBTU**

Programs:

IRA Home Efficiency Rebates
Home Energy Rebate Programs Requirements & Application Instructions

Low-Income Energy Affordability Network (LEAN) Multifamily Deep Energy Retrofit Rebates
Deep Energy Retrofit | LEAN Multi-Family (leanmultifamily.org)

Garden Style

Pathway: The most cost-effective pathway is a **comprehensive program** like Deep Energy Retrofit.

Average Incentives per building:

Direct install weatherization + direct pay heat pump rebate = average **$104,000** per building

Inflection point where a **comprehensive Deep Energy Retrofit path would be more cost-effective** = **297.1 MMBTU**

Programs:

IRA Home Efficiency Rebates
Home Energy Rebate Programs Requirements & Application Instructions

Low-Income Energy Affordability Network (LEAN) Multifamily Deep Energy Retrofit Rebates
Deep Energy Retrofit | LEAN Multi-Family (leanmultifamily.org)

DECARB PATHWAYS

Rebate Menu

PROGRAM	ADMISTRATOR	PATHWAY	TYPOLOGIES				WEATHERIZATION	ENERGY EFFICIENCY	HEATING ELETRIFICATION	DHW ELETRIFICATION	ELETRICAL UPGRADES
			WU	HR	G	O					
Mass Save Residential Rebates Residential Rebates & Incentives | Mass Save	Utility	By system	●		●		🟨	🟨	🟨	🟨	🟨
Low-Income Energy Affordability Network (LEAN) Multifamily Deep Energy Retrofit Rebates Deep Energy Retrofit | LEAN Multi-Family (leanmultifamily.org)	Utility	ECS	●	●	●		🟨	🟨	🟨	🟨	
LEAN Multifamily Direct Install Rebates Home | LEAN Multi-Family (leanmultifamily.org)	Utility	By system	●	●	●		🟨	🟨	🟨	🟨	🟨
IRA Home Efficiency Rebates Home Energy Rebate Programs Requirements & Application Instructions	State	ECS	●	●	●		🟨	🟨	🟨	🟨	
IRA Home Electrification and Appliance Rebates Home Energy Rebate Programs Requirements & Application Instructions	State	By system	●	●	●		🟨	🟨	🟨	🟨	🟨

Assumptions & Notes

1. ECS stands for Energy Cost Savings.
2. The IRA Home Efficiency Rebates and Home Electrification and Appliance Rebates will be administered by the State. However, the program is not active yet.
3. Submitting applications will require dedicated resources. This analysis recommends at least 1 full time employee dedicated to facilitating and tracking incentives.

Program is applicable: 🟨

Grants and Loans Menu

BHA should work with designated state and local agencies to engage in grant and loan programs.

PROGRAM	ADMISTRATOR	PATHWAY	TYPOLOGIES				WEATHERIZATION	ENERGY EFFICIENCY	HEATING ELETRIFICATION	DHW ELETRIFICATION	ELETRICAL UPGRADES
			WU	HR	G	O					
Climate Pollution Reduction Grant (CPRG) About CPRG Implementation Grants	EPA	By property	●	●	●	●	🟨	🟨	🟨	🟨	🟨
Weatherization Assistance Program (WAP) Weatherization Assistance Program (WAP)	EOHLC	By property	●	●	●		🟨				
Healthy and Green Building Retrofit Program Healthy and Green Retrofit Pilot Program | Boston.gov	Mayor's Office of Housing	By property	●		●		🟨	🟨	🟨	🟨	🟨

Notes

1. The proposed Zero Carbon Renovation Fund (ZCRF) would provide funding for decarbonization strategies outlined in this analysis.
2. Strategies included in this report align with Massachusetts's Climate Pollution Reduction Grant (CPRG) Priority Climate Action Plan (PCAP) including: B1. Increase building efficiency B2. Decarbonize building heating systems B3. Implement building-scale renewables.

Program is applicable: 🟨

Recommended Actions

Funding

Immediate

1-6 months

- **ASAP** - Connect with the Massachusetts Office of Climate Innovation and Resilience or the Metropolitan Area Planning Council (MAPC) to understand how you can benefit from EPA **Climate Pollution Reduction Grant (CPRG)** Funding.
- Check-in with Mass Save on the **selection process for the IRA rebate program administrator**, anticipated to be announced June 2024

Medium Term

1 year

- **Conduct an in-depth assessment** to determine best funding pathway for each property.
- **Apply for lighting retrofits prior to 2025** when it is anticipated that lighting programs will be suspended.

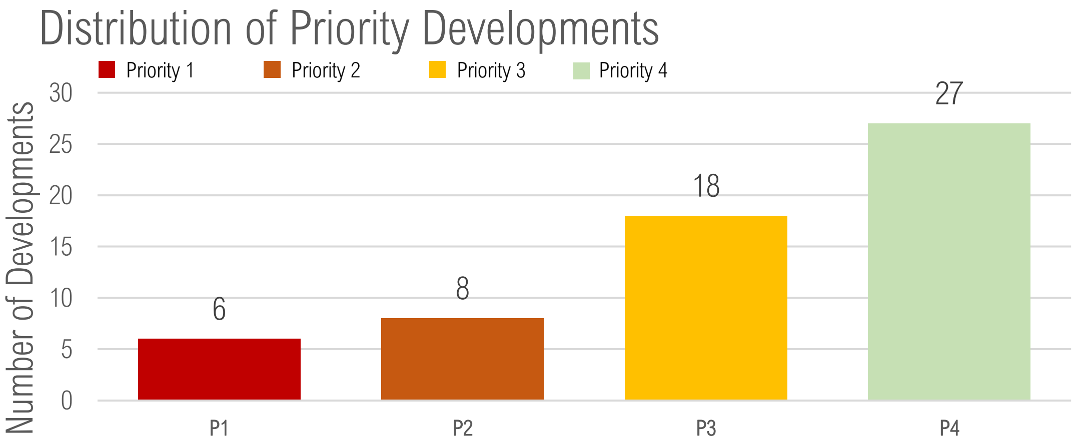
Long term

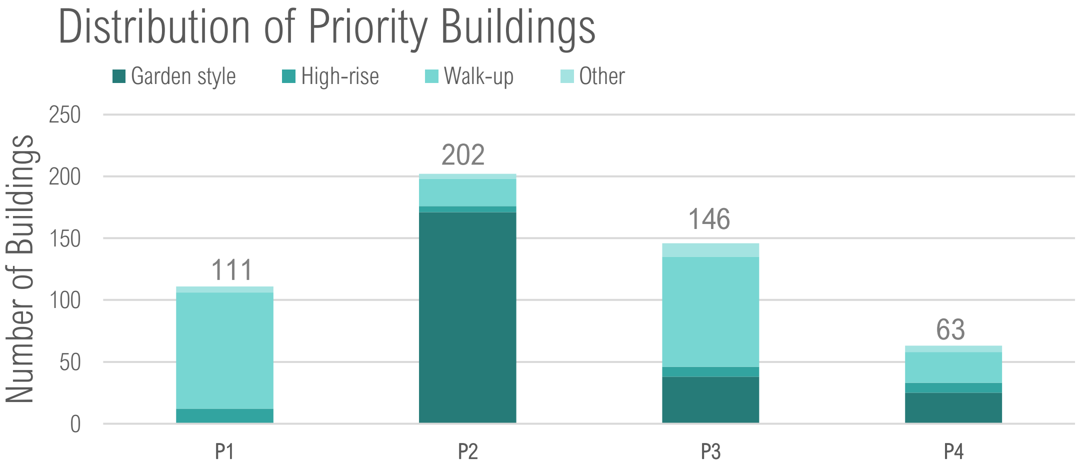
> 1 year

- **Develop common specifications** for heat pumps, envelope materials, ERVs and appliances.
- Hire at least 1 FTE **dedicated** to facilitating and tracking incentives.
- **Begin applying for incentive programs.**

Electrification Timeline

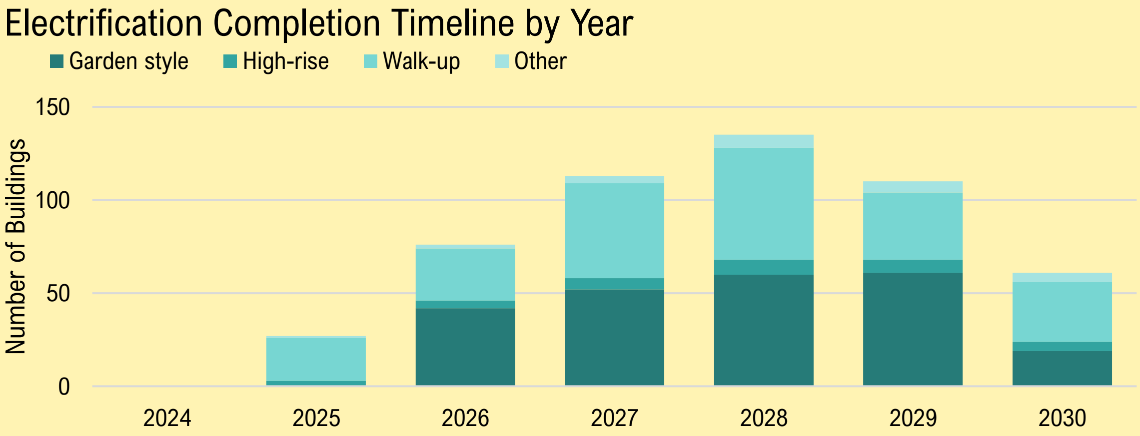
The prioritization exercise reveals that 111 buildings across 6 developments should be prioritized first. Of these buildings, the majority are Walk-Ups with the largest quantity occurring in the Charlestown and ME McCormack developments. As seen on the graphs below, P2 buildings are mostly Garden Style of which 134 are in the Gallivan Boulevard development. Priority 3 has 146 buildings across 18 Developments mostly compromised of Walk-Up. Priority 4 includes the highest quantity of developments but the lowest quantity of buildings. This demonstrates that the largest developments are being tackled first.

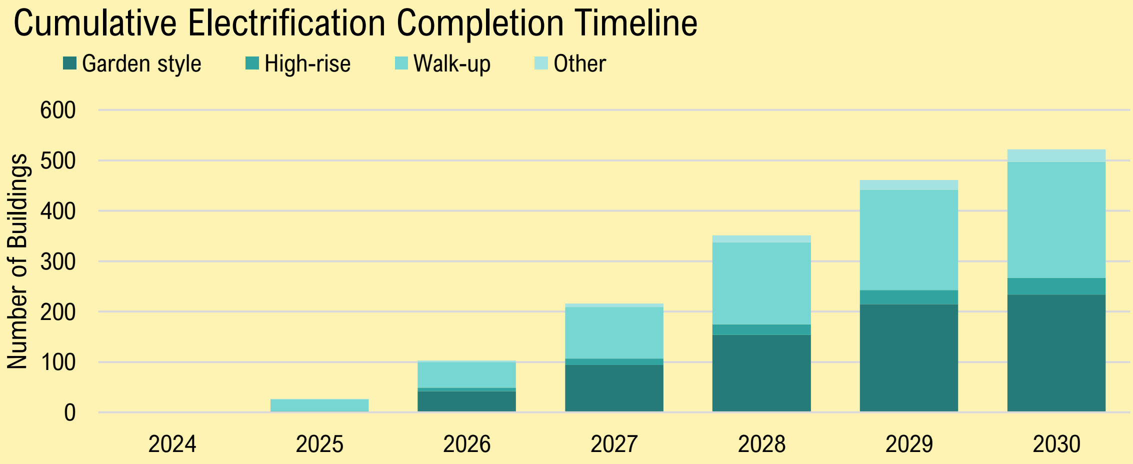

Distribution of Priority Developments


Distribution of Priority Buildings

Electrification Timeline
The graphs below show the distribution of electrification completion years for buildings within the BHA portfolio. This distribution considers that electrical and efficiency upgrades will occur first. It also assumes a 4-year timeline for P1 to P3 and a 3-year timeline for P4. With an overall timeline of 7-years for BHA to be entirely free of fossil fuels by 2030 the four priority groups overlap, showing a higher number of buildings completed in the middle of the timeline.

519
buildings in 7 years


Electrification Completion Timeline by Year


Cumulative Electrification Completion Timeline

Electrification Technology Briefs

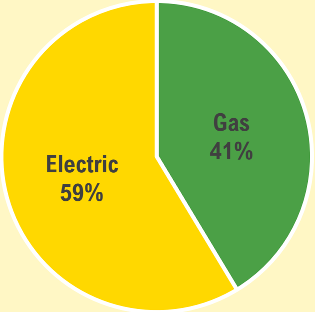
Electrify Gas Stoves

CURRENT STATE

BHA’s building portfolio has a mix of electric stoves and traditional gas appliances. Based on development-level data and dwelling unit quantities, 41% of kitchens in the BHA portfolio have gas cooking appliances and 59% have electric cooking. The majority of electric cooking is done through electric resistance.

Typical Gas Stove

Typical Electric Stove



REPLACEMENT TECHNOLOGY

The recommended replacement technology for gas stoves and electric resistance stoves is induction stoves. Induction cooktops use magnetic fields to directly heat the cookware, making them more energy-efficient than electric resistance stoves. They offer precise temperature control and faster heating compared to traditional electric stoves.

Typical Induction Stove

CHALLENGES

Switching from gas to electric appliances may require upgrades to the electrical infrastructure of a building.

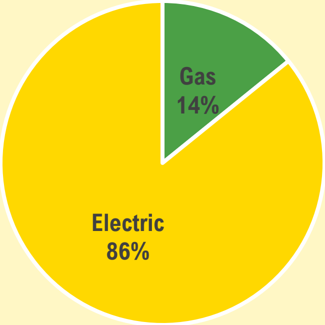
It is assumed that the replacement technology will be dropped-in/slid-in; however, if this is not the case structural or architectural updates may need to be made. Retrofitting kitchens for induction cooktops or electric ovens may require modifications to countertops, electrical wiring, and ventilation systems.

Induction cooking also requires specific cookware. With each stove upgrade, a package of pots and pans should be provided to the residents. Additionally, convincing residents to switch to new technologies may require education and awareness campaigns.

Electrify Gas Dryers

CURRENT STATE

BHA’s portfolio has a total of 127 dryers. These dryers are located in shared spaces. Of those dryers, 14% operate with gas. While these dryers represent a small portion of the overall building portfolio emissions they should be replaced with electric dryers as the opportunity arises and equipment reaches its end of life. Replacing gas dryers not only will aid in decarbonization but will also improve indoor air quality in these shared spaces as gas dryers produce combustion by products.



Typical Laundry Room

REPLACEMENT TECHNOLOGY

The recommended replacement technology for gas dryers is heat pump dryers. Heat pump dryers are more energy efficient and don’t rely on external ventilation allowing for a more versatile installation. Heat pump technology differs from traditional electric dryers. Traditional electric dryers use electric heating elements to generate heat. These elements warm the air inside the dryer, which is then circulated through the drum to evaporate moisture from wet clothes. Heat pump dryers use a heat exchanger, a refrigeration cycle, and a fan to remove moisture from clothes. Instead of using electric heating elements, they extract heat from the air, making them more energy-efficient.

CHALLENGES

Heat pump dryers typically require a dedicated electrical circuit and a higher voltage than traditional dryers. Teams will need to ensure that the building's electrical infrastructure can support the new equipment. There may be less availability of heat pump dryer models compared to traditional gas dryers. Expanding the range of available options and increasing market competition can help drive adoption.

Heat pump dryers may increase drying time, and inclusion of this new technology may benefit from resident education on the advantages.

Electrification Technology Briefs

Electrify Space Heating (continued)

A complete list of potential replacement technologies for each building typology and their pros and cons.

	Replacement Technology	Applicable Building Typology	Pros	Cons
Recommended	ASHP, split system	Garden Style High-Rise Walk-Up Office	Electrification Energy efficiency Emissions reduction Load-shifting Quick deployment	New electrical load New cooling load Refrigerant run limitations Structural upgrades
Alternative Options	Window Heat Pumps	High-Rise	Electrification Energy efficiency Emissions reduction Quick deployment	New and added electrical load
	VRF	Garden Style Walk-Up Office	Electrification Emissions Reduction	New electrical load New cooling load Refrigerant run limitations
	Water Source Heat Pumps	Garden Style High-Rise Walk-Up	Electrification Energy efficiency Emissions reduction Beneficial if existing hydronic systems can handle lower temperature distribution	New electrical load New cooling load Depends on existing distribution system
	Electric Boiler	Garden Style Walk-Up Office	Electrification Emissions reduction	Not as efficient Only recommended as a last resort to meet the needs of the building
	GSHP (Additional to ASHP)	Walk-Up High-Rise	Efficiency	Only for additionality; not anticipated to be sufficient on its own in most cases
	District Energy	High Rise	Electrification Energy efficiency Emissions reduction	Only for high-clustered buildings

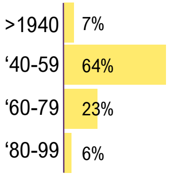
Archetype drill down: Walk Up

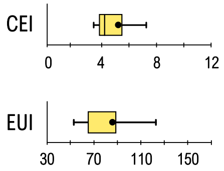
60% of total area
57% of total emissions

WALK UP

Developments	28
Buildings	226
Dwelling units	5,741
Area (sf)	5.6M
Typical Floors	3
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Tenant A/C
Ventilation	Passive
Cooking	Gas Stove

VINTAGE
% of buildings





Electrify Space Heating
218
Buildings to Electrify Space Heating

Electrify Domestic Hot Water
212
Buildings to electrify DHW

Electrify Gas Stoves
~2,800
Units with Gas Stoves

Electrify Gas Dryers
3
Gas Dryers

	Current State	**Archetype Challenges**
SPACE HEATING	Space heating in Walk Ups is primarily from gas-based systems. 36% of the portfolio-wide emissions are from space heating of Walk Ups. Electrifying space heating across the Walk-Ups demonstrates the highest carbon emissions potential. Of the 226 Walk Up buildings, 8 currently have all-electric space heating and are located in Hassan, Rockland, Monsignor Powers, and 606 Basilica Developments.	There are different roof types across the Walk Up buildings. For each building, careful consideration should be taken for the available roof space and structural considerations for equipment mounting. Additionally, adding systems that provide both heating and cooling might impact the cooling load if not previously provided by the building. As each building electrifies their space heating their scope 1 emissions will decrease while the scope 2 emissions will increase due to added electrical load. The added electrical load may require electrical capacity upgrades.
DOMESTIC HOT WATER	94% of Walk Ups use natural gas for domestic hot water. The natural gas used for domestic hot water across all 226 Walk Up buildings represents 7% of the overall portfolio emissions.	As each building electrifies their domestic hot water their scope 1 emissions will decrease while the scope 2 emissions will increase due to added electrical load. The added electrical load may require electrical capacity upgrades.
COOKING	Walk Up's in BHA's building portfolio have a mix of electric stoves and traditional gas appliances. Based on development-level data and dwelling unit quantities, 52% of dwelling units in Walk Ups have gas cooking appliances and 48% have electric cooking. The majority of electric cooking is done through electric resistance.	It is assumed that replacement cooking equipment will not require architectural changes to each dwelling unit; however, this should be considered for each building.
LAUNDRY	Laundry, when provided, is typically located in shared areas. Laundry is only provided in 6 developments with Walk Up buildings. In total there are only 45 dryers in these 6 developments, 93% of which are already electric. Laundry across all developments represents less than 1% of the BHA portfolio emissions.	Laundry represents a very small portion of Scope 1 emissions. It is assumed that new equipment can slide in place of existing equipment in shared laundry rooms.

Recommended loading order for Walk Ups

DECARB PATHWAYS

	1	2	3	4	5	OPPORTUNISTIC STRATEGIES INDEPENDENT OF LOADING ORDER		
	Envelope Weatherization	**Efficiency Upgrades**	**Electrical Capacity Upgrades**	**Electrify Domestic Hot Water**	**Electrify Space Heating**	**Electrify Gas Stoves**	**Electrify Gas Dryers**	
	Includes air sealing, roof insulation, wall insulation & targeted window upgrades	Includes lighting and appliance upgrades, controls, energy recovery & ductwork sealing and insulation	Includes panelboard upgrades, new utility supply lines & electrical distribution	Includes upgrading to heat pump water heaters (HPWH).	Includes ASHP units, terminal units, and refrigerant piping	Includes induction cooktop & induction-ready cookware set	Includes upgrading to heat pump dryers	
	Walk-up wall insulation would increase from R-4 to R-20, and roof insulation would increase from R-10 to R-30.	Assumes reducing lighting power density by 30% where possible.	Includes dwelling unit panelboards to be updated to 100A @ 120/240V single phase, cabling from service switch to be upsized, and building incoming service upgrades	Gas boilers and water heaters to be updated with HPWH. Existing electric resistance water heaters are not prioritized but can be upgraded for efficiency reasons.	Most buildings have gas boiler systems with hydronic distribution. It is anticipated that buildings will update to air source heat pumps with hydronic distribution.	Dwelling units with gas stoves update to induction stoves. Electric resistance stoves aren't prioritized for electrification; however, can eventually upgrade for efficiency reasons.	Gas dryers are to be replaced with HP dryers. Existing traditional electric dryers aren't prioritized for electrification; however, can eventually upgrade for efficiency reasons.	
Emissions Savings	N/A, this impact is reflected in the reduction percentage reported under "electrify space heating."	6% Mean Carbon Emissions Savings per building	N/A, this is enabling work required to electrify end uses in subsequent packages.	7% Mean Carbon Emissions Savings per building	32% Mean Carbon Emissions Savings per building	1% Mean Carbon Emissions Savings per building	<1% Mean Carbon Emissions Savings per building	46% Mean Total Emissions Savings per Walk Up building
Estimated Costs	$1M estimated mean cost per building, $39,800 estimated mean cost per dwelling	$207,000 estimated mean cost per building, $8,200 estimated mean cost per dwelling	$293,000 estimated mean cost per building, $11,600 estimated mean cost per dwelling	$262,000 estimated mean cost per building, $10,400 estimated mean cost per dwelling	$662,000 estimated mean cost per building, $26,300 estimated mean cost per dwelling	$5,400 Estimated mean cost per dwelling unit	$5,400 Estimated mean cost per dryer	$2.4M Mean Total Cost per Walk Up building
	EASY MED. ▼HARD	▼EASY	▼HARD	▼MED.	▼HARD	▼EASY	▼EASY	

Assumptions & Notes

1) Baseline insulation values were estimated from ASHRAE 90A-1980, Type A Building guidance and NREL data
2) Carbon emissions savings were calculated using a 2023 grid emissions factor (see *Appendix: Carbon Emissions Factors*). Carbon emissions reductions for "electrify space heating" includes space cooling savings.
3) Costs are high-level and do not include incentives, please refer to subsequent sections for the incentive analysis.

