The Future Is (Almost) Now

Planning for Commercial Central Heat Pump Water Heating in Multifamily Housing

PhiusCon 2022: Emissions Down, Power Up!

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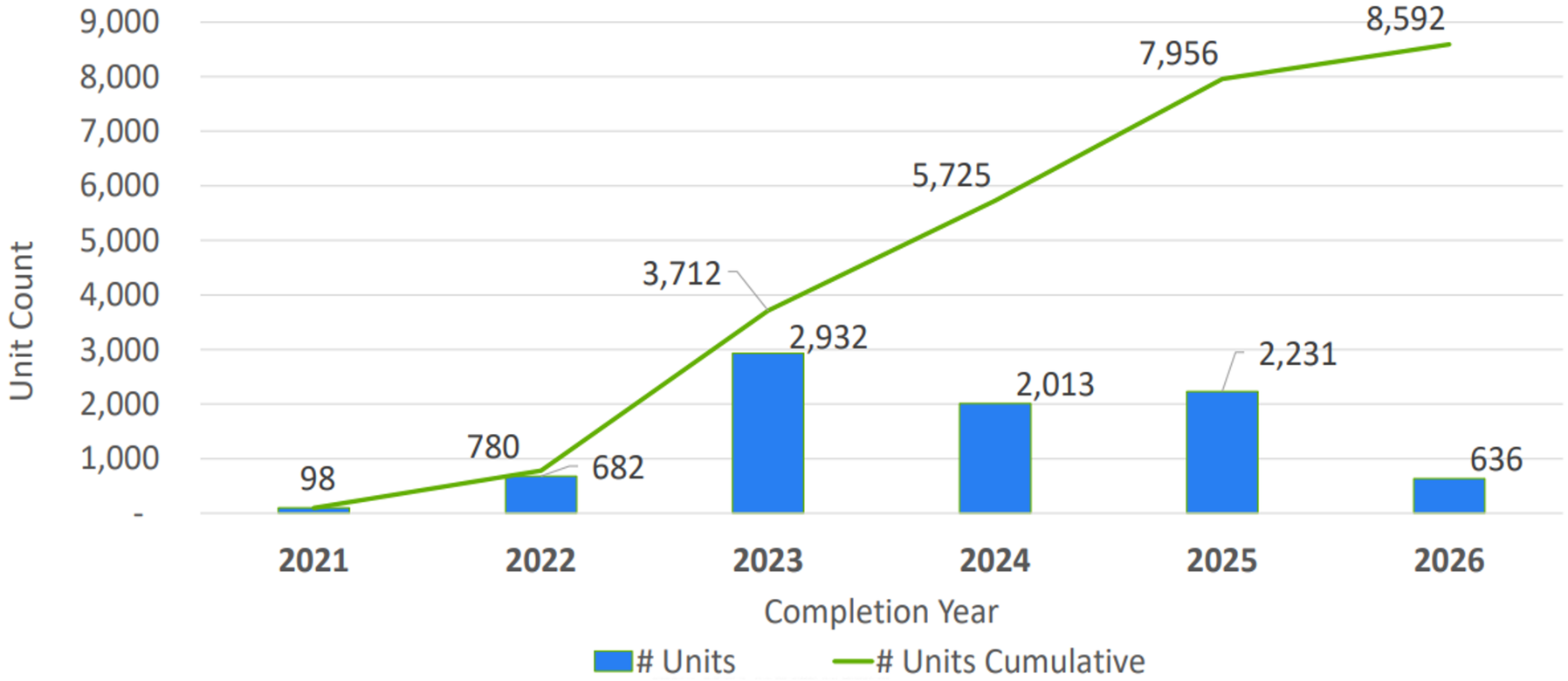
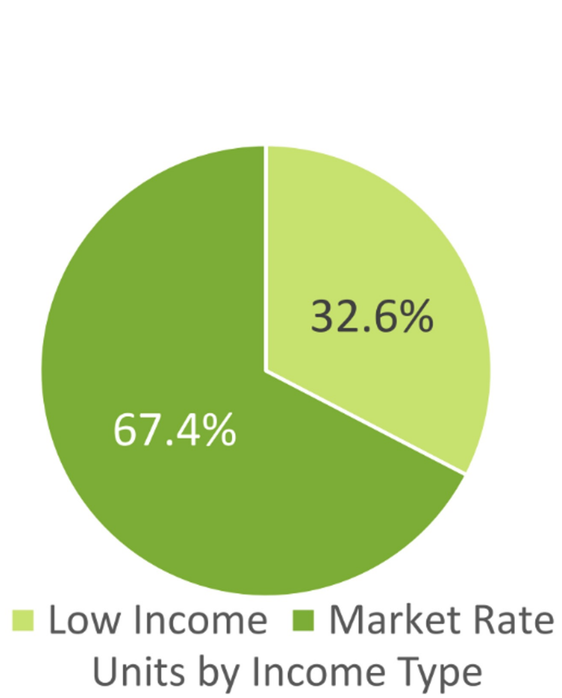
Context in Massachusetts



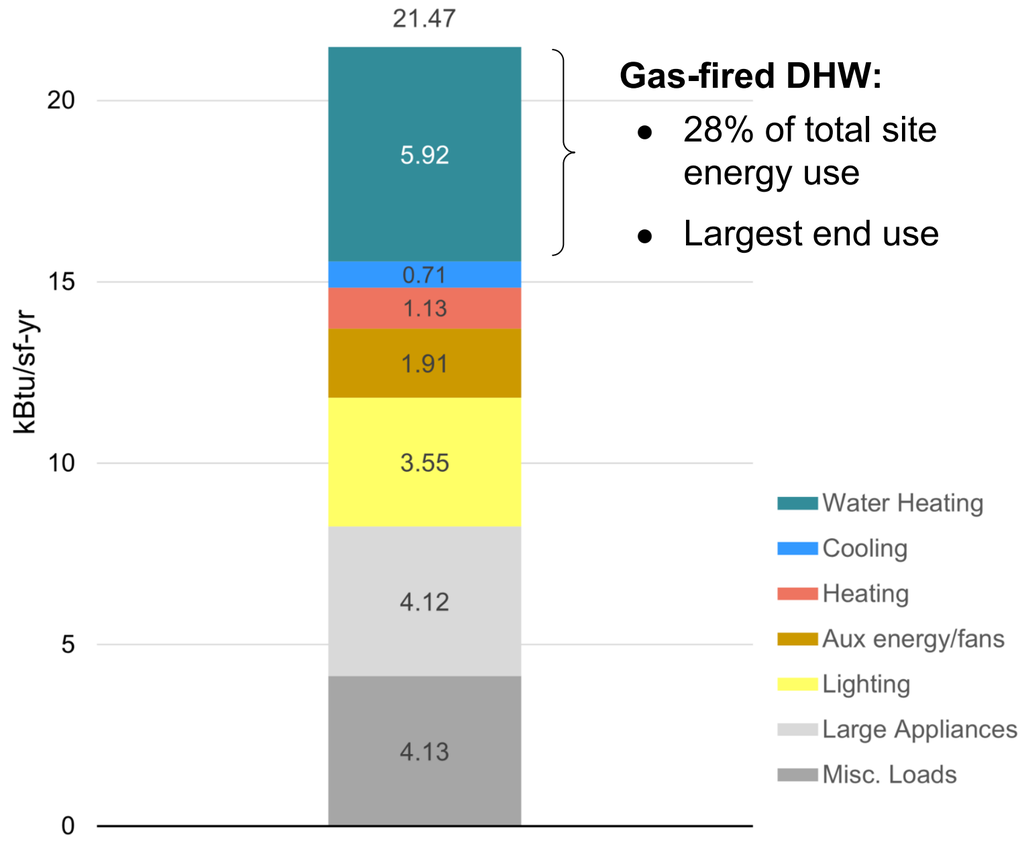


Enrolled Passive House project unit counts by year of estimated completion.
Source: Mass Save, accessed from https://www.masscec.com/sites/default/files/documents/ACEEE_PH_Slides.pdf