Archetype drill down: High Rise

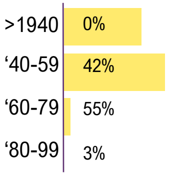
30% of total area
25% of total emissions

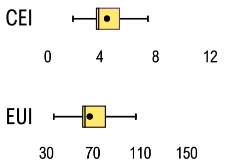
Electrify Space Heating	Electrify Domestic Hot Water	Electrify Gas Stoves	Electrify Gas Dryers
27 Buildings to Electrify Space Heating	33 Buildings to electrify DHW	634 Units with Gas Stoves	10 Gas Dryers

HIGH-RISE

Developments	21
Buildings	33
Dwelling units	2,753
Area (sf)	2.8M
Typical Floors	6-20
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Tenant A/C
Ventilation	Make-up air unit
Cooking	Gas Stove

VINTAGE
% of buildings





	Current State	Archetype Challenges
SPACE HEATING	Space heating in High Rise buildings is primarily from gas-based systems. 13% of the portfolio-wide emissions are from space heating of Walk Ups. Of the 33 high rise buildings, 6 currently have electric resistance space heating, Fredrick Douglass, Torre Unidad, St. Botolph, Hampton House, Washington Manor, and Doris Bunte.	For each building, careful consideration should be taken for the available roof space and structural considerations for equipment mounting. Additionally, adding systems that provide both heating and cooling might impact the cooling load if not previously provided by the building. As each building electrifies their space heating their scope 1 emissions will decrease while the scope 2 emissions will increase due to added electrical load. The added electrical load may require electrical capacity upgrades. Special consideration should be taken for refrigerant runs given the height of these High Rise buildings.
DOMESTIC HOT WATER	All in-scope High-Rise buildings use natural gas for domestic hot water. The natural gas used for domestic hot water across all 33 Walk Up buildings represents 4% of the overall portfolio emissions.	As each building electrifies their domestic hot water their scope 1 emissions will decrease while the scope 2 emissions will increase due to added electrical load. The added electrical load may require electrical capacity upgrades.
COOKING	Walk Up's in BHA's building portfolio have a mix of electric stoves and traditional gas appliances. Based on development-level data and dwelling unit quantities, 29% of dwelling units in High Rise buildings have gas cooking appliances and 71% have electric cooking. The majority of electric cooking is done through electric resistance.	It is assumed that replacement cooking equipment will not require architectural changes to each dwelling unit; however, this should be considered for each building.
LAUNDRY	Laundry, when provided, is typically located in shared areas. In total there are 60 dryers across all the High Rise buildings, 80% of which are already electric. Laundry across all developments represents less than 1% of the BHA portfolio emissions.	Laundry represents a very small portion of Scope 1 emissions. It is assumed that new equipment can slide in place of existing equipment in shared laundry rooms.

Recommended Loading Order: High Rise

	1	2	3	4	5	OPPORTUNISTIC STRATEGIES INDEPENDENT OF LOADING ORDER		
	Envelope Weatherization	**Efficiency Upgrades**	**Electrical Capacity Upgrades**	**Electrify Domestic Hot Water**	**Electrify Space Heating**	**Electrify Gas Stoves**	**Electrify Gas Dryers**	
	Includes air sealing, roof insulation, wall insulation & targeted window upgrades	Includes lighting and appliance upgrades, controls, energy recovery & ductwork sealing and insulation	Includes panelboard upgrades, new utility supply lines & electrical distribution	Includes upgrading to heat pump water heaters (HPWH).	Includes ASHP units, terminal units, and refrigerant piping OR Window Heat Pumps	Includes induction cooktop & induction-ready cookware set	Includes upgrading to heat pump dryers	
	High Rise wall insulation is assumed to increase from R-2.8 to R-20, and roof insulation would from R-10 to R-30.	Assumes reducing lighting power density by 30% where possible	Includes dwelling unit panelboards to be updated to 100A @ 120/240V single phase, cabling from service switch to be upsized, and building incoming service upgrades	Gas boilers and water heaters to be updated with HPWH. Existing electric resistance water heaters are not prioritized but can be upgraded for efficiency reasons	Most buildings have gas boiler systems with hydronic distribution. It is anticipated that buildings will update to Air Source Heat Pumps with hydronic distribution.	Dwelling units with gas stoves update to induction stoves. Electric resistance stoves aren't prioritized for electrification; however, can eventually upgrade for efficiency reasons.	Gas dryers are to be replaced with HP dryers. Existing traditional electric dryers aren't prioritized for electrification; however, can eventually upgrade for efficiency reasons.	
Emissions Savings	N/A, this impact is reflected in the reduction percentage reported under "electrify space heating."	7% Mean Estimated Carbon Emissions Savings per building	N/A, this is enabling work required to electrify end uses in subsequent packages.	8% Mean Estimated Carbon Emissions Savings per building	29% Mean Estimated Carbon Emissions Savings per building	1% Mean Estimated Carbon Emissions Savings per building	<1% Mean Estimated Carbon Emissions Savings per building	45% Mean Total Emissions Savings per High Rise building
Estimated Costs	$2.9M estimated cost per building, $34,900 estimated mean cost per dwelling	$618,000 estimated cost per building, $7,400 estimated mean cost per dwelling	$1M estimated cost per building, $12,900 estimated mean cost per dwelling	$608,000 estimated cost per building, $7,300 estimated mean cost per dwelling	$770k – $1M est. cost per building, $9.2k – $12.4k est. cost per dwelling	$5,400 Estimated cost per dwelling unit	$5,400 Estimated cost per dryer	$5.9M - $6.3M Mean Total Cost per High Rise building (*see comparison of High Rise heat pump options*)
	EASY MED. ▼HARD	▼EASY	▼HARD	▼MED.	▼HARD	▼EASY	▼EASY	

Assumptions & Notes

1) Baseline insulation values were estimated from ASHRAE 90A-1980, Type A Building guidance and NREL data
2) Carbon emissions savings were calculated using a 2023 grid emissions factor (see *Appendix: Carbon Emissions Factors*). Carbon emissions reductions for "electrify space heating" includes space cooling savings.
3) Costs are high-level and do not include incentives, please refer to subsequent sections for the incentive analysis.

Archetype drill down: High Rise

Electrify Space Heating

High rise buildings provide the most challenges for installing ASHPs, due to refrigerant runs, piping, and mounting of the systems. For the High Rise buildings using ASHP technology represents ~35% additional construction cost, this is translated into $951 M USD total scope or $9M USD additional cost from using Window Heat Pumps in this archetype. Despite being more costly, ASHP also represents more construction uncertainty due to the types of working tasks such as piping, rooftop units and steel dunnage or reinforcements.

ASHPs for High Rise buildings

Installing ASHPs can offer numerous benefits such as energy efficiency and cost savings, it also comes with challenges such as upfront costs, system complexity, and maintenance requirements. Careful consideration of these factors is essential for evaluating the feasibility of ASHPs for each building.

Installation
Includes installing outdoor units, which could be located on the roof or at ground level, one or more indoor units per dwelling, refrigerant piping, and requires electrical upgrades.

Cost Estimate for Space Heating
$12,400 per dwelling unit

Window Heat Pumps for High Rise buildings

Packaged window heat pump units offer a swift and economical solution for electrifying space heating with less disruption to occupants. They mitigating or eliminate several cost factors associated with installing conventional heat pump technologies, such as extensive refrigerant piping and the need for drilling and penetrations through walls

Installation
Hung directly on a windowsill and plugged into a 120V outlet.

Cost Estimate for Space Heating
$9,200 per dwelling unit

Archetype drill down: Garden Style

10% of total area
17% of total emissions

Electrify Space Heating
222
Buildings to Electrify Space Heating

Electrify Domestic Hot Water
210
Buildings to electrify DHW

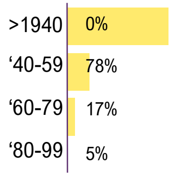
Electrify Gas Stoves
~200
Units with Gas Stoves

Electrify Gas Dryers
5
Gas Dryers

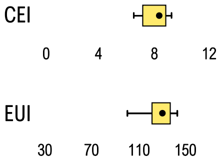
GARDEN STYLE

Developments	12
Buildings	234
Dwelling units	1,272
Area (sf)	1.5M
Typical Floors	2
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Tenant A/C
Ventilation	Passive
Cooking	Gas Stove

VINTAGE
% of buildings



EUI in kBtu/sf/yr
CEI in $kgCo_2e/yr$



	Current State	**Archetype Challenges**
SPACE HEATING	Space heating in garden style buildings is primarily from gas-based systems. 10% of the portfolio-wide emissions are from space heating of Garden style. Of the 234 garden-style buildings, 12 currently have electric-based space heating and are located in Groveland, Davison, and Spring Street Developments.	There are different roof types across the garden-style buildings. For each building, careful consideration should be taken for the available roof space and structural considerations for equipment mounting. Additionally, adding systems that provide both heating and cooling might impact the cooling load if not previously provided by the building. As each building electrifies their space heating their scope 1 emissions will decrease while the scope 2 emissions will increase due to added electrical load. The added electrical load may require electrical capacity upgrades.
DOMESTIC HOT WATER	95% of Walk Ups use natural gas for domestic hot water. The natural gas used for domestic hot water across all 234 Garden Style buildings represents 2% of the overall portfolio emissions.	As each building electrifies their domestic hot water their scope 1 emissions will decrease while the scope 2 emissions will increase due to added electrical load. The added electrical load may require electrical capacity upgrades.
COOKING	The majority of dwelling units in Garden Style buildings have electric cooking already. Based on development-level data and dwelling unit quantities, 87% of dwelling units have electric cooking.	It is assumed that replacement cooking equipment will not require architectural changes to each dwelling unit; however, this should be considered for each building.
LAUNDRY	Laundry, when provided, is typically located in shared areas. Laundry is provided in most developments with Garden Style buildings. In total there are only 22 dryers in these developments, of which only 5 are gas dryers.	Laundry represents a very small portion of Scope 1 emissions. It is assumed that new equipment can slide in place of existing equipment in shared laundry rooms.

Recommended Loading Order: Garden Style

	1	2	3	4	5	OPPORTUNISTIC STRATEGIES INDEPENDENT OF LOADING ORDER		
	Envelope Weatherization	Efficiency Upgrades	Electrical Capacity Upgrades	Electrify Domestic Hot Water	Electrify Space Heating	Electrify Gas Stoves	Electrify Gas Dryers	
	Includes air sealing, roof insulation, wall insulation & targeted window upgrades	Includes lighting and appliance upgrades, controls, energy recovery & ductwork sealing and insulation	Includes panelboard upgrades, new utility supply lines & electrical distribution	Includes upgrading to heat pump water heaters (HPWH).	Includes ASHP units, terminal units, and refrigerant piping	Includes induction cooktop & induction-ready cookware set	Includes upgrading to heat pump dryers	
	Walk-up wall insulation would increase from R-4 to R-20, and roof insulation would increase from R-10 to R-30.	Assumes reducing lighting power density by 30% where possible	Includes dwelling unit panelboards to be updated to 100A @ 120/240V single phase, cabling from service switch to be upsized, and building incoming service upgrades	Gas boilers and water heaters to be updated with HPWH. Existing electric resistance water heaters are not prioritized but can be upgraded for efficiency reasons	Most buildings have gas boiler systems with hydronic distribution. It is anticipated that buildings will update to Air Source Heat Pumps with hydronic distribution.	Dwelling units with gas stoves update to induction stoves. Electric resistance stoves aren't prioritized for electrification; however, can eventually upgrade for efficiency reasons.	Gas dryers are to be replaced with HP dryers. Existing traditional electric dryers aren't prioritized for electrification; however, can eventually upgrade for efficiency reasons.	
Emissions Savings	N/A, this impact is reflected in the reduction percentage reported under "electrify space heating."	9% Mean Estimated Carbon Emissions Savings per building	N/A, this is enabling work required to electrify end uses in subsequent packages.	8% Mean Estimated Carbon Emissions Savings per building	29% Mean Estimated Carbon Emissions Savings per building	1% Mean Estimated Carbon Emissions Savings per building	<1% Mean Estimated Carbon Emissions Savings per building	47% Mean Total Emissions Savings per Garden Style building
Estimated Costs	$395,000 estimated cost per building, $76,600 estimated mean cost per dwelling	$44,000 estimated cost per building, $8,600 estimated mean cost per dwelling	$100,000 estimated cost per building, $19,400 estimated mean cost per dwelling	$67,000 estimated cost per building, $13,100 estimated mean cost per dwelling	$165,000 estimated cost per building, $32,100 estimated mean cost per dwelling	$5,300 Estimated cost per dwelling unit	$5,252 Estimated cost per dryer	$771,741 Mean Total Cost per Garden Style building
	EASY MED. ▼HARD	▼EASY	▼HARD	▼MED.	▼HARD	▼EASY	▼EASY	

Assumptions & Notes

1) Baseline insulation values were estimated from ASHRAE 90A-1980, Type A Building guidance and NREL data
2) Carbon emissions savings were calculated using a 2023 grid emissions factor (see *Appendix: Carbon Emissions Factors*). Carbon emissions reductions for "electrify space heating" includes space cooling savings.
3) Costs are high-level and do not include incentives, please refer to subsequent sections for the incentive analysis.

Archetype drill down: Office

<1% of total area
1% of total emissions

Electrify Space Heating

23

Buildings to Electrify Space Heating

Electrify Domestic Hot Water

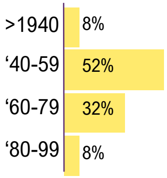
23

Buildings to electrify DHW

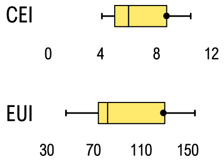
OFFICE

Developments	20
Buildings	25
Dwelling units	0
Area (sf)	70,240
Typical Floors	1
Typical Systems	
Space Heat	Gas Boiler
DHW	Gas Boiler
Cooling	Window Unit
Ventilation	AHU
Cooking	NA

VINTAGE
% of buildings



EUI in kBtu/sf/yr
CEI in $kgCo_2e/yr$



	Current State	Archetype Challenges
SPACE HEATING	Space heating in Office buildings is primarily from natural gas systems. Of the 25 in-scope buildings, 3 currently have electric-based space heating and are located in Groveland, Davison and Spring Street Developments.	There are different roof types across the office buildings. For each building, careful consideration should be taken for the available roof space and structural considerations for equipment mounting.
DOMESTIC HOT WATER	Groveland, Davison and Spring Street Developments also have electric hot water heating. The remaining 23 buildings have natural gas based hot water heating.	As each building electrifies their domestic hot water their scope 1 emissions will decrease while the scope 2 emissions will increase due to added electrical load. The added electrical load may require electrical capacity upgrades.

Recommended Loading Order: Office

1 Envelope Weatherization	2 Efficiency Upgrades	3 Electrical Capacity Upgrades	4 Electrify Domestic Hot Water	5 Electrify Space Heating
Includes air sealing, roof insulation, wall insulation & targeted window upgrades	Includes lighting and appliance upgrades, controls, energy recovery & ductwork sealing and insulation	Includes panelboard upgrades, new utility supply lines & electrical distribution	Includes upgrading to heat pump water heaters (HPWH).	Includes ASHP units, terminal units, and refrigerant piping
Walk-up wall insulation would increase from R-4 to R-20, and roof insulation would increase from R-10 to R-30.	Assumes reducing lighting power density by 30% where possible	Includes dwelling unit panelboards to be updated to 100A @ 120/240V single phase, cabling from service switch to be upsized, and building incoming service upgrades	Gas boilers and water heaters to be updated with HPWH. Existing electric resistance water heaters are not prioritized but can be upgraded for efficiency reasons	Most buildings have gas boiler systems with hydronic distribution. It is anticipated that buildings will update to Air Source Heat Pumps with hydronic distribution.
N/A, this impact is reflected in the reduction percentage reported under "electrify space heating."	7% Mean Estimated Carbon Emissions Savings per building	N/A, this is enabling work required to electrify end uses in subsequent packages.	1% Mean Estimated Carbon Emissions Savings per building	25% Mean Estimated Carbon Emissions Savings per building
$173,000 Estimated cost per building	$22,500 Estimated cost per building	$90,700 Estimated cost per building	$63,500 Estimated cost per building	$150,000 Estimated cost per building
EASY MED. ▼ HARD	▼ EASY	▼ HARD	▼ MED.	▼ HARD

33%
Mean Total Emissions Savings per Office building

$410,000
Mean Total Cost per Office building

Assumptions & Notes

1) Baseline insulation values were estimated from ASHRAE 90A-1980, Type A Building guidance and NREL data
2) Carbon emissions savings were calculated using a 2023 grid emissions factor (see *Appendix: Carbon Emissions Factors*). Carbon emissions reductions for "electrify space heating" includes space cooling savings.
3) Costs are high-level and do not include incentives, please refer to subsequent sections for the incentive analysis.

CONTEXT
THE CURRENT STATE
DECARB PATHWAYS
METHODOLOGY
APPENDICES

4.0 Methodology

- Building and Development Analysis
- Energy and Carbon Analysis
- Technology Analysis
- Cost & Incentives Analysis

Overview of methodology

Process

Baseline database creation

- Portfolio characteristic analysis
  - Vintage
  - Typology classification
  - Gross floor area
- Existing systems analysis
  - Equipment type
  - Equipment age
  - Fuel type
- NREL *ResStock* & *CommStock* refinement
  - Geographic filtering
  - Program refinement
  - BHA development datapoint cross-reference

Input definition

- Decarbonization technology definition
  - Efficiency assumptions
  - Installation prioritization
  - Externality qualification
- Projected ideal technology definition
  - Technology pairing by building typology
  - Tabulation of equipment counts
- Preliminary prioritization definition
  - Priority parameter scoring
  - Hazard analysis integration

Modeling design & calculation

- Parametric energy & carbon modeling
- Time-based carbon emissions modeling
  - Variable implementation start date testing
- Priority group refinement
  - Re-calibration of groupings
  - Incorporation of carbon emission reduction potentials
- Cost estimating
- Incentives analysis

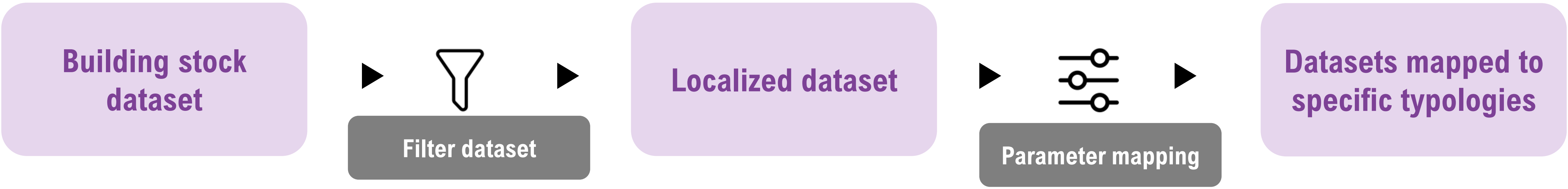
Results & recommendations

- Results classification
- Cost estimating updates
- Incentives analysis refinement
- Recommended course of action (timeline)
  - Cost and incentive data entwining
  - Idealized decarbonization technology implementation dates
  - Costing by package and calendar year

Creation of a BHA portfolio database

Building and development analysis

The first step in the decarbonization analysis was the creation of a database representing the entire BHA portfolio. Arup utilized this approach after BHA determined that whole-portfolio utility data would not be available for the scope of this analysis. As a result, Arup elected to use the housing stock characteristic and energy use databases provided by the National Renewable Energy Laboratory (NREL). These large datasets published in 2022 provide annual energy consumption data and hourly load profiles for both commercial and residential projects across all fifty U.S. states. In order to convert these larger datasets to a BHA-tailored dataset, Arup deployed the general process outlined in the diagram below. The application of geographic and building program parameters acted as the first step in filtering the NREL dataset to something usable for the creation of a BHA-portfolio dataset. Subsequently, building characteristics extracted from development level data (e.g., building vintage) in conjunction with parameters extracted from Physical Needs Assessment (PNA) reports furnished by BHA for federal sites (e.g., existing building mechanical systems) provided a final set of parameters for mapping the filtered NREL dataset to a tailored BHA-portfolio dataset for energy and carbon modeling and analysis. The subsequent pages provide additional details on the filtering and refinement of the NREL dataset to arrive at a benchmarked and usable BHA-portfolio dataset.



Building stock dataset ▶ Filter dataset ▶ **Localized dataset** ▶ Parameter mapping ▶ **Datasets mapped to specific typologies**

Creation of a BHA portfolio database

Building and development analysis

Building stock dataset

The NREL recently developed two large-scale building stock datasets for U.S. commercial and residential building typologies, referred to respectively as *ComStock* and *ResStock*. For the creation of BHA-portfolio dataset, Arup used both NREL datasets, as the BH portfolio does have some non-residential properties, though the *ResStock* dataset comprised the bulk of data used in this study.

Both *ComStock* and *ResStock* combine building characteristic with physics-based modeling to derive annual energy use figures and hourly load profiles. Additional information on these base datasets can be find on the NREL website.[1]

Localized dataset

Localizing the *ResStock* data and filtering out any irrelevant building typologies acted as the first step in creating a BHA-tailored building database. *ResStock* data is reported by state. Therefore, the following steps guided the dataset localization process:

1. Adopt the Massachusetts *ResStock* dataset.
2. Filter the dataset to by American Housing Survey (AHS) region to pull values only for the *Boston-Cambridge-Newton, MA-NH* region.
3. Filter the dataset by Residential Energy Consumption Survey (RECS) building type classification to include only *multi-family with 2-4 units* and *multi-family with 5+ units* typologies.

Datasets mapped to specific typologies

After creation of a filtered localized *ResStock* dataset, Arup created an energy use profile for each of the in-scope BHA developments. This process employed key parameters provided at the development level or extrapolated from federal site PNA data. This mapping exercise produced total annual energy use data broken down by end-use (e.g., heating energy used) for each of the four principal typologies (as defined in the *Current State* section of this report) for each BHA development. The following parameters guided the dataset mapping process:

- Building vintage
- Building gross floor area (GFA)
- Number of building floors
- Space heating fuel
- Space heating technology
- Hot water fuel
- Cooking (i.e.: stove) fuel

The table to the right summarizes the list of acceptable filter inputs for each of the parameters listed above.

The general framework of this process was replicated with the *CommStock* dataset for the fraction of BHA-properties that are classified as “Office” (i.e.: non-residential).

Further details on the existing systems within the BHA portfolio can be found in the subsequent methodology sections.

Parameter	Possible Inputs
Building vintage	<1940 1940-’59 1960-’79 1980-’99 2000-’09 ≥2010
Building gross floor area	<4,000 4,000+
Number of building floors	<8 8+
Space heating fuel	Electricity Natural gas Oil
Space heating technology	(Electric) ASHP Electric Boiler Electric Baseboard Natural Gas Fuel Boiler Natural Gas Fuel Furnace Fuel Oil Fuel Boiler Fuel Oil Fuel Furnace
Hot water fuel	Electricity Natural gas
Cooking fuel	Electricity Natural gas

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1. NREL (2023): ResStock – NREL.
2. Both *Appendix: EUI Benchmarking: BHA development data v. modeled data* and *Appendix: EUI Benchmarking: BHA building-level data v. modeled data* provide EUI benchmarking during the database creation validation process.

Evaluation of BHA existing system conditions

Building and development analysis

BHA provided PNA data for the federal sites within the portfolio. Arup used this data to survey the baseline space heating, domestic hot water, and cooking equipment currently installed within the BHA portfolio. This data for the federal sites was later augmented by state site data shared by BHA.[1] The following system characteristics were extracted from the PNA data:

- Space heating system type (i.e.: name)
- Space heating system fuel used (e.g.: natural gas)
- Space heating system distribution type (e.g.: hydronic)
- Domestic hot water system type
- Domestic hot water system fuel used
- Domestic hot water system location (e.g.: unitary)
- Cooking equipment
- Cooking equipment fuel
- Presence of unique cooling equipment (e.g.: window A/C)
- Estimated equipment end-of-life date

In addition to the PNA data, BHA also furnished separate data on laundry facilities, including the number of washers and dryers and fuel used (i.e.: gas- v. electric-dryer).

Using this data, the type cross-referenced these characteristics against the building and development typologies to understand trends in system application in each building. The tables to the right list the condensed and simplified list of baseline existing systems found in the BHA portfolio.[2]

Existing building systems

SPACE HEATING

Base system	Base system fuel
Condensing boiler, modulating	Natural gas
Furnace	Natural gas
Baseboard heater	Electricity
Cabinet heater	Electricity
Wall heater	Electricity
Mini-split	Electricity
Heat pump	Electricity
Heat pump (air-to-water)	Electricity
Cabinet heater	Electricity

Existing building systems, cont.

DOMESTIC HOT WATER

Base system	Base system fuel
Unitary water heater	Natural gas
Boiler	Natural gas
Resistance heater	Electricity

COOKING

Base system	Base system fuel
Range/oven	Natural gas
Electric coil stove	Electricity

LAUNDRY

Base system	Base system fuel
Washer/dryer	Natural gas
Washer/dryer	Electricity

---

1. Whereas federal site data was provided in the form of actual PNA reports in .pdf format, the state site PNA data was provided via BHA input into an Excel spreadsheet tracker created by Arup.
2. *Appendix: Baseline system efficiency mapping* contains additional information on the baseline systems within the BHA portfolio, and the mapping of technologies to a simplified list.

Definition of decarbonization packages

Technology analysis

After analyzing the existing conditions data for the BHA portfolio, the team developed a series of potential retrofit technologies in order to decarbonize the following end-uses:

- Space heating
- Domestic hot water
- Cooking
- Laundry

Arup reviews the suitability of these potential decarbonization technologies, which included consideration of the inherent building characteristics in order to ensure compatibility (i.e.: recommending different approaches for a high-rise v. a Walk Up), the existing technology distribution, and required changes to building electrical capacity. The approach ranked the decarbonization technologies, suggesting the ideal or "preferred" option, with other options ranked subsequently based on suitability. These potential systems were mapped against the existing conditions.

The tables at the right summarize, by building typology, the preferred system decarbonization technology and the assumed technology efficiency. The full list of potential decarbonization technologies considered can be found in *Appendix: Definition of decarbonization packages: garden style-other*. Including the preferred technologies, eleven (11) different technologies were proposed across the four (4) end-uses to be decarbonized.

WALK-UP

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	Induction stove	0.75
Laundry	Heat pump dryer	4.36[2]

HIGH-RISE

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	Induction stove	0.75
Laundry	Heat pump dryer	4.36[2]

GARDEN STYLE

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	Induction stove	0.75
Laundry	Heat pump dryer	4.36[2]

OFFICE/OTHER

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	N/A	-
Laundry	N/A	-

1. The value of 2.25 represents an assumed annual coefficient of performance (CoP) for heating, whereas the 3.80 represents the assumed CoP for cooling.
2. The unit of efficiency reported from dryers is "CEF."

Parametric modeling of decarbonization approaches

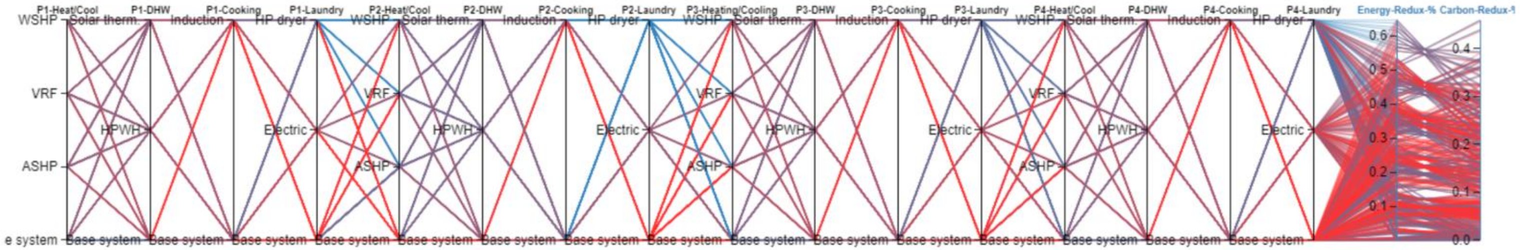
Energy and carbon analysis

The analysis of portfolio energy use and carbon emissions reductions used the list of defined decarbonization technologies to parametrically model all permutations of technology installations.[1] This full factorial calculation therefore tested 384 different decarbonization technology permutations across the entire BHA portfolio. Using this approach, the Arup was able to develop a robust "best-course of action" based on the resultant energy and carbon emissions reduction modeling.

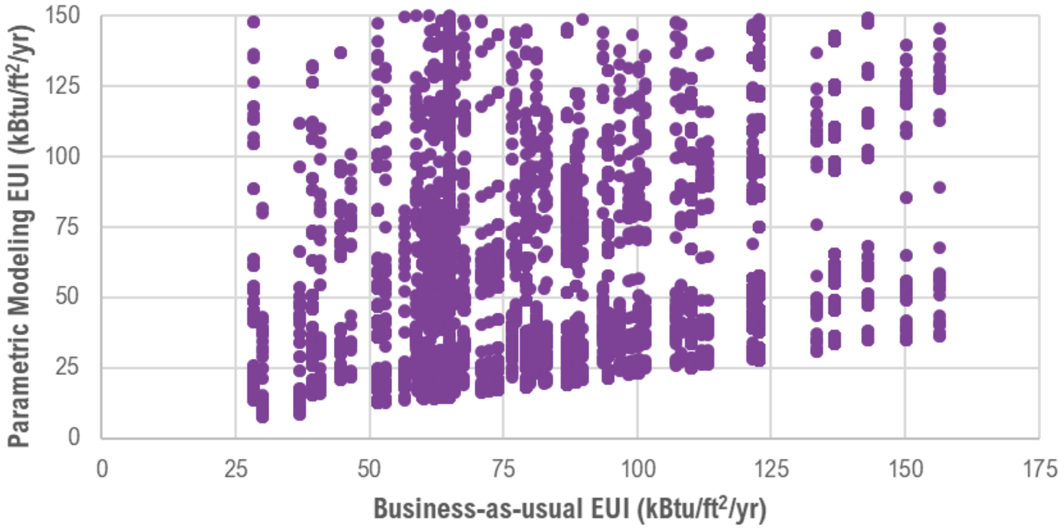
The primary inputs of this modeling approach were the baseline systems in each building and their assumed performance ratings. These assumed existing efficiencies were used to convert the baseline portfolio energy consumption to a raw load. Application of the performance factors for the proposed decarbonization technologies presented in the *Definition of decarbonization packages* section allowed for the definition of new annual energy use figures by building. Conversion of energy use to carbon emissions occurred via the use of factors for grid electricity and natural gas consumption. The principal outputs of this analysis were the following:

- Total annual energy use
- Annual energy use broken out by end-use
- Energy use intensity (EUI)
- Percentage reduction in annual building energy use
- Total annual carbon emissions
- Annual carbon emissions broken-out by end-use
- Carbon emissions intensity (CEI)
- Percentage reduction in annual carbon emissions

Parametric modeling permutation input and outputs results tracker



Full factorial modeling output visualization of BAU v. parametric options: EUI Testing



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1. Modeling also included assumptions for building heating and cooling load reductions as a result of weatherization upgrades. These load reductions were applied across all 384 permutations as it was assumed that all buildings would be weatherize. Additional information can be found in the *Appendix: Impacts of weatherization on heating/cooling load*.

Parametric modeling of decarbonization approaches

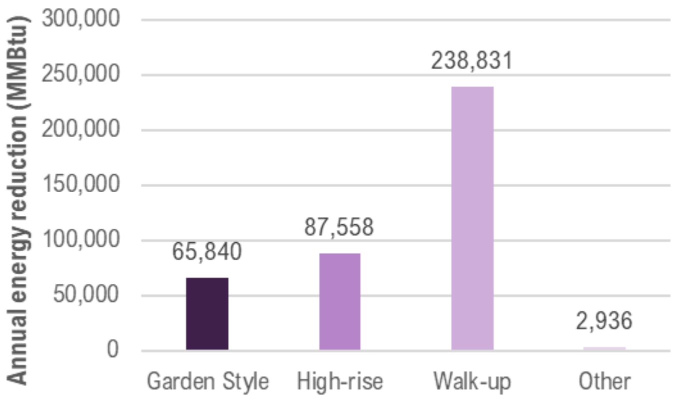
Energy and carbon analysis

METHODOLOGY

Via the full factorial calculation of all decarbonization technology options, the team was able to review the results and potential impacts to portfolio energy use and carbon emissions as part of the development of the proposed decarbonization timeline for the BHA portfolio. The results of this analysis fed into the development of the priority groups as well, with properties being classified in part relative to their carbon emissions reduction potential.

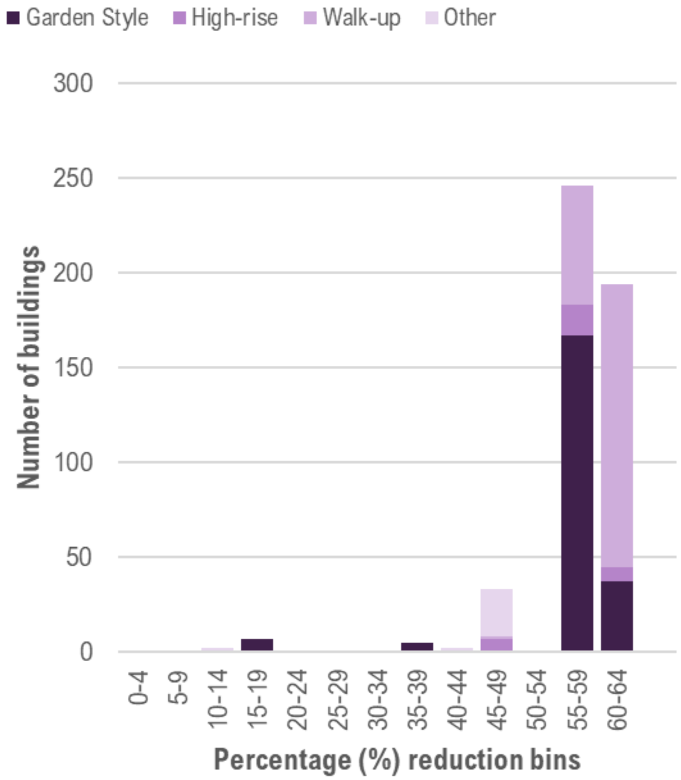
Additionally, the results of this analysis fed into the incentive analysis in order to understand which incentives that are tied to energy use and/or carbon emissions reductions could be unlocked.

Total energy savings per typology

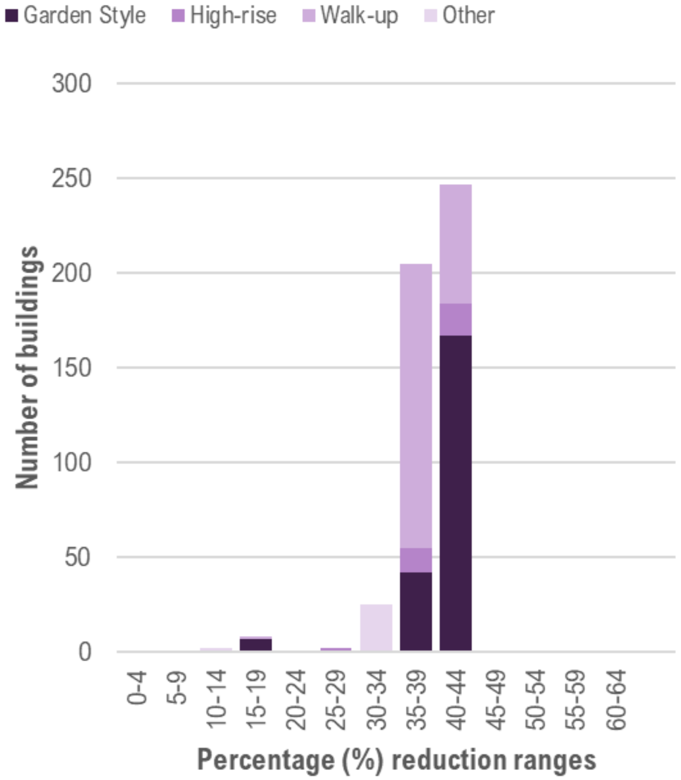


**Energy savings in MMBtu is an example of a metric used during incentive analysis.*

Summary of annual energy use reduction with the preferred decarbonization technology package



Summary of annual carbon emissions reduction with the preferred decarbonization technology package



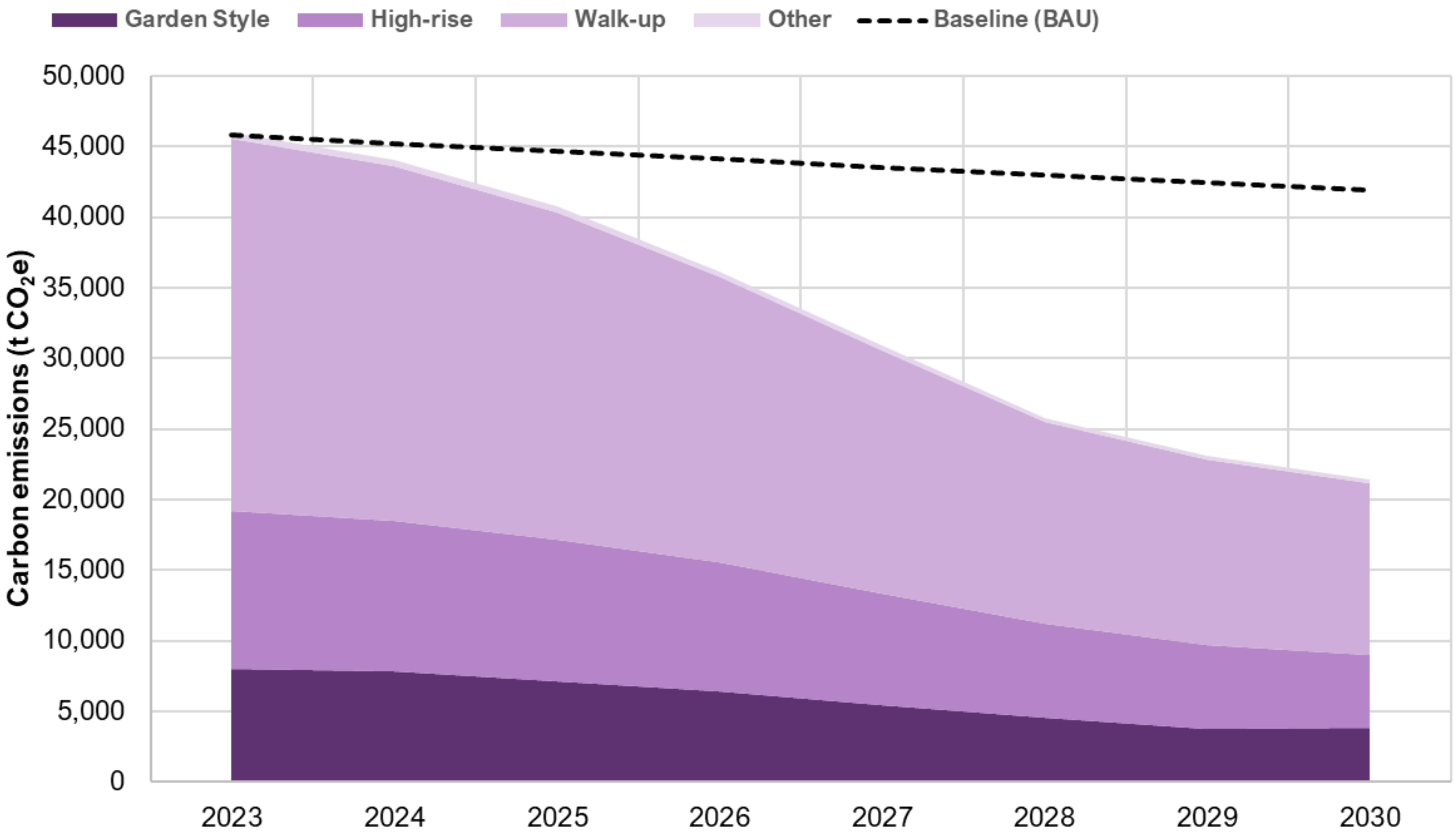
Dynamic decarbonization timeline modeling

Building understanding to unlock the roadmap to 2030

The decarbonization timeline presented in the section ***A roadmap to 2030*** was developed during synthesis of energy, carbon emissions, costing, and incentives analysis. In order to fully vet the impact of different start and end dates relative to BHA portfolio emissions, Arup developed a dynamic timeline decarbonization modeling tool allowing for testing the impact of different implementation time horizons for each of the priority groupings and decarbonization technology packages. The findings from this dynamic modeling analysis helped inform the final recommended decarbonization timeline. The image as the right shows a snapshot of this timeline modeling tool showing total portfolio carbon emissions (both Scopes 1 and 2) and modeled changes resultant changes in portfolio carbon emissions relative to a business-as-usual baseline.

This dynamic timeline decarbonization modeling approach required the use of time-based carbon emissions factors to account for project future changes in the carbon intensity of electricity generation in New England.1 Consequently, while most carbon emissions reductions presented in this report use a 2023 grid electricity carbon emissions factor, as the BHA portfolio decarbonizes and switches from Scope 1 and 2 emissions to only Scope 2 emissions under a full electric operation, an all-electric BHA portfolio will be benefit from future decreases in grid electricity carbon intensity.

DECARBONIZATION TIMELINE MODELING TOOL



Defining dollar values to decarbonize

Cost and incentive analysis

Cost analysis

The project costing model utilized an Association for the Advancement of Cost Engineering (AACE) Level 4 estimate, which entails a costing range of accuracy of approximately ±40%. Cost estimating was built-up based on the decarbonization measures proposed during the technical analysis. Costing analysis consider the decarbonization of each building end-use, both on a priority group and building typology basis. Whole portfolio costs were developed via summation of these discrete values. In addition to the cost of decarbonization technologies, the cost estimate also consider the cost of building weatherization improvements. In cases where decarbonization technologies facilitated changes (if any) to the building electrical infrastructure, those costs were included as a line item in that scope of work

Cost modeling consider both direct and indirect costs. Direct cost estimating utilized RS Means and vendor quotes. Indirect costing was based in wages and other data provided by the U.S. Bureau of Labor Statistics. In aggregate, the total direct and indirect costs developed during analysis were cross-referenced against recent reference completed by the BHA.

Costing analysis was sensitive to building characteristics, such as age, when estimating the labor required to work in older buildings or with older building infrastructure.

Additional details on the cost estimating can be found in [Appendix A].

Incentive analysis

Incentive analysis considered a myriad of state, federal, and utility incentive programs. The first step in this process was the survey of utility, governmental, and third-party incentive programs. This analysis also included consideration of the timeline for each incentive program. Analysis of BHA incentive eligibility was based upon the building typologies and decarbonization packages considered. Additionally, incentives reviewed utilized the projected portfolio energy and carbon savings to further fine-tune the projections in potential possible dollar values available to BHA.

After understanding the available incentives and BHA-eligibility, incentive analysis reviewed the specifications and design standards required to earn the maximum funding amounts. Subsequently, the analysis examined different financial pathways.

Additional details on the incentives analysis can be found in [Appendix C].

Entwined cost and incentive analysis

In addition to conducting the discrete cost and incentive analysis, these two pieces of analysis were entwined. Entwining the base costs data with possible incentive utilization allowed for projection of construction cost after incentives, including review of the projected percentage of construction costs covered by incentives on a work package basis.

Additional details on the entwined cost and incentives analysis can be found in [Appendix C].

COST & INCENTIVES SUMMARY

Line item	Total construction cost (million $)	Incentive savings (million $)	Incentives as a % of construction cost
Weatherization	404	121	30%
Efficiency	75	19	25%
Electrical upgrades	120	-	0%
Heating electrification	209	96	46%
Domestic hot water	93	17	18%
Kitchen electrification	40	4	9%
Laundry electrification	1	0	6%
Total	**942**	**256**	**27%**

Appendices

Appendices

A: Technical Analysis
B: Costing report
C: Incentives and procurement pathways report

Carbon Emissions Factors: fossil fuel emissions

Appendix A

Fossil fuel emissions, or Scope 1 emissions, result from the burning of fossil fuels on-site at BHA properties. The principal fossil fuel consumed at BHA is natural gas (some out of scope buildings reported the use of oil).

Unlike electricity grid emissions, which can vary over time, carbon emissions resulting from fossil fuel use are not time based: consuming 1 MWh of natural gas-based heat releases the same amount of carbon emissions in 2024 as in 2050.

The tables at the right high the carbon emissions factors used for Scope 1 emissions calculations in this report.

Fuel source	Emissions Factor[1] (t CO_2e/MWh)
Natural gas	0.1812
Oil[2]	0.2532

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1. Energy Star, Portfolio Manager, Technical Reference: Greenhouse Gas Emissions (2023): https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf
2. Assumes “fuel oil (no. 2).

Carbon Emissions Factors: electricity grid decarbonization

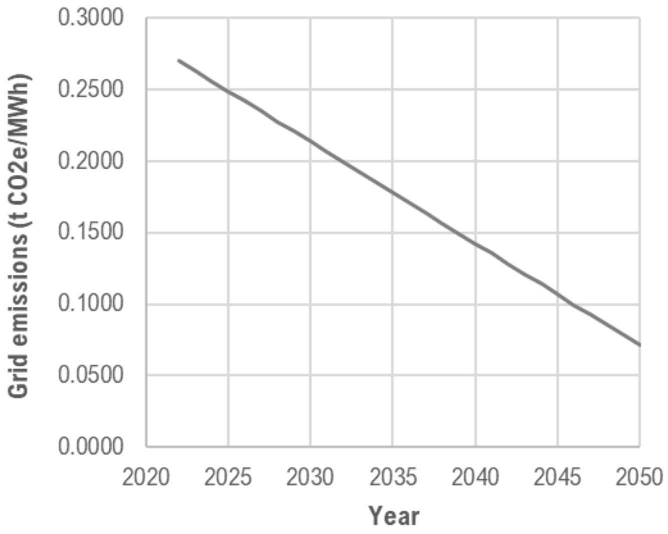
Appendix A

Carbon emissions modeling of purchased (grid) electricity assumed a time-variable carbon emissions factor. The conversion factor to convert from MWh of grid electricity consumed to [metric] ton CO_2e emitted was based on the BERDO Policies & Procedures Appendix A,[1] which is in turn based on the Boston Building Emissions Performance Standard.[2] In concert, these documents prescribed projected electricity grid carbon emissions factors based on the proposed reductions in the carbon emissions intensity of electricity production within the New England electricity grid, and specifically the electricity delivered to metro-Boston. These grid carbon emissions factors are used in the BERDO regulatory environment for carbon emissions reporting and have therefore been adopted into this study as the basis for future carbon emissions projections associated with electricity production.

The general modeling assumption in BERDO Appendix A is that the carbon emissions intensity of delivered electricity decreases linearly from a value of 0.2705 t CO_2e/MWh in 2022 to a value of 0.0714 t CO_2e/MWh in 2050. Per this projection, it should be noted that the grid is not projected to be carbon neutral at any point before 2050. This linear projection assumes a parity year of natural gas and grid emissions in 2034/2035; this means that in late 2034, early-2035, the carbon emissions from consuming 1 MWh of grid electricity-based energy or 1 MWh of natural gas-based energy emit the same amount of CO_2e. Prior to parity, it is assumed that grid electricity is more carbon intensive than natural gas; after, natural gas is assumed to be more carbon intensive than grid electricity. Therefore, any consumer of grid electricity wishing to achieve operational carbon neutrality would need to produce or procure electricity from renewable sources (e.g.: onsite solar photovoltaics or purchasing of RECs).

Year	Projected Grid Emissions Factor (t CO_2e/MWh)	Year	Projected Grid Emissions Factor (t CO_2e/MWh)
2022	0.2705	2043	0.1209
2023	0.2636	2044	0.1141
2024	0.2564	2045	0.1068
2025	0.2491	2046	0.0995
2026	0.2423	2047	0.0927
2027	0.2350	2048	0.0855
2028	0.2277	2049	0.0782
2029	0.2209	2050	0.0714
2030	0.2136		
2031	0.2064		
2032	0.1995		
2033	0.1923		
2034	0.1850		
2035	0.1782		
2036	0.1709		
2037	0.1636		
2038	0.1568		
2039	0.1495		
2040	0.1423		
2041	0.1355		
2042	0.1282		

Modeled carbon intensity of the electricity grid



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1. BERDO Policies & Procedures, v2.5 (2023): https://www.boston.gov/sites/default/files/file/2023/12/12.20.23%20Full%20Policies%20-%20Clean%20Version.pdf.
2. Boston Building Emissions Performance Standard: Technical Methods Overview (2021): https://drive.google.com/file/d/1p3CiB6j3dYpc7F4YHGP7oaAN7SthQgK_/view.

Carbon Emissions Factors: historical v. project emissions

Appendix A

The carbon intensity of purchased grid electricity is determined by the primary fuels and generation techniques used to provision consumers with electricity. In the case of decarbonization modeling, it is necessary to examine projected future electricity grid emissions in order to reflect projected future changes in the blend of renewables used in regional electricity generation and the resultant impact on consumers. However, projected grid emissions are modeled approximations of future performance, but do not guarantee future performance.

In New England, the Regional Transmission Organization ISO New England Inc. (ISO-NE), which oversees regional generation and transmission, publishes annual reports on the carbon emissions associated with regional electricity generation.[1] The carbon emission rates published in the ISO-NE report describe emissions resulting from localized electricity generation, as well as emissions with "net imports," the latter reflecting the impact of electricity imported to New England from neighboring New York, New Brunswick, and Québec. In terms of carbon emissions, ISO-NE benefits from these imports, especially those from Québec, as public utility Hydro-Québec provides low carbon intensity hydro-electric power. As reflected in the tables at the right, lower carbon intensity electricity imports to New England generally decrease the carbon intensity of purchased grid electricity between 12%-14% annually.

The projected grid emissions used in this study are aligned with guidance in BERDO (see *Appendix: Carbon Emissions Factors: electricity grid decarbonization*). As noted in the tables and graph at the right, these projected BERDO values reflect the emissions ISO-NE reports as including net imports.

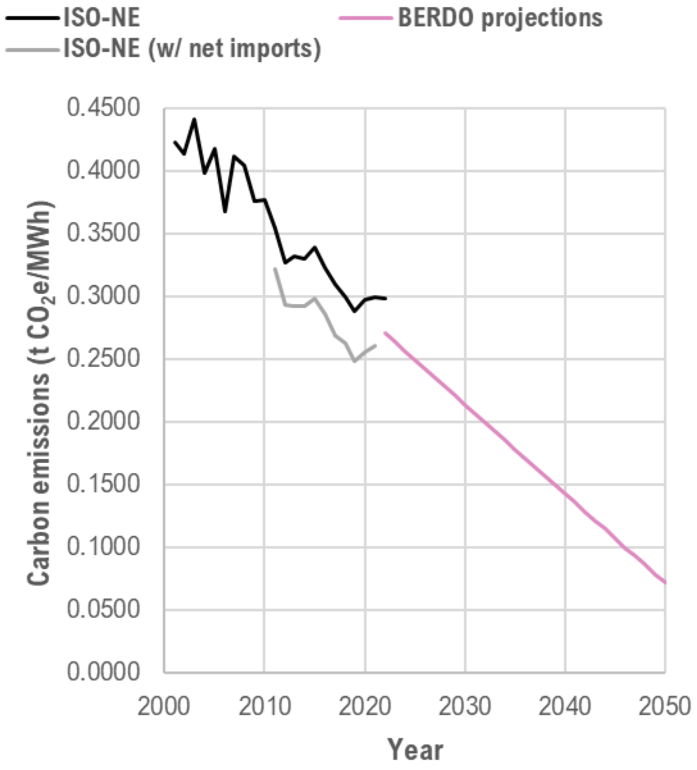
Projected grid emissions as outlined in BERDO

Year	Projected Grid Emissions Factor ($t\ CO_2e/MWh$)
2022	0.2705
2023	0.2636
2024	0.2564

Historical electricity emissions as reported by ISO-NE: carbon emissions with and without net import

Year	Grid Emissions ($t\ CO_2e/MWh$)	Grid Emissions with Net Imports ($t\ CO_2e/MWh$)
2018	0.2991	0.2623
2019	0.2877	0.2486
2020	0.2973	0.2550
2021	0.2991	0.2609
2022	0.2985	Not reported

Historical ISO-NE grid emissions (with and without net imports) v. BERDO projected future emissions



- 1. 2021 ISO New England Electric Generator Air Emissions Report (2023): https://www.iso-ne.com/final_2022_air_emissions_report.pdf and https://www.iso-ne.com/2023/04/2021-air-emissions-report.pdf.

Sensitivity analysis of prioritization groups

Appendix A

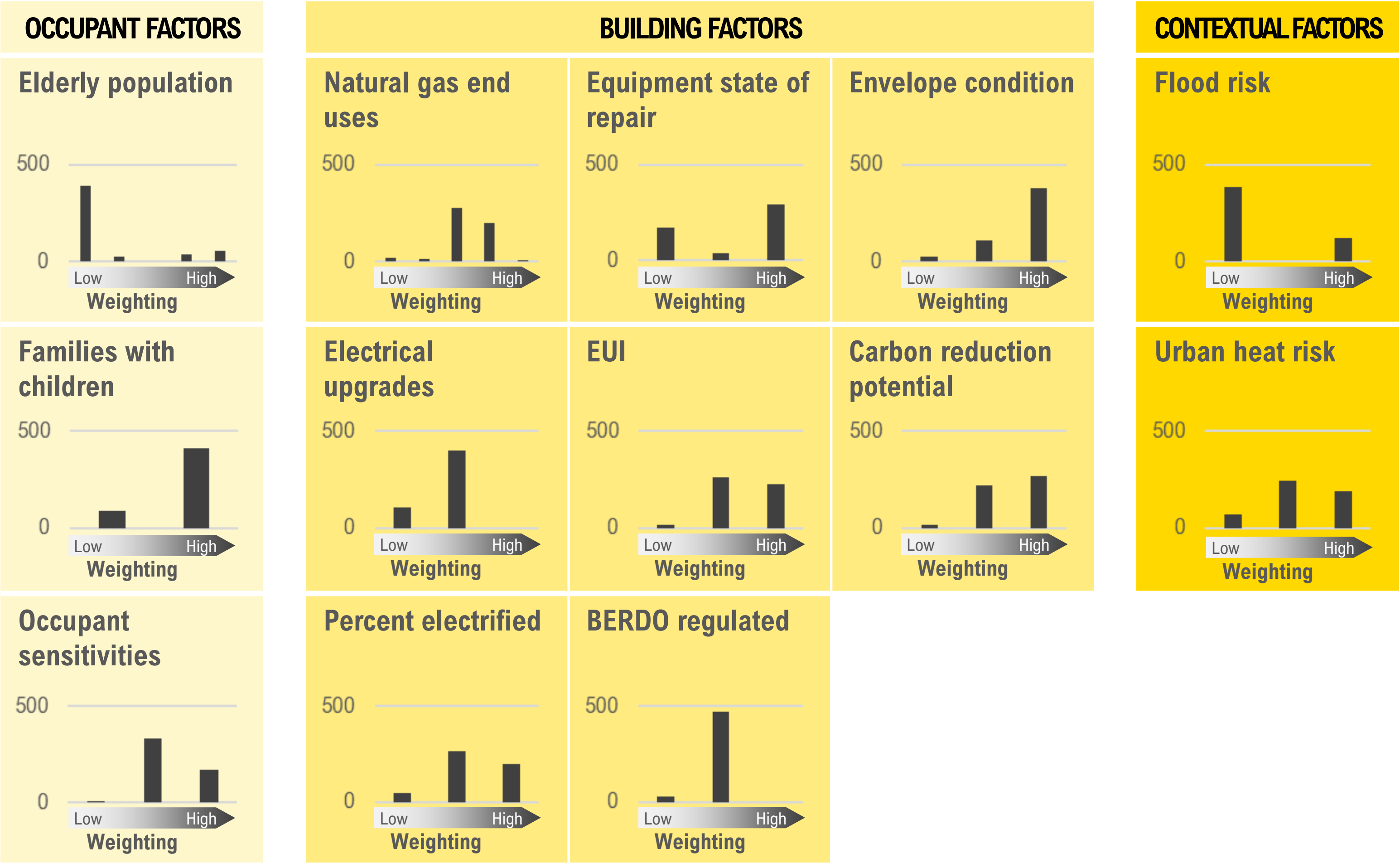
A range of prioritization criteria were used to categorize the BHA buildings into priority groups. This process of priority group identification served to inform the implementation planning of the decarbonization measures.

The priority criteria were classified as *occupant factors*, *building factors*, or *contextual factors*. Each prioritization criteria within factor groupings was scored relative to criteria-specific weighting indicators. The result of this approach meant that the most significant drivers pushing a building into a higher priority group were criteria with both a high relative weighting **and** a broader and more equal distribution of buildings across the low, moderate, and high weighting indicators. As pertains to the latter, this meant that a prioritization criteria needed to exhibit at least three or more data quantiles, of which two had to each account for at least 25% of the total dataset. Alternately, if only two quantiles were used for a criteria-specific indicators, they needed to exhibit between a 50:50 and a 33:67 split in order to noticeably influence the final priority groupings development.

The analysis of the prioritization weighting sensitivity revealed the following prioritization criteria **as the most influential** due to their combined overall weighting and quantile characteristics:

- Natural gas end uses
- EUI
- Carbon reduction potential
- Percent electrified

Factors of secondary influence included *equipment state of repair* and *BERDO regulated*. Prioritization criteria with the **lowest impact** on priority group development included *families with children*, *elderly population*, and *flood risk*.



Utility cost reduction modeling

Appendix A

Via the full factorial calculation of all decarbonization technology options, the team was able to review the results and potential impacts to portfolio energy costs. The energy cost values utilized the following rates:[1]

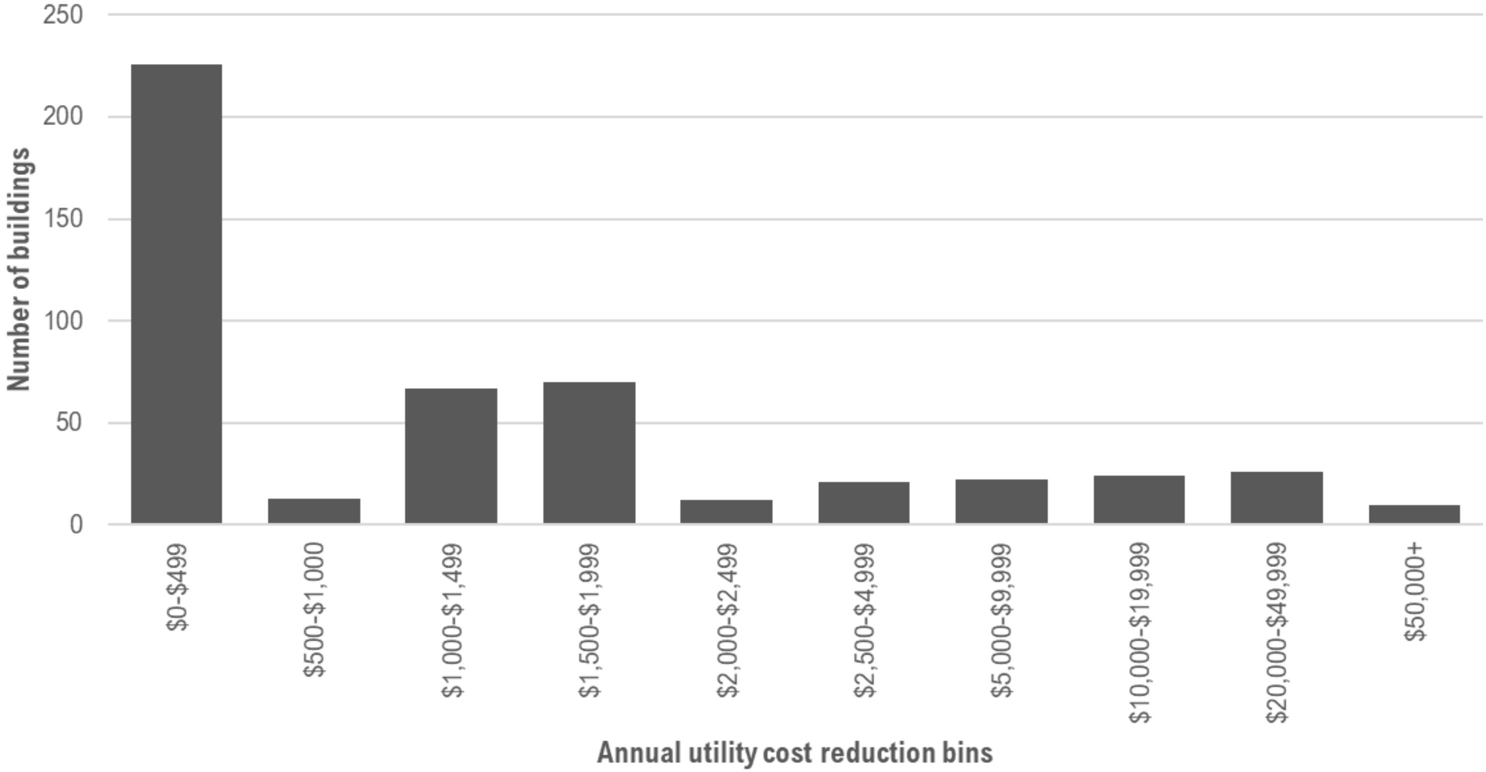
- Grid electricity: $189.60/MWh
- Natural gas: $55.84/MWh

This current pricing model reflects a financial bias towards natural gas at present. However, this utility pricing does not consider future financial penalties associated with fossil fuel consumption (i.e.: BERDO).

Based on the application of utility cost data, the mean reduction in building-level utility costs owing to the application of decarbonization technologies was **$4,706** per year.

**These calculations do not include future cost modeling.*

Summary of annual energy cost reduction (in dollars) with the preferred decarbonization technology package



EUI Benchmarking: BHA development data v. modeled data

Appendix A

BHA provided development-level energy performance date for all the in-scope developments. This data was used to assess the appropriateness of the modeled database used for energy and carbon emissions reductions modeling and build confidence in calculation results.

This checking of modeled database energy and carbon values against BHA provided utility data showed general alignment between the two datasets, with variation within acceptable ranges. The table at the right and on the subsequent page shows the variance between the BHA-provided development level roll-up and the Arup modeled dataset, with the percentage variance of the two datapoints.

		EUI (kBtu/ft^2/yr)		
Development Name	Development No.	BHA-provided	Arup modeled dataset	Variance
Ruth Barkley (Cathedral)	106	62.1	62.0	<1%
Alice Taylor	114	86.8	86.9	<1%
Franklin Field (Family)	189	88.6	88.2	<1%
Charlestown	201	65.0	70.9	-9%
Mildred C. Hailey (Bromley Park/Heath St)	219	65.0	63.8	2%
ME McCormack	223	65.0	65.5	-1%
Margaret Collins (Pond St)	226	143.1	147.9	-3%
Annapolis	227	101.5	101.3	<1%
Ashmont	228	291.0	290.0	<1%
Holgate	229	89.1	89.0	<1%
Foley	230	79.9	79.9	<1%
Groveland	232	44.5	45.6	-2%
Davison	234	28.4	29.1	-2%
Washington Street	235	30.0	30.0	<1%
West Ninth St.	236	100.4	74.3	26%
JJ Meade	238	108.2	108.2	<1%
ML King	240	96.6	96.6	<1%
Eva White	241	68.3	68.4	<1%
Doris Bunte (Walnut Park)	242	64.8	64.8	<1%
Frederick Douglass	244	81.1	81.1	<1%
General Warren	247	51.6	51.7	<1%

EUI Benchmarking: BHA development data v. modeled data

Appendix A

		EUI (kBtu/ft²/yr)		
Development Name	Development No.	BHA-provided	Arup modeled dataset	Variance
Torre Unidad	249	81.2	81.2	<1%
Rockland	250	67.6	67.6	<1%
Codman	251	107.2	107.2	<1%
Heritage (BHA PBV)	252	79.1	79.3	<1%
St. Botolph St	253	59.1	59.1	<1%
Pasciucco	254	82.6	82.6	<1%
Lower Mills (BHA PBV)	257	83.1	83.1	<1%
Ausonia	261	60.7	60.7	<1%
Hassan	262	77.4	77.4	<1%
Spring Street	270	39.3	39.9	-1%
Patricia White (BHA PBV)	271	42.4	40.9	3%
Roslyn (Cliffmont)	272	61.4	61.4	<1%
Bellflower	277	53.0	53.0	<1%
Commonwealth Family	282	65.0	66.9	-3%
Peabody	283	56.7	56.7	<1%
Joseph Malone	290	59.9	60.0	<-1%
Highland Park	293	65.0	66.0	-2%
Commonwealth Elderly	295	37.1	37.1	<1%
Hampton House	298	76.6	76.6	<1%
Washington Manor	299	104.5	93.6	10%
West Broadway	501	122.8	121.7	1%

		EUI (kBtu/ft²/yr)		
Development Name	Development No.	BHA-provided	Arup modeled dataset	Variance
Washington Manor	299	104.5	93.6	10%
West Broadway	501	122.8	121.7	1%
Fairmount	505	121.4	118.9	2%
Archdale	507	94.5	94.5	<1%
Gallivan Boulevard	510	136.9	137.2	<-1%
South Street	512	110.0	110.2	<1%
Franklin Field (Elderly)	602	63.4	66.5	-5%
Monsignor Powers	603	58.6	58.6	<1%

EUI Benchmarking: BHA building-level data v. modeled data

Appendix A

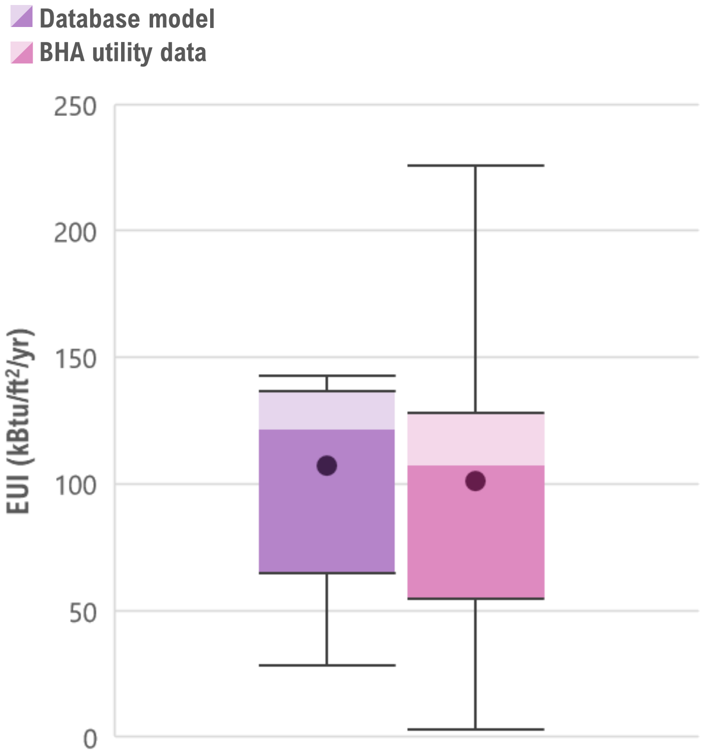
BHA provided building-level utility data on January 26, 2024, for buildings where utility data was tracked and reported. Shared data covered electricity and fossil fuel (natural gas and oil) use for the years 2021, 2022, and 2023 (the latter where possible).

This data was used principally to further assess the appropriateness of the modeled database used for energy and carbon emissions reductions modeling and build increased confidence in calculation results. During this process of modeling database spot-checking, BHA utility data for the years 2021, 2022, and 2023 was averaged together to create a blend reference building-level reference EUI. This approach was selected to address year-on-year variability performance, as well as account for possible COVID-19 impacts on building level energy use in 2021.

This checking of modeled database energy and carbon values against BHA provided utility data showed general alignment between the two datasets, with variation within acceptable ranges. Unsurprisingly, the BHA provided utility data exhibited greater distribution of individual building-level energy use values.

In the box and whisker chart at the right, both the modeled data (purple) and the BHA provided data (magenta) report mean EUI values of 107.4 kBtu/ft^2/yr and 101.5 kBtu/ft^2/yr, respectively. As visualized in this figure, the BHA utility data exhibits a larger spread of data, as highlighted by the larger respective ranges in the outer quartiles of the BHA utility data box and whisker.

Comparison of the distribution of building-level energy performance data (on an EUI basis) in the constructed model v. BHA utility data for CY 2021, 2022, and 2023



EUI Spot Check Examples

The below shows select EUIs (in kBtu/ft^2/yr) for both the modeled database used in calculations (“database”) and the BHA-supplied utility data used to construct a mean reference EUI (“BHA”) from the reported years 2021, 2022, 2023.

	EUI		
	Database	**BHA**	**Variance**
Garden Style Typology			
FTB002: Fairmount	121.4	125.0	+3%
GWB00M: General Warren	51.6	46.9	-9%
SPB005: Spring Street	39.3	38.2	-3%
High-Rise Typology			
COB007: Commonwealth	65.0	61.6	-5%
SEB00A: Ruth Barkley	62.1	64.1	+3%
WTB001: ML King	96.6	86.6	-10%
Walk-Up Typology			
ARB003: Archdale	94.5	90.2	-4%
COB011: Commonwealth	65.0	69.0	+6%
HSB003: MC Hailey	65.0	63.4	-2%

Baseline system efficiency mapping

Appendix A

Review of the BHA provided Physical Needs Assessment (PNA) data on existing building systems provided insight into the range and types of systems used for space heating and water heating. For the purposes of energy and carbon reduction performance modeling, the most critical feature of each baseline system was its performance characteristics (i.e.: efficiency). The diagram at the right visualizes the process of mapping the baseline systems for space heating (HVAC) to an assumed efficiency.

In cases where PNA data was not provided for a property, the fuel use characteristics for each end use (e.g.: gas for space heating) was used to assign an assumed existing building system.

The hot water, cooking, and laundry baseline systems exhibited a more constrained list of existing systems. The following existing system efficiency assumptions were used for each of the following additional end uses:

Hot water

- Boiler (gas): 0.80
- Heat pump (elec.): 2.78
- Water heater (elec.): 0.95

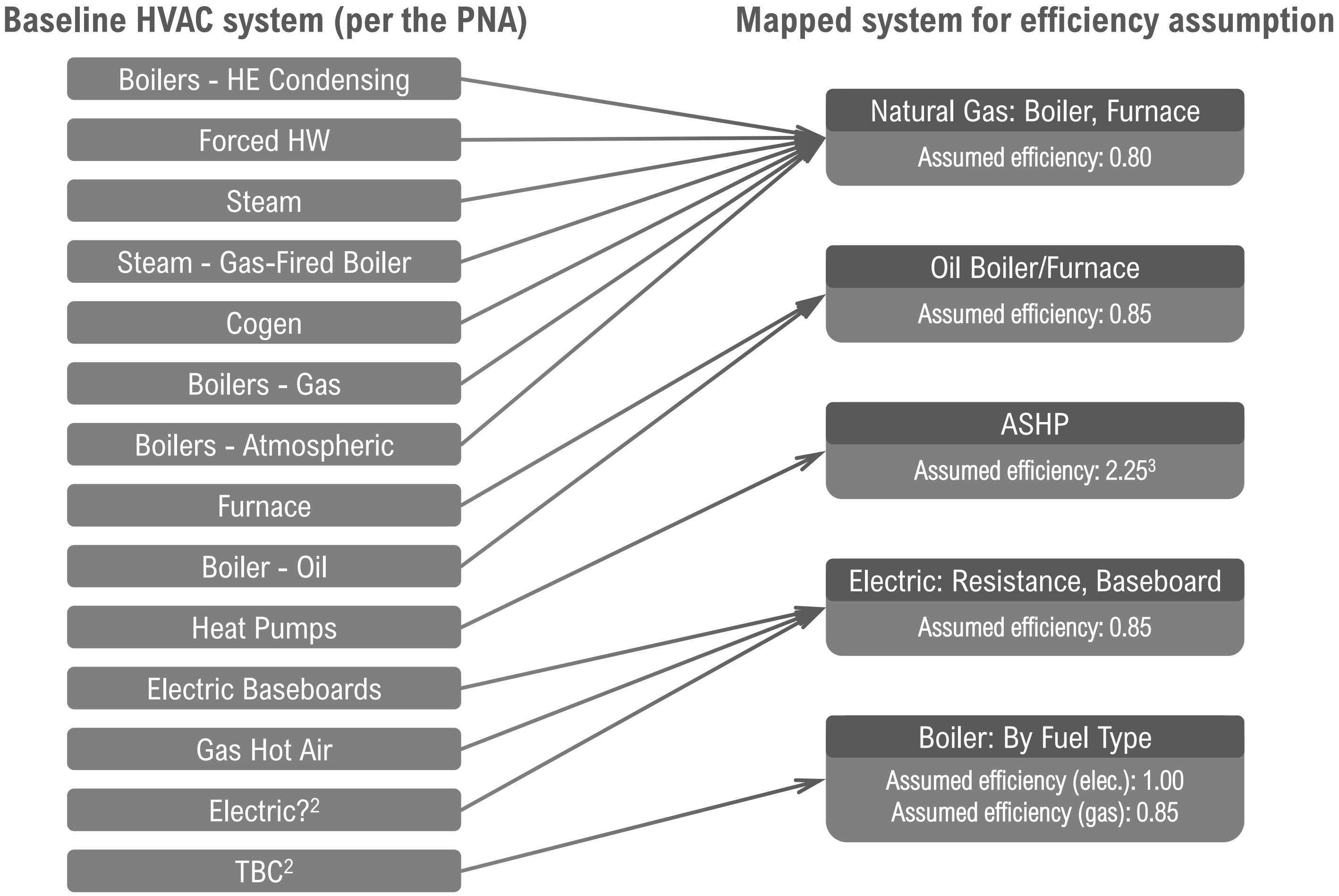
Cooking

- Coil stove (elec.): 0.65
- Range/oven (gas): 0.32

Laundry[1]

- Washer/dryer (elec.): 3.93
- Washer/dryer (gas): 3.48

**In practice, efficiency from building-to-building and unit-to-unit may vary based on the age of an HVAC unit, state of repair, etc.*



Baseline HVAC system (per the PNA)

Boilers - HE Condensing

Forced HW

Steam

Steam - Gas-Fired Boiler

Cogen

Boilers - Gas

Boilers - Atmospheric

Furnace

Boiler - Oil

Heat Pumps

Electric Baseboards

Gas Hot Air

Electric?[2]

TBC[2]

Mapped system for efficiency assumption

Natural Gas: Boiler, Furnace
Assumed efficiency: 0.80

Oil Boiler/Furnace
Assumed efficiency: 0.85

ASHP
Assumed efficiency: 2.25[3]

Electric: Resistance, Baseboard
Assumed efficiency: 0.85

Boiler: By Fuel Type
Assumed efficiency (elec.): 1.00
Assumed efficiency (gas): 0.85

---

1. Efficiency expressed in terms of CEF.
2. The identifiers “Electric?” and “TBC” indicate a property without PNA data: these terms reflect those used in the master data-exchange spreadsheet received from BHA.
3. This values represents an assumed annual performance value.

Definition of decarbonization packages: garden style

Appendix A

This appendix provides supplemental information on the decarbonization technologies used in the study. As presented in the section *Definition of decarbonization packages*, a principal system was identified for each energy end use for each building typology. In addition to the principal system option, second through third-options were identified. The alternate systems were ranked lower due to lower efficiencies and/or technical issues related to their use in retrofit.

PRINCIPAL SYSTEM OPTION

System	Decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	Induction stove	0.75
Laundry	Heat pump dryer	4.36[2]

Secondary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Variable refrigerant flow	3.50 (7.20)[1]
Hot water	Electric boiler	1.00
Cooking	Electric coil stove	0.42
Laundry	Electric dryer	3.90[2]

Tertiary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Electric boiler	1.00 (1.00)[1]
Hot water	-	-
Cooking	-	-
Laundry	-	-

---

1. The value of first value represents an assumed annual coefficient of performance (CoP) for heating, whereas the value in parentheses represents the assumed CoP for cooling.
2. The unit of efficiency reported from dryers is “CEF.”

Definition of decarbonization packages: high-rise

Appendix A

This appendix provides supplemental information on the decarbonization technologies used in the study. As presented in the section *Definition of decarbonization packages*, a principal system was identified for each energy end use for each building typology. In addition to the principal system option, second through third-options were identified. The alternate systems were ranked lower due to lower efficiencies and/or technical issues related to their use in retrofit.

PRINCIPAL SYSTEM OPTION

System	Decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	Induction stove	0.75
Laundry	Heat pump dryer	4.36[2]

Secondary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Window heat pump	2.60 (4.00)[1]
Hot water	Electric boiler	1.00
Cooking	Electric coil stove	0.42
Laundry	Electric dryer	3.90[2]

Tertiary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Ground-source heat pump	3.50 (39.20)[1]
Hot water	-	-
Cooking	-	-
Laundry	-	-

---

1. The value of first value represents an assumed annual coefficient of performance (CoP) for heating, whereas the value in parentheses represents the assumed CoP for cooling.
2. The unit of efficiency reported from dryers is “CEF.”

Definition of decarbonization packages: Walk Up

Appendix A

This appendix provides supplemental information on the decarbonization technologies used in the study. As presented in the section *Definition of decarbonization packages*, a principal system was identified for each energy end use for each building typology. In addition to the principal system option, second through third-options were identified. The alternate systems were ranked lower due to lower efficiencies and/or technical issues related to their use in retrofit.

PRINCIPAL SYSTEM OPTION

System	Decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	Induction stove	0.75
Laundry	Heat pump dryer	4.36[2]

Secondary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Water-source heat pump	4.30 (3.80)[1]
Hot water	Electric boiler	1.00
Cooking	Electric coil stove	0.42
Laundry	Electric dryer	3.90[2]

Tertiary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Variable refrigerant flow	3.50 (7.20)[1]
Hot water	-	-
Cooking	-	-
Laundry	-	-

1. The value of first value represents an assumed annual coefficient of performance (CoP) for heating, whereas the value in parentheses represents the assumed CoP for cooling.
2. The unit of efficiency reported from dryers is “CEF.”

Definition of decarbonization packages: office/other

Appendix A

This appendix provides supplemental information on the decarbonization technologies used in the study. As presented in the section *Definition of decarbonization packages*, a principal system was identified for each energy end use for each building typology. In addition to the principal system option, second through third-options were identified. The alternate systems were ranked lower due to lower efficiencies and/or technical issues related to their use in retrofit.

PRINCIPAL SYSTEM OPTION

System	Decarbonization technology	Assumed system efficiency
Space heating	Air-source heat pump	2.25 (3.80)[1]
Hot water	Heat pump water heater	2.78
Cooking	N/A	-
Laundry	N/A	-

Secondary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Variable refrigerant flow	3.50 (7.20)[1]
Hot water	Electric boiler	1.00
Cooking	N/A	-
Laundry	N/A	-

Tertiary system option

System	Preferred decarbonization technology	Assumed system efficiency
Space heating	Electric boiler	1.00 (1.00)[1]
Hot water	-	-
Cooking	N/A	-
Laundry	N/A	-

---

1. The value of first value represents an assumed annual coefficient of performance (CoP) for heating, whereas the value in parentheses represents the assumed CoP for cooling.
2. The unit of efficiency reported from dryers is “CEF.”

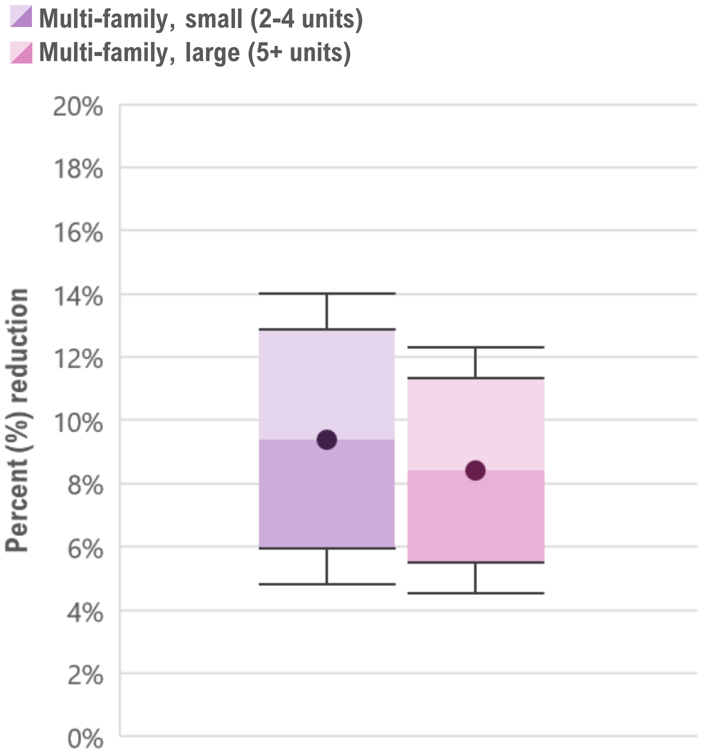
Impacts of weatherization on heating/cooling load

Appendix A

The energy and carbon reduction modeling process sought to incorporate the impacts of weatherization on building energy use in order to reflect the anticipated heating and cooling load reductions resulting from more efficient building envelopes with reduced heat transfer with the external environment. This study utilized the results two evaluation studies conducted by Oakridge National Lab[1] to apply load reduction assumptions to each BHA building receiving weatherization upgrades. This study employed load reduction assumptions based on building size in order to correlate with the methodology used in the Oakridge studies.

The graph and table to the right summarize the findings of the Oakridge studies. For the purposes of this study, the ***mean*** value with the Oakridge were adopted for modeling the reduction in heating and cooling load of BHA properties receiving weatherization upgrades.

Heating/cooling load reduction in multi-family buildings as the result of weatherization upgrades as determined in the Oakridge National Lab study



HEATING/COOLING LOAD REDUCTION VALUES

	Multi-family, small (2-4 units)	Multi-family, large (5+ units)
Maximum	14.0%	12.3%
75th percentile	11.7%	10.4%
Mean	9.4%	8.4%
25th percentile	7.1%	6.5%
Minimum	4.8%	4.5%

---

1. See *National Weatherization Assistance Program Impact Evaluation: Energy Impacts for Small Multifamily Buildings* (2014): https://weatherization.ornl.gov/ORNL_TM-2014_325.pdf and *National Weatherization Assistance Program Impact Evaluation: Energy Impacts for Large Multifamily Buildings* (2014); https://weatherization.ornl.gov/ORNL_TM-2014_332.pdf for primary Oakridge studies.

Appendix B – Financing and Cost Estimating

Basis of Estimate, Methodologies, Assumptions and Exclusions

BHA Decarbonization – Financing and Cost Estimating

Basis of Estimate, Methodologies, Assumptions and Exclusions

Presented: December 2023
Prepared by Americas Cost Consulting

Cost Methodology

Estimate Level	Estimate Description	Design Phase	Level of Completion	Methodology	Accuracy Range
5	Rough Order of Magnitude	Planning Schematic Design	0% to 5%	Parametric Models Capacity Factored Historical Costs	L: -20% to - 50% H: +30% to +100%
4	**Concept Feasibility**	**Planning** **Schematic Design**	**1% to 15%**	**Equipment Factored Parametric Models**	**L: -15% to - 30%** **H: +20% to +50%**
3	Budget Authorization	Planning Schematic Design Design Documents	10% to 40%	Unit Costs Assembles	L: -10% to - 20% H: +10% to +40%
2	Budget Control Estimate	Preliminary Design Engineering Design Documents Construction Documents	30% to 70%	Detailed Unit Cost Detailed Take-Off	L: -5% to - 15% H: +5% to +30%
1	Bid	Detailed Design Engineering Construction Documents	50% to 100%	Detailed Unit Cost Detailed Take-Off Productivities Subcontractor Quotes	L: -2% to - 5% H: +3% to + 15%

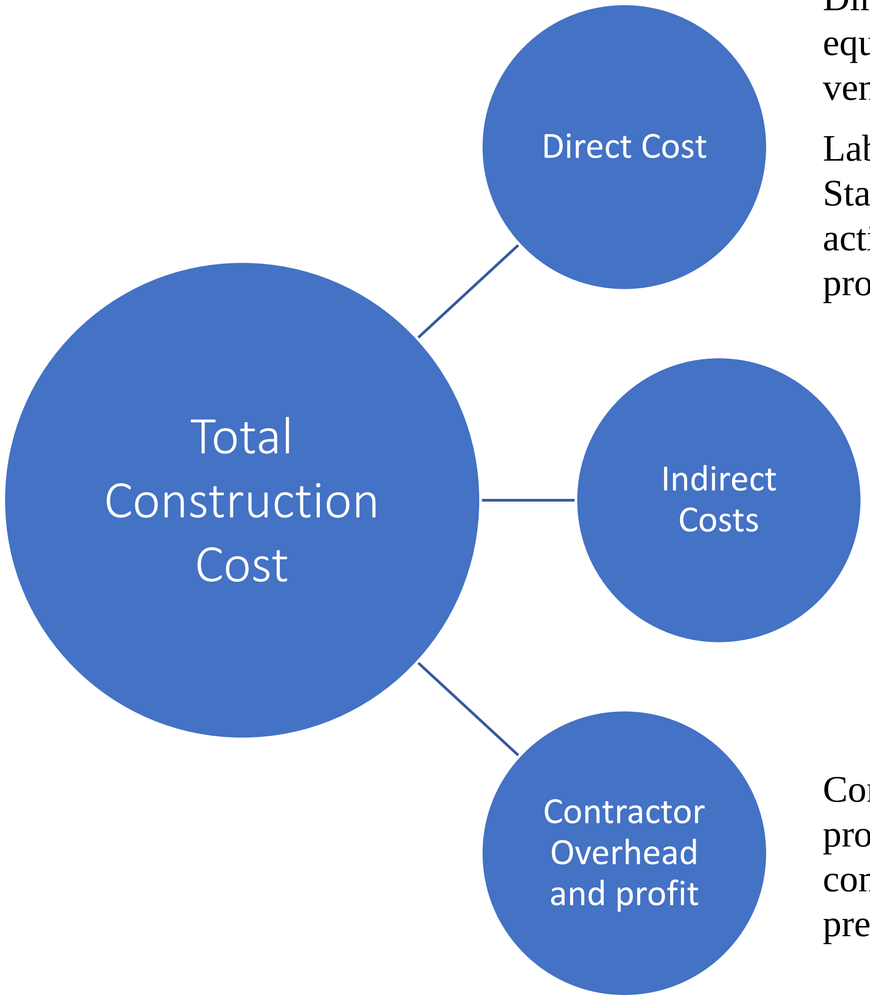
Based on the project phase and information availability, the cost estimate is defined as Level 4 estimate, utilizing AACE international best practices.

The accuracy range of this estimate has been determined to be -35% and +40%. The accuracy range is a gauge of likely bid prices if the project was issued to tender at this current stage

Pricing shown reflects probable construction costs obtainable for the works on the 4th quarter of 2023.

The main methodology used to estimate the scope of work is Equipment Factored, Parametric Models and Unit Costs Assembles

Construction Cost



Direct costs are the resources required to execute a construction activity. They include materials, labor, equipment, and subcontracts. Materials are estimated primarily using RS Means, complemented by vendor quotes and insights from contractors.

Labor costs are computed based on contractor wages and resources from the US Bureau of Labor Statistics. A crew is formed based on the crew effort needed and is then assigned to the construction activity, providing a productivity ratio (units per hour). Moreover, labor costs are influenced by a productivity factor determined by job site conditions, site accessibility, and the skill level of workers.

Indirect costs constitute a portion of the contractor's expenses and includes all resources that apply to multiple construction activities, including project coordination, utilities, site office, traffic management, document control, quality control, and similar items. These costs are typically calculated as a percentage of the direct costs, estimated between 20% and 25%, depending on the nature of the work.

Contractor's overhead and profit are the final components included in the total construction cost of the project, generally accounting for approximately 15% of both direct and indirect costs. Further considerations like escalation, often estimated at 4% annually, have not been factored into the numbers presented in the estimate.

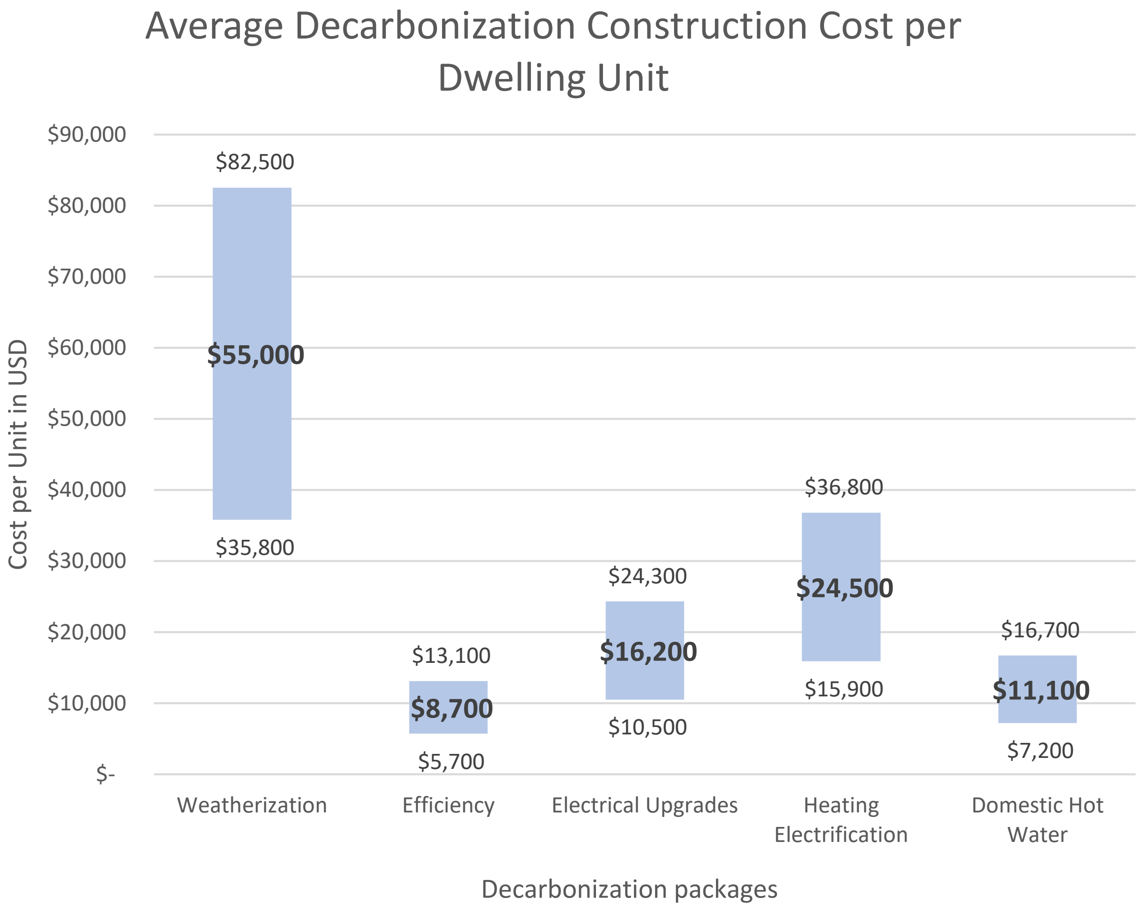
Basis of Estimate

- The project involves creating a construction cost estimate for BHA's existing building portfolio by implementing various decarbonization measures specified by the technical team.
- These measures consider Weatherization (envelope), Efficiency enhancements, Electrical Upgrades, Domestic Hot Water, and Kitchen and Laundry Electrification.
- They are applicable across BHA's diverse building typologies, including Garden Style, Walk-up, High-rise, and Office buildings.
- The estimate represents the needed construction works to implement the decarbonization measures to the existing buildings and infrastructure.
- The estimate is sensitive by the condition of the building's electrical, mechanical, and gas infrastructure.
- A vintage factor is applied, with potential increases of up to 15.4% in the estimate for buildings constructed before the 1940s. The estimate is based on a unit cost build-up, corroborated through a parametric approach and historical data from actual investments and contractor's bids.
- The values are expressed in US dollars as of the fourth quarter of 2023 and are specific to the city of Boston and its surrounding areas

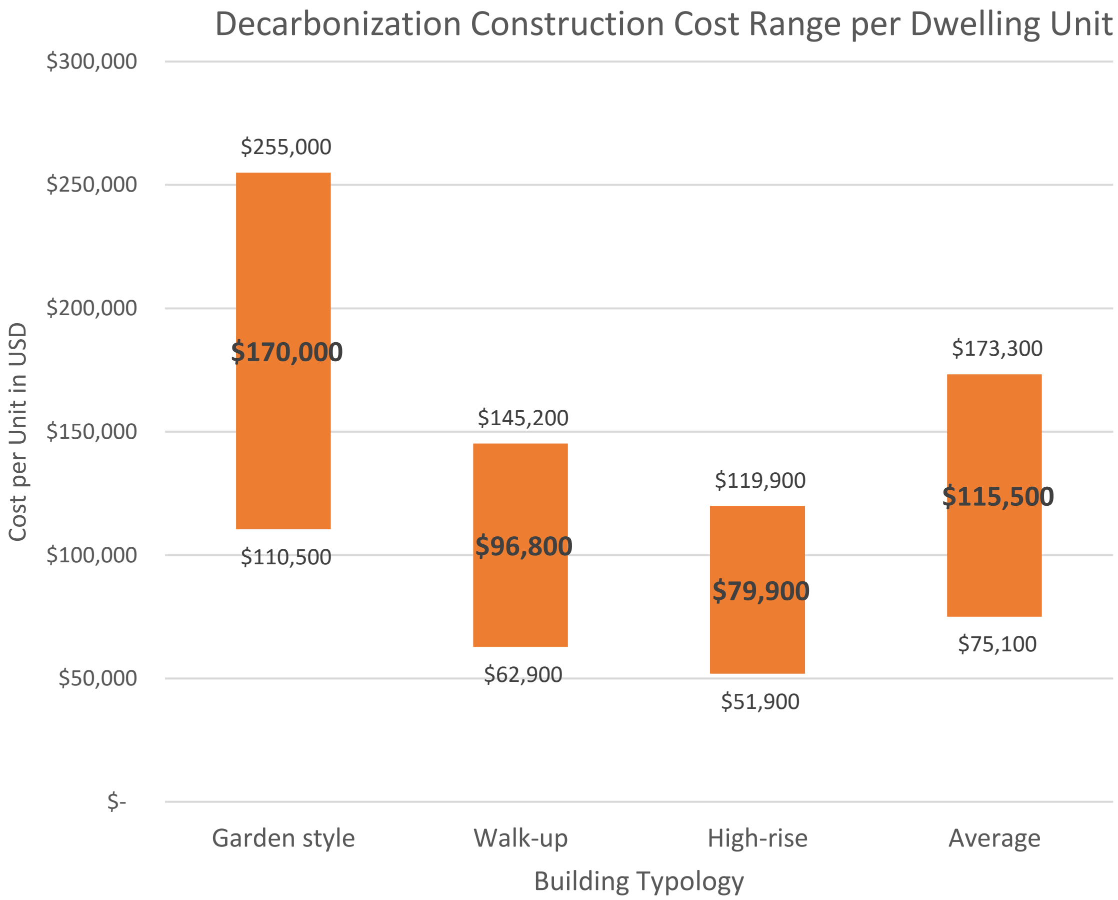
Exclusions

- Owner’s costs
- Design and construction contingency
- Engineering and consulting services
- Professional liability & other non-construction insurance
- Legal, permits, surveys and site investigation fees
- Risk-based contingency analysis
- The costs or impacts of latent environmental issues
- Operational and maintenance works
- Local taxes and duties
- Right of way and or land acquisition costs
- Removal and disposal of hazardous materials
- Owner’s contingency

Results

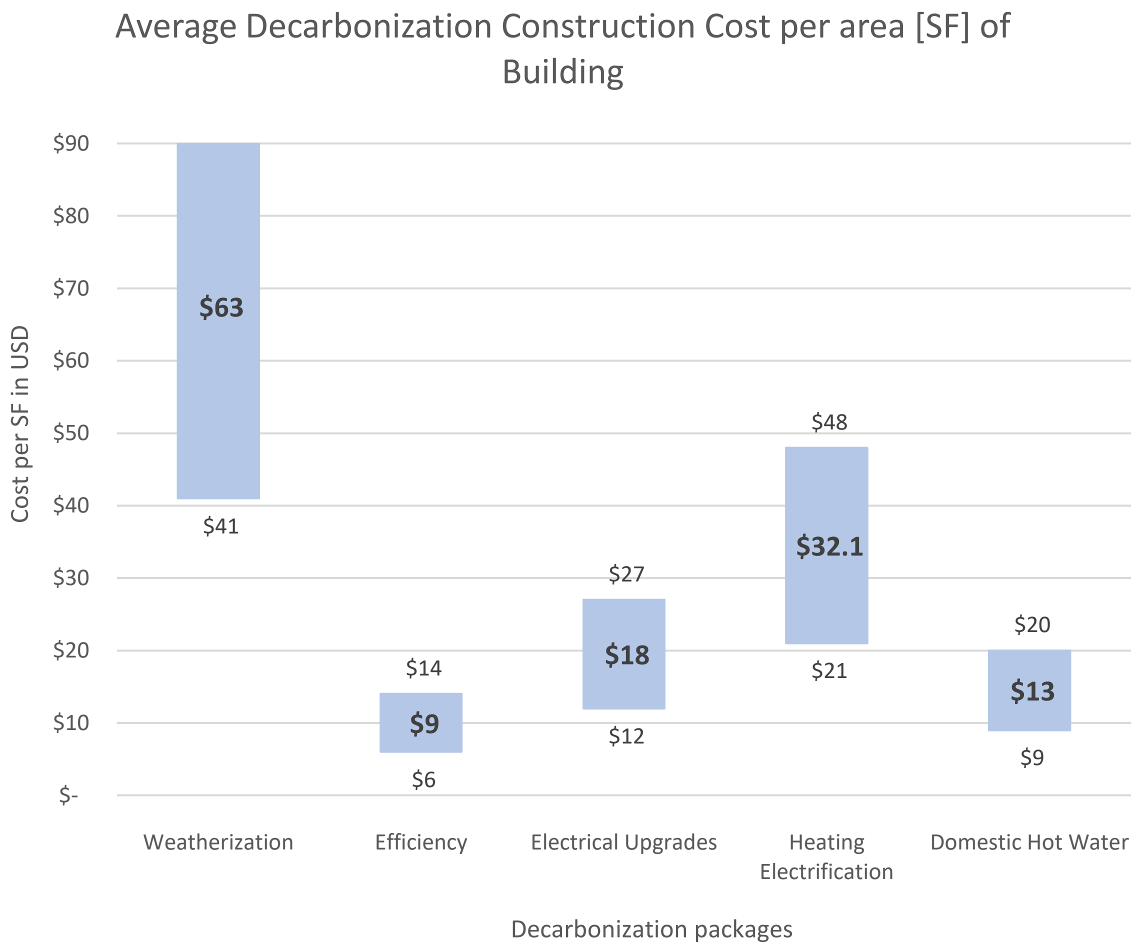


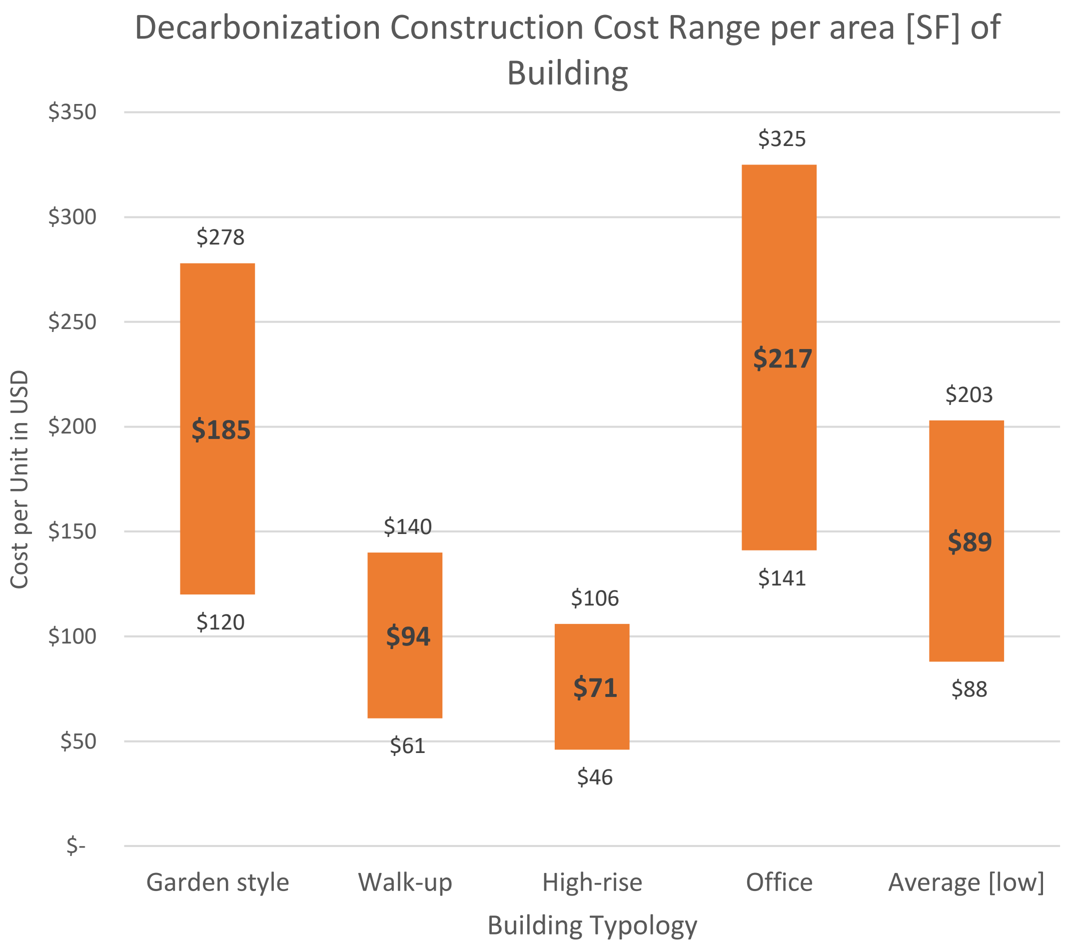
Average Decarbonization Construction Cost per Dwelling Unit
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$-
Cost per Unit in USD
$82,500
$55,000
$35,800
$13,100
$8,700
$5,700
$24,300
$16,200
$10,500
$36,800
$24,500
$15,900
$16,700
$11,100
$7,200
Weatherization
Efficiency
Electrical Upgrades
Heating Electrification
Domestic Hot Water
Decarbonization packages



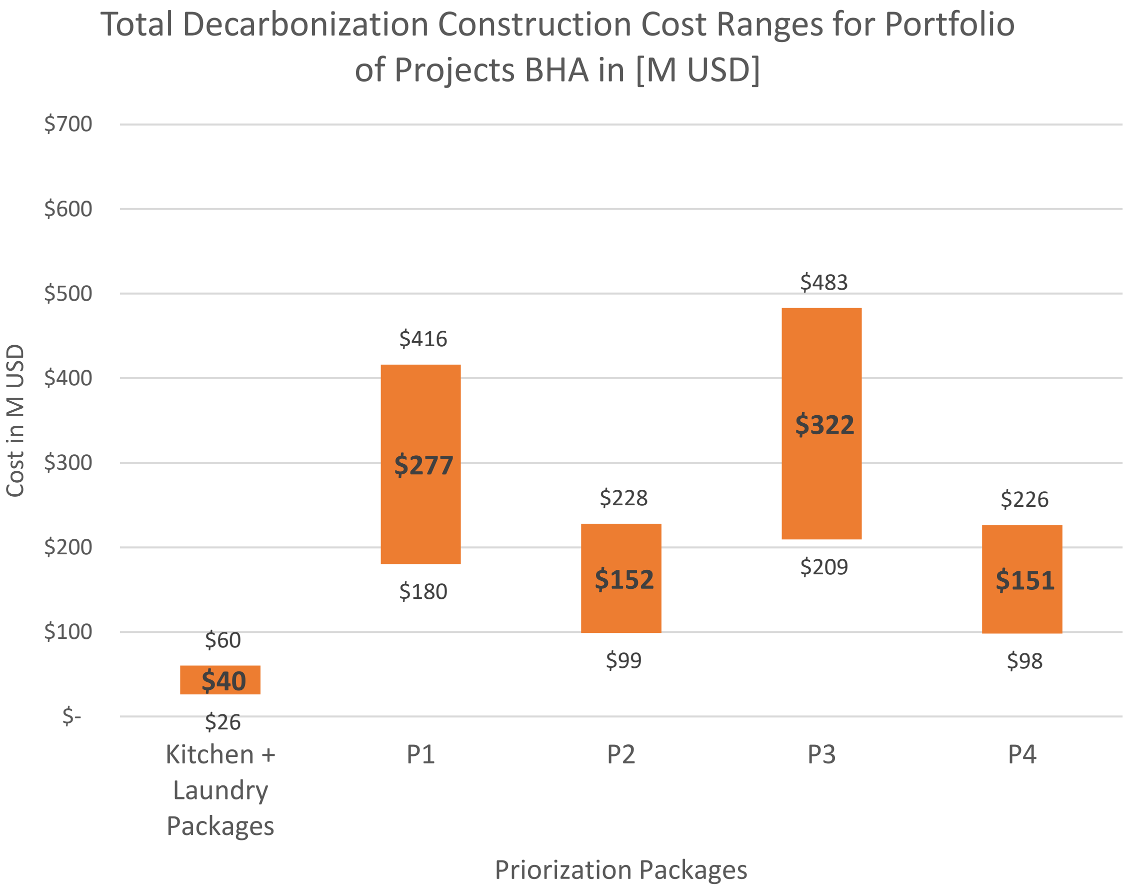
Decarbonization Construction Cost Range per Dwelling Unit
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$-
Cost per Unit in USD
$255,000
$170,000
$110,500
$145,200
$96,800
$62,900
$119,900
$79,900
$51,900
$173,300
$115,500
$75,100
Garden style
Walk-up
High-rise
Average
Building Typology

Results

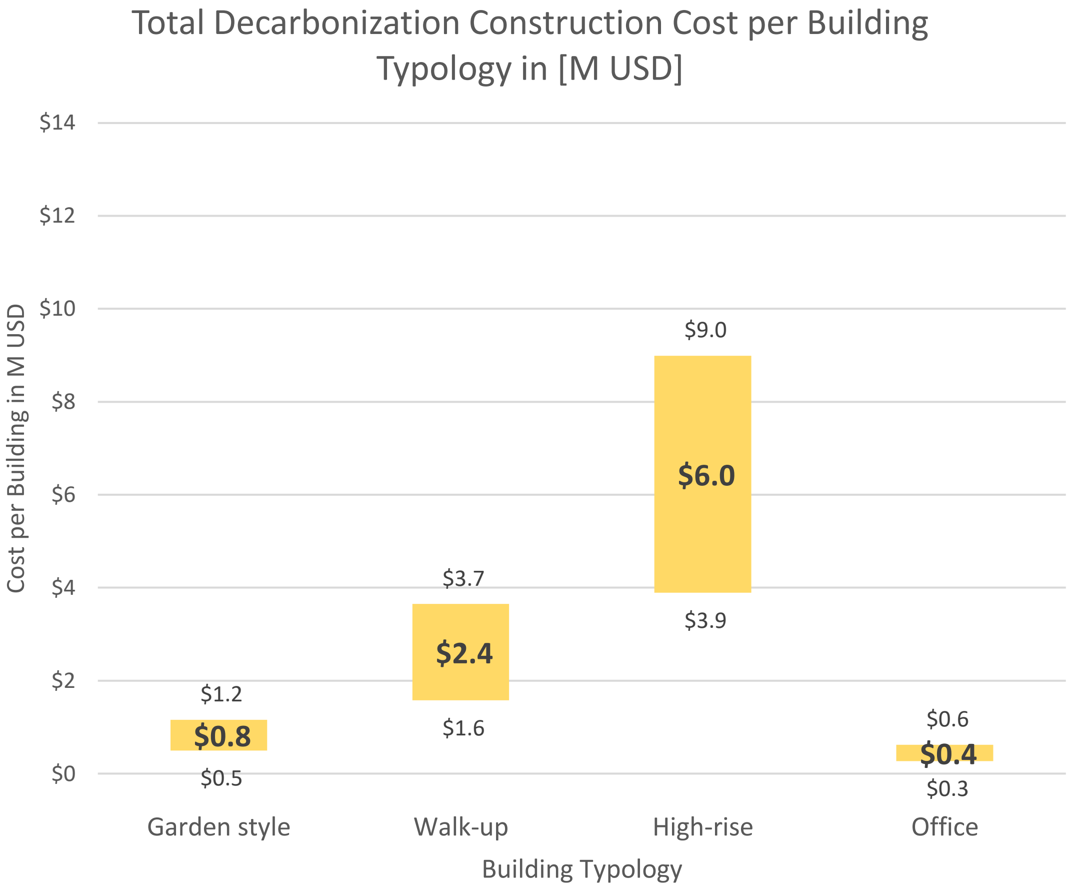

Average Decarbonization Construction Cost per area [SF] of Building
Cost per SF in USD
$90
$80
$70
$60
$50
$40
$30
$20
$10
$-
$63
$41
$14
$9
$6
$27
$18
$12
$48
$32.1
$21
$20
$13
$9
Weatherization
Efficiency
Electrical Upgrades
Heating Electrification
Domestic Hot Water
Decarbonization packages


Decarbonization Construction Cost Range per area [SF] of Building
Cost per Unit in USD
$350
$300
$250
$200
$150
$100
$50
$-
$278
$185
$120
$140
$94
$61
$106
$71
$46
$325
$217
$141
$203
$89
$88
Garden style
Walk-up
High-rise
Office
Average [low]
Building Typology

Results



Total Decarbonization Construction Cost Ranges for Portfolio of Projects BHA in [M USD]
Cost in M USD
$700
$600
$500
$400
$300
$200
$100
$-
$60
$40
$26
$416
$277
$180
$228
$152
$99
$483
$322
$209
$226
$151
$98
Kitchen + Laundry Packages
P1
P2
P3
P4
Priorization Packages



Total Decarbonization Construction Cost per Building Typology in [M USD]
Cost per Building in M USD
$14
$12
$10
$8
$6
$4
$2
$0
$1.2
$0.8
$0.5
$3.7
$2.4
$1.6
$9.0
$6.0
$3.9
$0.6
$0.4
$0.3
Garden style
Walk-up
High-rise
Office
Building Typology

Appendix C

Incentives and Procurement Pathways

Recommendations

- Incentive analysis and survey of utility, governmental, and third-party incentive programs, timelines, and recommendations

Let’s start with the modeled measures

Measures Identified for each Typology

- Insulation R-20 (Wall)
- Insulation R-30 (Wall)
- Triple pane windows
- LED fixtures
- Energy Star Appliances
- Heat pumps
- Energy Recovery Ventilators
- Heat pump water heater
- Induction stove top
- Heat pump dryer

1. These are the measures identified via virtual modeling for each property type
2. **Incentive analysis was specifically performed based on these measures**
3. Additional measures could be identified through site assessments and likely alter the recommended strategy
4. Additional measures not modeled however prevalent through additional investigation include – VFDs, Motors, Chillers, Rooftop units, etc.
5. Additional measures would add more viable programs

Definitions

Adding clarity to the myriad of programmatic references

- **Comprehensive**
  - Refers to program like LEAN Deep Energy Retrofit (DER) and includes multiple measures and measure types
  - Technology agnostic and all-inclusive as long as 40% GHG reduction is accomplished
- **Direct Install** - refers to any program that directly installs a defined list of weatherization and devices (i.e., programmable TSTATS, low flow showerheads, etc.) are installed by program approved contractor
- **Prescriptive** - refers to any program that pays out a pre-determined rebate amount based on per widget basis, and often a tiered structure based on $ per equipment capacity (i.e., $ per Ton, $ per HP, etc.)
- **Custom** - refers to any program where the rebate is typically tied to measured and verified savings with the incentive amount offered at $ per unit of savings (i.e., $.12 per kWh, $350 per MMBTU)

The key decision point for each individual Boston Housing Authority property is which pathway provides higher incentive $$ and if equal, and considers cost of administrative burden (more on that later)

- One-stop shop like Comprehensive which covers ALL modeled measures on previous slide

---OR---

- Combination of Direct Install and Prescriptive program which covers weatherization and appliances within Direct Install and Heat pumps within prescriptive

We considered Massachusetts programs

Navigating the maze of subsidy programs available in Massachusetts

Federal

- LIHEAP
- Weatherization Assistance Program (WAP)
- Inflation Reduction Act (Estimated Launch mid-2024)
  - Likely flow through Mass DOER or Mass CEC
  - Anticipated availability mid-2024

We considered all Massachusetts programs – Part II

Navigating the maze of subsidy programs available in Massachusetts

Utility/State*

- The LEAN Multifamily program
  - ○ Deep Energy Retrofit (DER)
  - ○ Direct Install

State*

- Mass Department of Energy Resources (DOER) Electrification
- Mass Save® Multifamily Rebates and Incentives

Utility***

- Eversource Custom and Prescriptive
- National Grid Custom and Prescriptive

***LEAN program is part of the statewide Mass Save® and funded and administered by sponsoring utilities.** The LEAN program includes both comprehensive (DER) track and Direct Install track

**Additional State programs shown in Appendix

***State programs have sponsoring Utilities and/or Program Administrators

- Eversource, National Grid, Eversource, Berkshire, CLC, Liberty, and Unitil
- Eversource and National Grid are the most relevant program administrators to BHA

We also considered ancillary programs and grants

Programs for Low to Moderate Income

City of Boston

- Healthy and Green Building Retrofit Program (City of Boston)
  - Lottery system with uncertain allocations
- Technical Assistance Grants (City of Boston)
  - Does not fund projects and only provides subsidies for technical assessments
  - Uncertain allocations and does not incentivize the project itself
- City of Boston American Rescue Plan Housing Funding
  - ARPA funding available if demonstrate 50% savings on per building basis

United States Department of Energy (DOE)

- Largest is the Loan Program Office Loan Programs Office | Department of Energy
- Minimum of $100M are available but require sponsorship and connection points to a State Energy (e.g., Green Bank)
- Recipients must demonstrate scalability and ability to develop into a long-term program

Based on the recommended measures, below are the recommended incentive paths

1

LEAN Multifamily Deep Energy Retrofit

Requires demonstrated GHG reduction of 40% per building

- Technology and equipment flexible
- $350 per MMBTU measured and & verified
- Engineering needs to be performed upfront
- 6–12-month process
- **No cap per customer basis, but program budget for city of Boston ~ $12M per year**
- Increased participation may prompt an increase in overall budget

2

Mass DOER Electrification

Fuel switching technologies

- Air and Ground Source Heat pumps
- Renewables
- **Program launch now (November ‘23)**
- Up to $14,000 per dwelling
- 6–8-month process
- No cap per customer basis, but program budget is $37M
- Increased participation may prompt in increase in overall budget

3

LEAN Multifamily Direct Install

Weatherization Assistance

- Can be done in combination with Electrification program if measures are complimentary
- Assessment performed upfront by program implementer
- Direct Install program
- **Up to $4,725 per dwelling**
- Includes energy efficiency, lighting, low flow faucets, smart connected devices, and appliances
- 1 to 3-month process

4

One-Off Utility, State, and Local Programs

Additional programs for additional ancillary projects

- **Eversource Comprehensive Incentives (Custom)**
- National Grid Income Eligible
- Utility Prescriptive
- Technical Assistance Grants (Boston)

Why those programs?

Most relevant based on customer classification, measures, and GHG reduction outcomes

The programs below are statewide specific offerings **tailored to Affordable Housing**; Utilities such as Eversource would offer one-off program (such as Custom) in cases where there is no overlap/conflict with existing state programs (aka no double dipping)

- The **LEAN Deep Energy Retrofit program** requirement is commensurate with current models which demonstrate a minimum reduction of 40% GHG reduction; this program would be **inclusive of all relevant measures in the current plan** (one stop shop)
- **Massachusetts Department of Energy Resources (Mass DOER)** has recently launched an electrification program inclusive of air sourced heat pumps; this offers a simple and easier route when coupled with weatherization
- The **Mass Save LEAN** umbrella also includes a **Direct Install program** separate from DER pathway; offers ability to **subsidize weatherization in already electrically heated buildings/units.**

Additional Clarifications:

- Each of these programs above **have fixed annual budgets**; meaning when the rebates are subscribed in any given program year the program will either resort to a waitlist, push into next program year, or file for increase in annual budget
- The key decision point for each property comes down to either leveraging a comprehensive program like DER OR participating in multiple non-conflictual programs (aka **prescriptive + direct install**)
- The **Inflation Reduction Act** funding in the U.S. will flow through the **State Energy Offices (SEOs),** however the administration in for Massachusetts may be through **Mass DOER** or **Mass Clean Energy Center** (TBD)

Portfolio Recommendations

Realistic Achievement of Maximum incentives

- For **most of the BHA building stock**, a decision tree approach favors **bundling direct install, direct pay, and prescriptive rebates** as most cost-effective path to maximum incentives
  - BHA can continue to participate in LEAN weatherization program and still participate in Deep Energy Retrofit, however the per unit incentives for heat pumps (whether Mass Save or eventually IRA) are higher on average than $350/MMBTU
  - Two critical factors are engineering costs associated with the DER program and the time/resources associated with programmatic administration
- For some **Garden Style** properties, the **comprehensive approach** provides slightly higher incentives on average, but need to factor in soft costs such as administrative burden and engineering
- For at least 7 of the **Highrise** buildings**,** the most cost-effective pathway is a **comprehensive program** like Deep Energy Retrofit, especially when decommissioning central heating plants and building energy efficiency to offset the increase in kWh via electrification
- For most **Walk-up** buildings, the most cost-effective pathway will be **piecemealing prescriptive programs**

Inflation Reduction Act (IRA) Recommendations

Much anticipated Federal IRA funding will likely take place this year

Anticipated program characteristics:

- Assuming **IRA** formally launches this year, it will provide a new prescriptive pathways to secure fixed rebate amounts for **air source heat pumps, heat pump water heaters, and potentially electric appliances**
- IRA rebates will undergo due diligence and programmatic approval process similar to the current utility or state programs which BHA participates in today
- Given the sheer size of the Massachusetts program, the anticipated timing of the program launch and time to be fully operational **WILL BE SLOW**

Recommendations:

- Upon specification level building assessments are complete, instruct the engineering firm and/or energy consultant to immediately assemble program documentation – equipment specifications, model/serial numbers, savings calculations, panel upgrade detail, building attributes
- Factor into the pro forma “slower than normal” distribution of rebate funds (e.g., see slide that discusses bridge loans to offset delays in payment)

Other Financing Pathways

Based on savings risk, utility rate uncertainty, and cost of capital

Recommended for consideration

- **Energy as a Service**
  - Potentially establish a hedge on rates within a Power Purchase Agreement to shift risk from BHA to 3rd party investor

Recommended for ad hoc consideration

- **Energy Service Performance Contracts** – whether through HUD or directly with ESCO
  - Turnkey installations for portfolios are proven, however contract terms are increasing beyond 20 years to produce positive cash flows
  - “Stipulated” savings are defined as normalized kWh or therms and do not protect against increase in utility bills
- **Climate Banks**
  - Lower interest rates for LMI
  - Savings risk factors above apply
  - Total fund right now covers small fraction of total project assets in current model

Not Recommended

- **Heat Pump with package finance** firms are well-backed by reputable institutions such as **Goldman Sachs and Chase**
  - Turnkey installation capabilities to scale are thus far unproven
  - End of term buy out provisions produces excessive cost of ownership and high risk if electricity rates increase in the future
- **Traditional Bank Loans**
  - High returns when depth of savings opportunity is realized, however not hedged on potential increase in utility rates or gradual reduction in savings
  - Interest rates are not expected to return to pre-pandemic levels in 2024

Procedural recommendations and next steps

Incentives as part of BHA's project implementation process

1. **Develop a common specification and repository** for heat pumps, envelope materials, ERVs and appliances and assign based on building type and individual unit capacities
2. **Apply for lighting retrofits prior to 2025** when it is anticipated that lighting programs will be suspended
3. **Submit applications to LEAN DER for the 6 high-rise buildings that exhibit the highest GHG reduction opportunity**
   - Highest rebate amounts to capitalize on 2024 fund allocation early in the year
   - Most "complex" projects which are most easily repurpose-able to other smaller buildings
4. Submit application to **Mass Save Heat Pump program for priority Walk-Up properties**
5. **Check-in with Mass Save** on the selection process of **IRA rebate program administrator**
   - Anticipate Q2 2024
   - For the 363 buildings with lowest depth of opportunity (0-1000 MMBTU), prepare the list, attributes and specification package in preparation for launch of IRA rebate program
6. **Conduct an in-depth site assessment** to determine best funding pathway for each property

Key Incentives Comparison

Economic decision point between Comprehensive vs. Program Combinations by typology

Since comprehensive programs are based on measured and verified savings, it's important to identify the inflection point where it makes sense to choose comprehensive over prescriptive

Garden Style

- Direct Install Weatherization + Direct pay heat pump rebate = Average **$104,000** per building
- Inflection point for Comprehensive Deep Energy Retrofit = $104,000/$350/MMBTU = **297.1 MMBTU**

Walk up

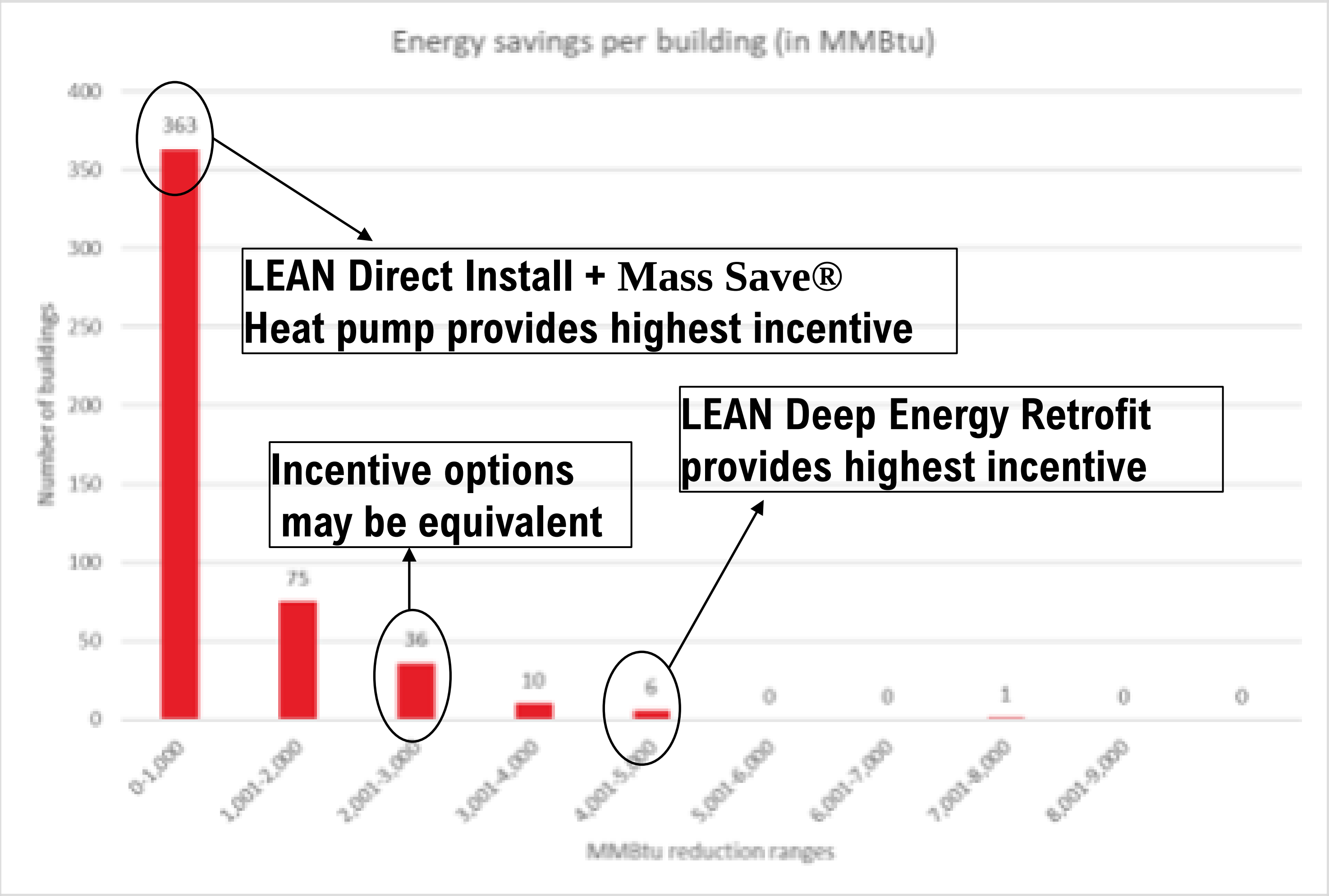
- Direct Install Weatherization + Direct pay heat pump rebate = Average **$451,360** per building
- Inflection point for Comprehensive Deep Energy Retrofit = **1,289.6 MMBTU**

High-rise

- Direct Install Weatherization + Direct pay heat pump rebate **=** Average **$1,458,240** per building
- Inflection point for Comprehensive Deep Energy Retrofit = **4,166.4 MMBTU**

Per Building Incentive Overview

Higher Reduction Ranges in Building Stock will lean toward comprehensive and custom programs for maximum incentives



LEAN Direct Install + Mass Save®
Heat pump provides highest incentive

Incentive options
may be equivalent

LEAN Deep Energy Retrofit
provides highest incentive

Incentives Summary

Master Summary [M USD] (entire scope)				
	Total Construction Cost [M USD]	Total Incentive Savings [M USD]	Total Construction Cost w/incentives [M USD]	% of Incentives vs Construction cost
Weatherization	$ 404	$ (121)	$ 282	30%
Efficiency	$ 75	$ (19)	$ 57	25%
Electrical Upgrades	$ 120	$ -	$ 120	0%
Heating Electrification	$ 209	$ (96)	$ 113	46%
Domestic Hot Water	$ 93	$ (17)	$ 77	18%
Kitchen Electrification	$ 40	$ (4)	$ 36	9%
Laundry Electrification	$ 1	$ (0)	$ 1	6%
Total	$ 942	$ (256)	$ 686	27.2%

- **$256M** in incentives is the estimate for the scope and specific projects within the current model
- **27% incentive to construction cost ratio** is commensurate with other US decarbonization initiatives of similar size and scope

Assumptions/Notes

- Incentive amounts reflect what is *currently available today* and with programs that are anticipated to be operational until 2030
- Additional subsidies may be available through federal DOE grants and/or future statewide programs

Additional Comparison per Building

Specific to the measures in the current model

Energy Reductions [MMBtu] by End-Use & Typology			
Fuel Source	Garden Style	High-rise	Walk-up
Heating	49,843	62,393	180,105
Cooling	1,056	1,629	3,925
DHW	12,974	19,581	44,306
Cooking	587	1,322	5,852
Laundry	27	166	70
Other electricity	1,354	2,466	4,574
Total	**65,840**	**87,558**	**238,831**
Energy Reduction per Building			
Number of Buildings	219	33	230
Average Reduction per Building (MMBTU)	301	2653	1038
DER Incentive per MMBTU	$350	$350	$350
Average DER Incentive	$ 105,224	$ 928,645	$ 363,438
*Combination Incentive	$ 104,000	$ 1,458,000	$ 451,000

***"Combined Incentive" refers to combination of direct install weatherization and separate heat pump programs**

Important Clarifications

Subsidy Regulations

- **While most of the Massachusetts programs have no incentive caps on per building or transaction basis, they all have allotted budgets that will require strategic staging of each project to ensure the programs do not oversubscribe within any given year**
- Non-Direct Install programs issue incentive amounts directly tied to Measured & Verified savings and not a percentage of project cost
- Incentive estimates were calculated based on individual measure savings and does not include a factor for parasitic effects of multiple measures

Mass Save

- Heat pumps must be installed by a contractor participating in the Mass Save Heat Pump Installer Network
- Heat Pumps must be used as the sole source of heating during heating season. Whole-home verification form must be completed and signed. *Weatherization recommendations made during a Home Energy Assessment must be complete prior to installation*.
- For the Mass Save program, customers replacing existing Condensing Natural Gas Furnaces or Boilers are not eligible for Tier II incentive levels. If pursuing maximum rebates, pre-verification is required prior to installation.

Best Practices with Utility program participation

- Utility program requirements
- Maximum funding amounts if/when dealing with Utility programs

Maximizing Utility Program Incentives

Guidance specific to Utility Custom and Comprehensive Programs

- Relevant programs are through Eversource, National Grid, and Mass Save
- **Important: Custom programs are 3rd party evaluated on the basis of program influence**

Recommendations:

- Clearly state your intention that your purchasing decisions were made for improving efficiency and decarbonization
- Terminology – You’re opting for *early retirement vs. equipment burn out*
  - This results in the difference between code baseline and existing baseline
  - Incentives are impacted by as much as 15% (e.g., a rebate of $50,000 could be reduced by $7,500
- Create your own savings calculations and/or request to firms you’re engaged with on per project basis such as consulting engineers, contractors, design build firms

Utility Program Requirements

Regulatory adherence

- Programs that pay on GHG reduction basis must **demonstrate fuel switching technologies** to be implemented
- Projects requiring **customized calculations cannot be implemented** unless authorized by program manager and/or formal pre-approval has been issued
- Must demonstrate an increase in efficiency, or that the replacement technology is above code baseline efficiency
- All projects that are not prescriptive fall into Custom program category

Financial Pathways

- MA Green Bank
- Utility Buy Down programs
- Energy as a Service (EaaS)
- Heat Pump Leasing
- HUD Performance Contract Program

Financial Pathways Analysis

Assessing options (private sector) by relative risk level

Finance Type	Structure	Rate	Cost of Capital	Risk Level
Energy as a Service	PPA	Above prime	High	Low with sufficient EE savings
Energy Service Performance Contract	Lease/Loan	Above prime	High	Medium Utility rate risk
Heat Pump Packaged Finance	Lease	Above prime	High	High utility rate risk
Bank Loan	Loan with interest	Some prime	Medium	Medium risk, high reward if sufficient savings are present
Rebate Buy Down	Bridge Loan	Below prime	Low	Low risk, low reward
On Bill Financing (Utility)	Loan	Below prime	Low	Low risk, low reward
Climate Bank	Loan with interest	Below prime	Low	Medium risk, high reward if sufficient savings are present

Cost of capital ratings above are relative to each other; and may or may not be relative to BHA or other Housing Authorities

Interest Rates vary by institution; example Banks are currently offering prime rates in some circumstances, however most are above prime

Massachusetts Climate Bank

Imminent source of funding for capital projects

- **This is the first Green bank dedicated to affordable housing**
- Seeded with $50 million in state funds from the Department of Environmental Protec
- Targets the periodic cycle of affordable housing refinance to bundle other property needs with decarbonization measures
- Financing measures such heat pumps, building envelopes (i.e., efficiency upgrades to windows and walls), heat pump water heaters, high-efficiency appliances, and solar panels
- In the process of selecting an administrator or multiple administrators to manage the project and funding flow
- Other similar Climate Banks are able to issue sub-prime loans and typically prefer projects above $500,000
- Anticipated formal launch – June 2024

ARUP

Utility Buy Down Program

Verdant Capital leverages incentives to reduce interest rates on traditional loans

- **National Grid** is making it easy to pay for efficiency projects by teaming up with Verdant Commercial Capital to offer low-cost financing for 24- to 84- month financing with $0 down.
- Once a project is approved for funding, our financing partner (Verdant Commercial Capital) will pre-fund the amount financed less the subsidy payment to the contractor giving them immediate cash flow.
- Customer receives a portion of the rebate
- If customer cedes all of the rebate to the contractor, Verdant will offer bridging the gap between project completion and issuance of the rebate

Heat Pumps packaged with Financing

Multiple Finance Options with dedicated heat pump projects

Known Turnkey Installers

- Bloc Power
- Sealed
- Empeq
- Endurant
- Delta Financing
- LED Finance
- Brightcore
- Bondi Corp

Common Contract Structure

- Lease Structure
- On and off-balance sheet accounting
- 3-7 years duration depending on savings and cash flow
- End of term buyout amount determined to be market rate, although fixed buyout prior to contract is negotiable

Energy as a Service (EaaS)

Alternative to Leasing and Traditional Loans

Known Turnkey Installers

- Redaptive
- Budderfly
- Carbon Lighthouse
- Metrus
- Sparkfund
- Schneider
- Noresco
- Ameresco

Common Contract Structure

- Most similar to a Power Purchase Agreement (PPA), where monthly amount varies with savings achieved
- EaaS owns and maintains the assets during the agreement term
- Bundled electrification with energy efficiency to leverage total savings
- Typical 20–30-year contract durations
- Positive cash flows are typically present if 25% depth of savings opportunity exist

US Department of Housing and Urban Development

Performance Contract Option

- **The Energy Performance Contract program (EPC) is a financing technique that uses energy and/or water cost savings from reduced energy and/or water consumption to repay the cost of installing Energy Conservation Measures (ECMs)**
- BHA can contract development and implementation with companies called Energy Service Companies (ESCOs) that work in this market and contract with institutional energy and/or water users such as housing authorities
- Typical ESPC Structure
  - 15–25-year contract
  - Monthly fixed payment, often a lease or traditional bank loan with prime+ interest rate
  - Pro formas are generated to demonstrate positive case flow based on “guaranteed savings”
  - Savings guarantee is based on “stipulated savings” and not actual reductions on utility bills
- **Please note: Whether eligible for HUD programs or not, BHA can engage with any ESCO to obtain an Energy Service Performance Contract (ESPC)**

Econometric Considerations

Understanding each option given the current climate today

- With prime Interest Rates at 8.5%, levelized rate of returns for energy efficiency and electrification are < 12% and below “typical” averages
- For traditional loans, some properties will NOT see sufficient utility bill savings to produce positive cash flow for contracts less than 20 years
- Eversource electric rates expecting a 39% reduction through June 2024; 5 years projections are uncertain and should plan on returning to 2023 rates
  - There are EaaS firms that offer structures that hedge on utility rate fluctuations to stabilize monthly payments
- For firms that package heat pumps with financing, equipment lease rates exceed “typical” cost of capital for most municipal entities

Common considerations when evaluating risk – Utility Bill savings, Utility rate volatility, interest rate volatility, cost of capital, future state of the economy, solvency and debt to income ratios of the financial institution(s)

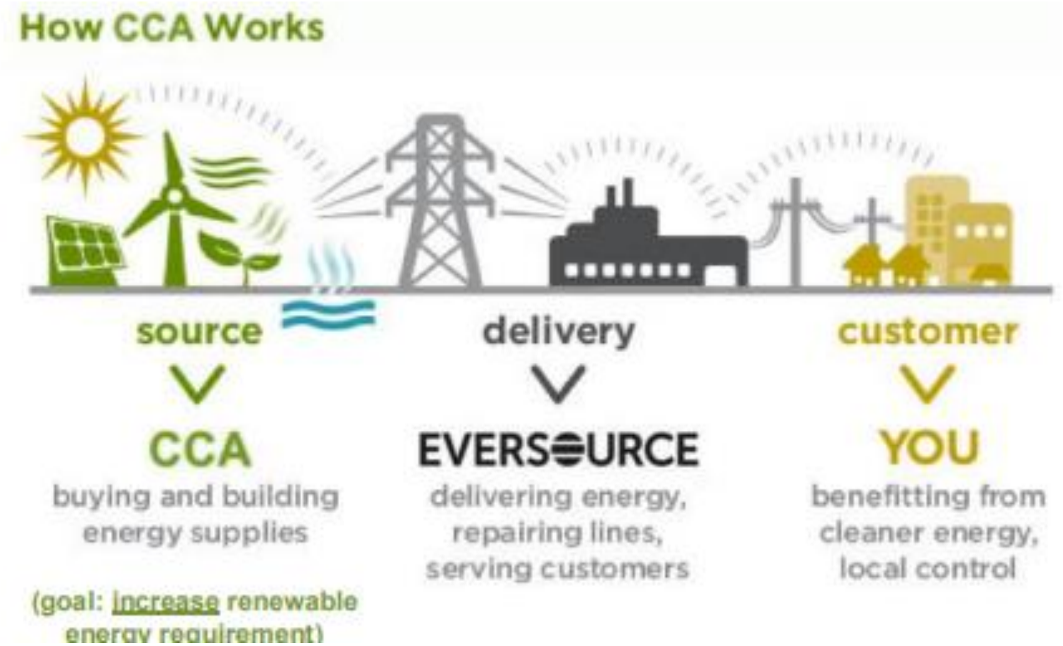
Supply Side Options

- Community Choice Aggregators
- Renewable Energy Credits
- Energy Buying Consortiums
- Reverse Auctions
- 3rd Party Asset Ownership

Community Choice Aggregators

Supply side option for obtaining partial credit off carbon footprint

Community Choice Aggregation (CCA) is a process by which municipalities can aggregate and switch the electricity of the households and small businesses from basic service over to cleaner energy



Community Choice Aggregators

Outline of the Process

- Community or **neighborhood approval** to pursue CCA
- Issue RFP to **hire energy broker** (not required, but good practice)
- Broker creates **aggregation plan** (no cost to town)
- Board of Selectmen **approves aggregation plan**
- **Department of Energy Resources reviews aggregation plan**
- **Department of Public Utilities approves plan**
- Broker **issues RFP for competitive supplier**
- Town **selects competitive supplier**
- Broker publicizes CCA to residents and small businesses, and handles all opt out requests

Community Choice Aggregators

Pros and Cons

Pros	Cons
Depending on local legislation, purchasing through CCAs will result in some credit on your carbon footprint; most municipal authorities that have leveraged this receive a broad range of 10-30% reduction on GHG footprint	CCA agreements can result in higher spend for the same power
CCAs must comply with regulations set in states having renewable energy mandates, just like any utility company generating power	Opt-out provisions are not well defined
Increased FTM Solar installations in Boston will provide increased opportunities to procure clean energy	Multiple Aggregators are fragmented across Boston proper resulting in multiple disparate agreements and inconsistency of terms

- Clean Energy supply side capacity is limited and currently unlikely to support BHA's portfolio
- Recommend working closely with local utility on green power options as the Massachusetts climate plan evolves

Boston Community Choice Electricity Program

Massachusetts’ largest municipal aggregator program

- The program is an opt-out program in accordance with Massachusetts law (M.G.L. c. 164, § 134)
- Current retail supplier is Direct Energy, however Eversource would still be the utility
- Does not preclude participation in energy programs, payment plans, and solar credits
- Opt in or out at any time
- **The rates of the Community Choice Electricity program may not always be lower than the Eversource Basic Service rate**
- **The program would apply to individual buildings (not portfolios) and therefore would require individual agreements**
- **Current clean energy capacity on the grid (FTM) is not projected to support 100% carbon free supply serving the current Boston building stock by 2030**

Massachusetts Renewable Energy Credits

Proof of purchase

- One Renewable Energy Credit (REC) is equal to one MWh of renewable energy generated
- SRECs are RECs generated by solar PV resources
- Once purchased, it becomes a tradeable asset
- RECs typically add 5% – 10% to overall energy spend
- Similar to CCA, there are number of practitioners who are authorized to buy and sell RECs
- Recommend interviewing the available pool of independent consultants
- Gather intel on pricing based on anticipated procurement needs between now and 2030

Energy Buying Consortiums

Supply side organizations that assist non-profits

Typical Services:

- **Competitive RFP electricity & natural gas procurement –** Facilitate competitive procurement process with the largest suppliers in the region.
- **Pricing options that reflect your risk tolerance –** These range from fixed all-in, to a layered buying approach, to wholesale market access.
- **Strike pricing –** Predetermined price at which as specific security can be purchased.
- **Tariff Review** – Ensure that each property is paying correct rate based on customer classifications

Recommendations:

- Explore fixed pricing options
- Explore purchasing large strips of power in advance, especially if market volatility takes place in 2024

Reverse Auctions

Supply side option with pros and cons

- Supply side distributor puts out a request for electricity or gas, inviting businesses to compete against each other with bids for the amount they are willing to pay for utilities being requested by the specified timeline
- “Common” outcome for buyers to purchase power for 5-7% less than daily market rate
- Reverse auctions can make a lot of sense when price is the most important factor and quality of service is not a driving decision point
- There are an inordinate amount of consulting firms that facilitate this service, making it difficult to evaluate based on legitimacy

3rd Party Asset Ownership

Option that disaggregates utilities in some cases

- Similar to EaaS, there are multiple investor backed firms that acquire large energy consuming assets - typically existing central plants, solar, storage, and electrification equipment
- They would own and maintain the equipment during a fixed time period
- Depending on the depth of the savings opportunity, the contract structure would be in the form of a Power Purchase Agreement
  - Fixed monthly payment
  - Owner would handle monthly transactions with the utilities
  - Metered energy savings would pay for project activity
- Not common for residential facilities but an option to consider since from a tax treatment, BHA is likely not deducting equipment asset value based on depreciation

Appendices

- Massachusetts state programs
- Building typology considerations/sample measure calculations
- Inflation Reduction Act anticipated program rules of engagement
- Incentive process administrative burden considerations

We considered multiple programs

Massachusetts State Programs

Statewide Program	Statewide Core Initiative	Sub-Initiative
A1 - Residential New Buildings	A1a - Residential New Homes & Renovations	A1a-Residential New Homes & Renovations
A2 - Residential Existing Buildings	A2a - Residential Coordinated Delivery	A2a - RCD - High Rise
A2 - Residential Existing Buildings	A2b - Residential Conservation Services (RCS)	A2b-Residential Conservation Services (RCS)
A2 - Residential Existing Buildings	A2c - Residential Retail	A2c-Residential Retail - Consumer Products
A2 - Residential Existing Buildings	A2c - Residential Retail	A2c-Residential Retail - Small Equipment
A2 - Residential Existing Buildings	A2d - Residential Behavior	A2d-Residential Behavior
A2 - Residential Existing Buildings	A2e - Residential Active Demand Reduction	A2e - Res ADR - DR
A3 - Residential Hard-to-Measure	A3e - Residential Workforce Development	A3e - Residential Workforce Development
A3 - Residential Hard-to-Measure	A3h - Residential R&D and Demonstration	A3h - Residential R&D and Demonstration
B1 - Income Eligible Existing Buildings	B1a - Income Eligible Coordinated Delivery	B1a-Income Eligible Coordinated Delivery - MF
B1 - Income Eligible Existing Buildings	B1b - Income Eligible Active Demand Reduction	B1b - LI ADR - DR
B1 - Income Eligible Existing Buildings	B1b - Income Eligible Active Demand Reduction	B1b - LI ADR - Storage
B2 - Income Eligible Hard-to-Measure	B2e - Income Eligible Workforce Development	B2e - Income Eligible Workforce Development
C2 - C&I Existing Buildings	C2b - C&I New & Replacement Equipment	C2b-C&I New & Replacement Equipment - Downstream HP
C2 - C&I Existing Buildings	C2b - C&I New & Replacement Equipment	C2b-C&I New & Replacement Equipment - Upstream Lighting
C2 - C&I Existing Buildings	C2c - C&I Active Demand Reduction	C2c - C&I Demand Management - DR
C2 - C&I Existing Buildings	C2c - C&I Active Demand Reduction	C2c - C&I Demand Management - Storage
C3 - C&I Hard-to-Measure	C3e - C&I Workforce Development	C3e - C&I Workforce Development
C3 - C&I Hard-to-Measure	C3h - C&I R&D and Demonstration	C3h - C&I R&D and Demonstration

Garden Style

Typology #1

- Measures in current model that are eligible for subsidies
  - **Insulation R-20 (Wall)**
  - **Insulation R-30 (Wall)**
  - Triple pane windows
  - **LED fixtures (BULBS ONLY)**
  - Energy Star Appliances
  - Heat pumps
  - Energy Recovery Ventilators
  - Heat pump water heater
  - Induction stove top
  - Heat pump dryer

Recommended Pathway

- The LEAN Multifamily Program | LEAN Multi-Family
- Umbrella program serving Low-income multi-family properties owned by public housing authorities, non-profit or for-profit organizations
- The program installs approved, cost-effective energy efficiency measures. This program is part of Mass Save® and is funded by the Massachusetts Energy Efficiency Program Administrators (PAs).
- **Process**
  - Assessment=➔Contractor Selection=➔Measure Selection=➔Authorization to Proceed=➔Post Inspection
- **Recommendation**
  - The TOTAL savings on average for Garden Style are not conducive to the Deep Energy Retrofit pathway, and most beneficial to leverage standard/direct install and combine with other direct pay heat pump programs

Garden Style

Measure Calculation Example

- Measures in current model that are eligible for subsidies
  - **Insulation R-20 (Wall)**
  - **Insulation R-30 (Wall)**
  - Triple pane windows
  - **LED fixtures (BULBS ONLY)**
  - Energy Star Appliances
  - Heat pumps
  - Energy Recovery Ventilators
  - Heat pump water heater
  - Induction stove top
  - Heat pump dryer

Sample measure calculation if applying DER:

- Insultation R-20 (Wall)
- Q = UA∆T = 1/R*A(TH - TL)
- Assume baseline of R-12
- Q = 1/8*2721*30 deg F = 10,203 BTU
- Average TRM operating hours = 2,621 hours
- Savings = 26.74 MMBTU
- DER Incentive = $350 x 26.74 MMBTU = **$9,360**

This calculation example is for ONE arbitrary measure. When rolling up multiple measures the numbers are commensurate with the current modeled savings. The respective program and program implementer's calculation methodology may vary.

ARUP

Walk-up

Typology #2

- Measures in current model that are eligible for subsidies
  - Insulation R-20 (Wall)
  - Insulation R-30 (Wall)
  - **Triple pane windows**
  - LED fixtures (BULBS ONLY)
  - Energy Star Appliances
  - **Heat pumps**
  - **Energy Recovery Ventilators**
  - **Heat pump water heater**
  - Induction stove top
  - Heat pump dryer

Recommended Pathway

- The LEAN Multifamily Program | LEAN Multi-Family
- 100% of Energy Assessment
- 50% of Detailed Technical Assessment
- Implementation Plan with Milestones and Verification
- Air Source Heat Pumps | Residential | Mass Save
  - Whole Home Rebate up to $16,000 for ASHPs

Rebate form and supporting documentation must be received by February 29, 2024 (Please note: this is currently posted on the website, however expected the program will continue another cycle)

- **Process**
  - Scoping Study=➔Detailed TA Study=➔DER Roadmap=➔Project Specification=➔Implementation
- **Recommendation**
  - For most Walk-up properties in BHA portfolio, it is more beneficial to bundle weatherization programs with electrification programs to maximize incentive amount

Walk-up

Typology #2

- Measures in current model that are eligible for subsidies
    - Insulation R-20 (Wall)
    - Insulation R-30 (Wall)
    - **Triple pane windows**
    - LED fixtures (BULBS ONLY)
    - Energy Star Appliances
    - **Heat pumps**
    - **Energy Recovery Ventilators**
    - **Heat pump water heater**
    - Induction stove top
    - Heat pump dryer

Example measure calculation:

- Assume Enthalpy Wheel
- $\mu_e = (h_2 - h_1) / (h_3 - h_1)$ (3)
- μ_e = *enthalpy transfer efficiency*
- h_1 = *enthalpy in outside make-up air **before** the heat exchanger Btu/lb*
- h_2 = *enthalpy in outside make-up air **after** the heat exchanger Btu/lb*
- h_3 = *enthalpy in outlet air **before** the heat exchanger Btu/lb*
- u = (15 –10)/(20-10)* 3 = 16.7% efficiency gain
- Savings = .05 MMBTU * .167 = .00835 MMBTU
- Average TRM operating hours - 512
- Incentive (Building) = 4.28 MMBTU x $350 **= $1,500**

This calculation example is for ONE arbitrary measure. When rolling up multiple measures the numbers are commensurate with the current modeled savings. The respective program and program implementer's calculation methodology may vary.

Highrise

Typology #3

- Measures in current model that are eligible for subsidies
  - Insulation R-20 (Wall)
  - Insulation R-30 (Wall)
  - Triple pane windows
  - LED fixtures
  - Energy Star Appliances
  - **Heat pumps**
  - Energy Recovery Ventilators
  - Heat pump water heater
  - **Induction stove top**
  - **Heat pump dryer**

Recommended Pathway

- Deep Energy Retrofit | LEAN Multi-Family (leanmultifamily.org)
- For at least 6 of the high rises in the BHA portfolio, the estimated savings would produce an incentive equal to or larger than piecemeal program approaches
- Example band of properties with 4,000-6,000 MMBTU results in incentive range of $1,400,000 to $2,100,000
- **Process**
  - Verify Eligibility=➔Prepare home=➔Weatherize home=➔Work with an in-network contractor=➔Claim rebate
- **Recommendation**
  - For Highrise properties with individual systems, recommend rebate program or potentially Inflation Reduction Act funding as opposed to savings-based program. Scoping study may identify financial advantage towards DER program; however, the administrative burden may justify direct pay incentive for heat pumps

Inflation Reduction Act

Federal program with rules of engagement currently in flux

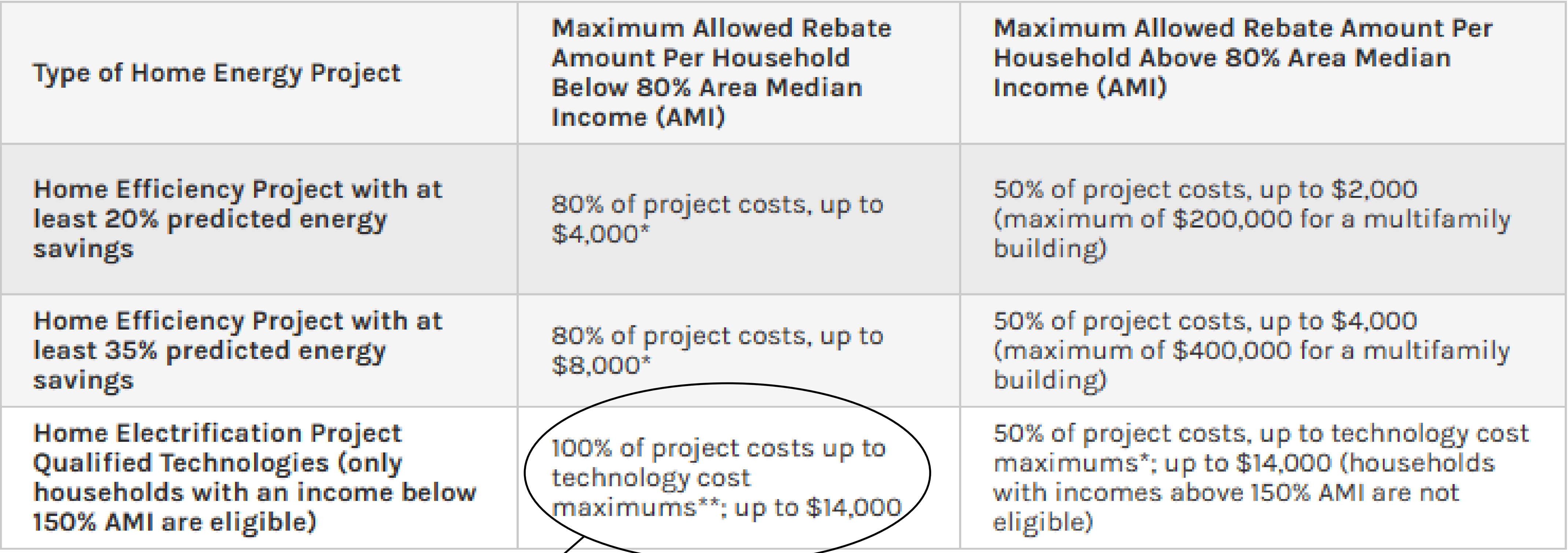
- Projected to be run through Massachusetts DOER or Mass CEC
- Administration process and program manager TBD; potentially multiple program implementers
- Once program implementer(s) are in place, the program will roll out shortly thereafter
- Current timeline for **formal launch is June 2024**
- The Department of Energy Guidelines have been formalized for each state; however, implementation guidelines will vary from state to state

Two Tracks:

- HOMES - $14,000 tax credit or direct payment
- HEEHRA – Instant Discount of $8,000 per dwelling

Inflation Reduction Act

Preparing the right IRA track



Type of Home Energy Project	Maximum Allowed Rebate Amount Per Household Below 80% Area Median Income (AMI)	Maximum Allowed Rebate Amount Per Household Above 80% Area Median Income (AMI)
Home Efficiency Project with at least 20% predicted energy savings	80% of project costs, up to $4,000*	50% of project costs, up to $2,000 (maximum of $200,000 for a multifamily building)
Home Efficiency Project with at least 35% predicted energy savings	80% of project costs, up to $8,000*	50% of project costs, up to $4,000 (maximum of $400,000 for a multifamily building)
Home Electrification Project Qualified Technologies (only households with an income below 150% AMI are eligible)	100% of project costs up to technology cost maximums**; up to $14,000	50% of project costs, up to technology cost maximums*; up to $14,000 (households with incomes above 150% AMI are not eligible)

Most applicable track based on current list of recommended interventions BHA should prepare for whole home electrification specification as the application process will resemble current statewide programs

Inflation Reduction Act

Potential Appliance and Electric Capacity upgrade rebates

Mass DOER **may** provide rebates for the following products:

- ENERGY STAR-certified electric heat pump water heater
- ENERGY STAR-certified electric heat pump for space heating and cooling
- ENERGY STAR-certified electric heat pump clothes dryer
- ENERGY STAR-certified electric stove, cooktop, range, or oven (note: Energy Star-certified ovens are pending at the time of this update)
- **Electric load service center (i.e., electrical panel)***
- **Electric wiring**
- **Insulation, air sealing, and mechanical ventilation**

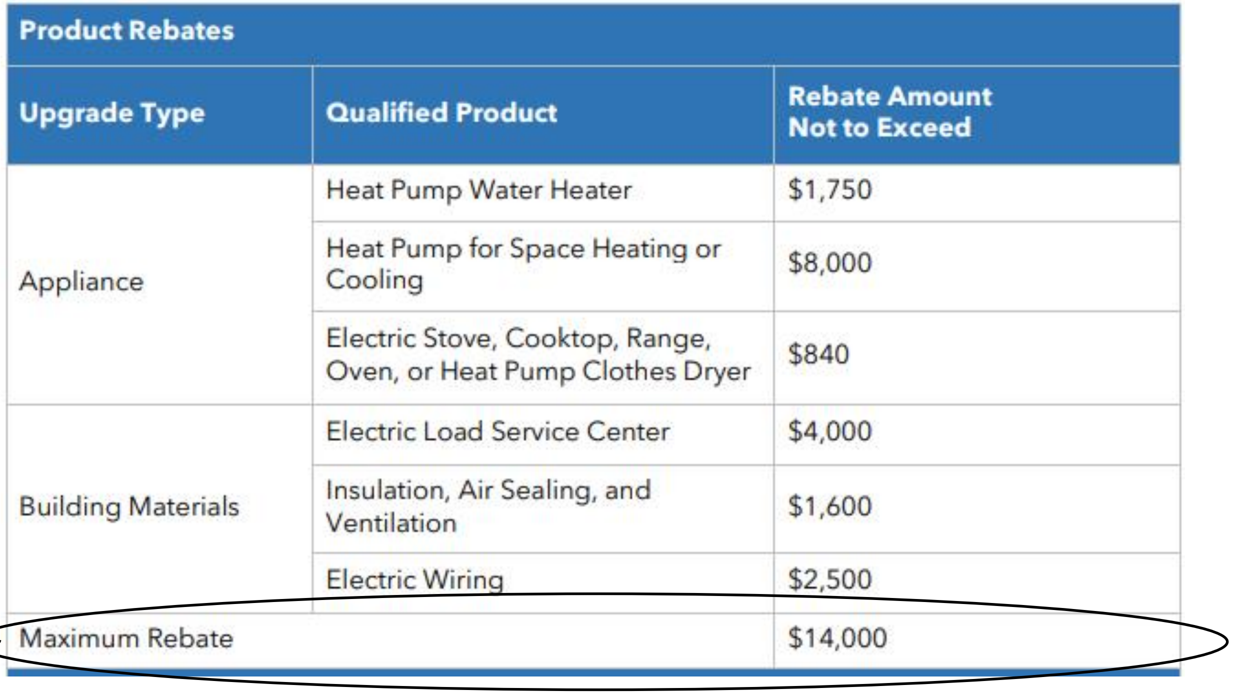
*State Energy Offices are encouraged to assist where existing electric service capacity requires increase as mentioned, the IRA rebate programs will vary from state to state, and MA is still under development. This is potentially the most viable pathway to incentivize electric panel upgrades

Inflation Reduction Act

Additional Rules of Engagement

- The Department of Energy Program Guidelines Home Energy Rebate Programs Requirements & Application Instructions
- The Home Electrification and Appliance Rebates Program will apply to the owner of renter-occupied buildings, including both single- and **multi-family buildings**
- The MA process for Multifamily is TBD but anticipated that building owners may apply for rebates across their portfolio

Full Rebate Breakdown is as follows:



Product Rebates		
Upgrade Type	**Qualified Product**	**Rebate Amount Not to Exceed**
Appliance	Heat Pump Water Heater	$1,750
	Heat Pump for Space Heating or Cooling	$8,000
	Electric Stove, Cooktop, Range, Oven, or Heat Pump Clothes Dryer	$840
Building Materials	Electric Load Service Center	$4,000
	Insulation, Air Sealing, and Ventilation	$1,600
	Electric Wiring	$2,500
Maximum Rebate		$14,000

Please note: $14,000 per dwelling includes water, appliances and weatherization

Incentive Processing Level of Effort

The administrative burden will require dedicated resources

Typology	Incentive	Number of Properties	Property Unit (avg)	Total Max Incentive	Max Number of Applications	Est Number of Applications
Garden style	$ 31,400	219	6	$ 41,259,600	1314	438
Walk-up	$ 31,553	230	26	$ 188,686,940	5980	598
High-rise	$ 31,159	33	84	$ 86,372,748	2772	33

- Given the shear volume of applications and programmatic interface, **recommend facilitating a Project Management Office** whether internally or externally to set up the systems, process and governance
  - **Estimate 500-1,000 applications for current scope over the next 6 years**
  - For 150 applications – Estimate 12 hours per application, which **equates to 1 FTE dedicated** to **facilitating and tracking incentives** if all performed in one year
  - Administrative tasks includes Pre- and Post- Site visits, program implementer coordination and stakeholder interface, specification sheets, scoping discussions with program trade allies, data requests, application paperwork, and follow up
  - **DOE funding requires Grant writer and typically takes 80 hours to generate submission**
  - Inflation Reduction Act **will likely incorporate rules of engagement similar to utility programs**