DHW in Context: Energy and Carbon

65-unit Multifamily Passive House

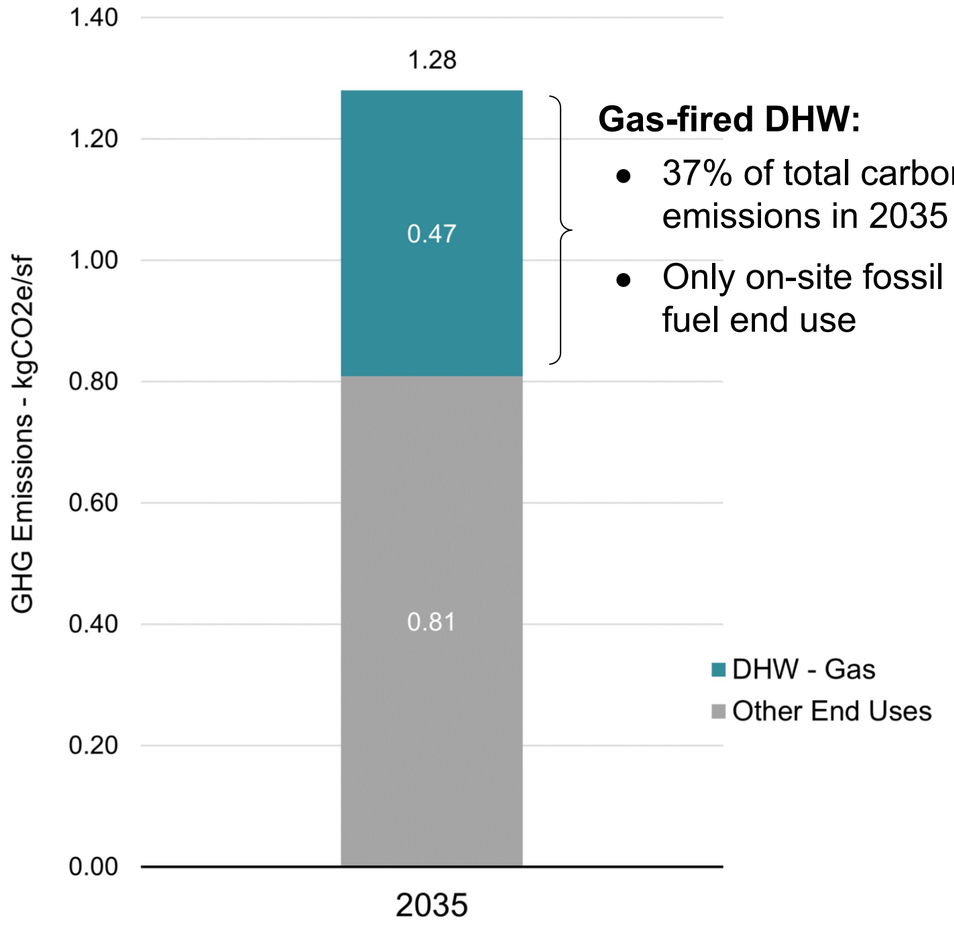
Site Energy Use Intensity



Gas-fired DHW:

- 28% of total site energy use
- Largest end use

Carbon Emissions Intensity



Gas-fired DHW:

- 37% of total carbon emissions in 2035
- Only on-site fossil fuel end use

Two Boston Affordable Multifamily Case Studies

3371 Washington Street, Boston, MA
39 units (78 Occupants)
Estimated Completion: 2024
Phius 2021 Registered, In Design

1599 Columbus Avenue, Boston, MA
65 units (184 Occupants)
Estimated Completion: 2023
PHIUS+ 2018 Core Pre-Certified

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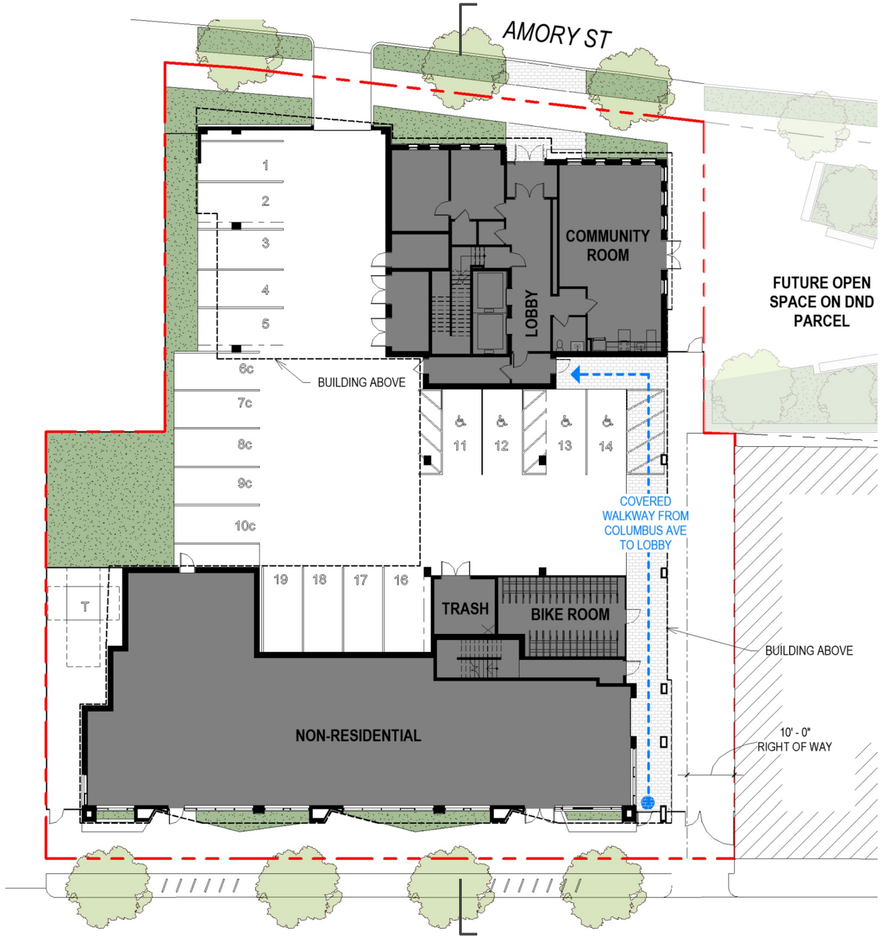
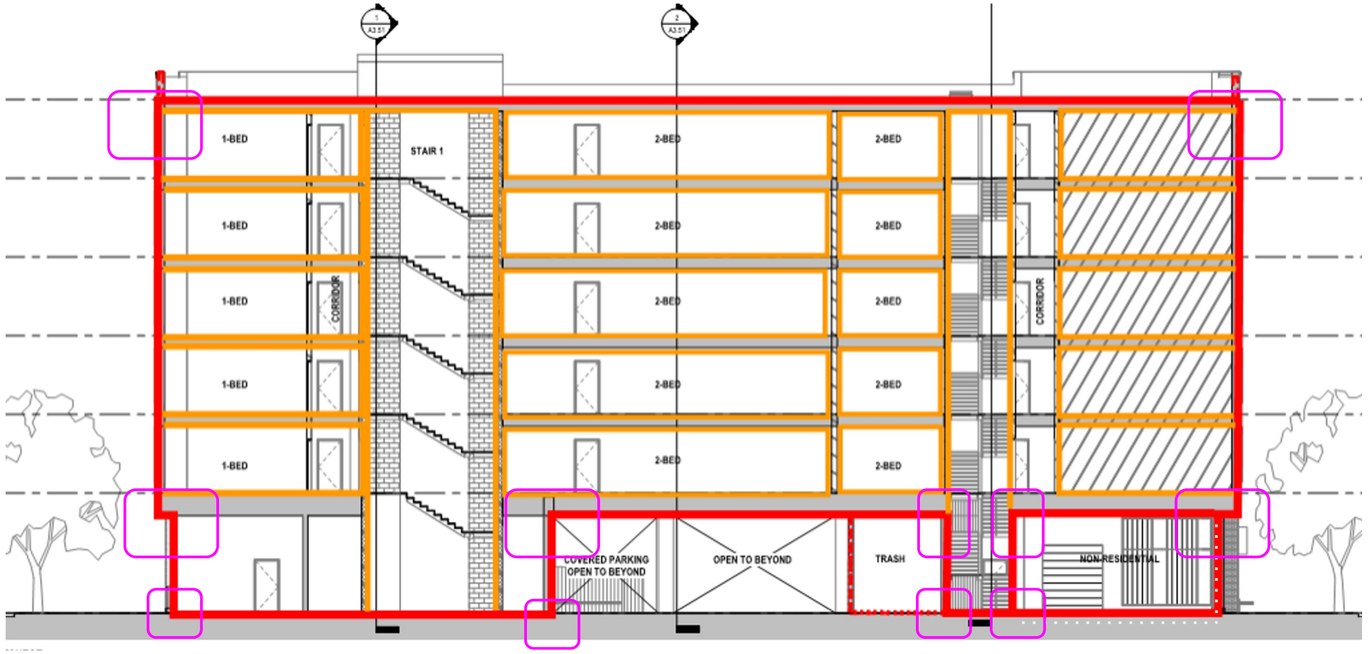
Schematic Design (2019)



Ground Floor Plan



East-West Section Looking North

Water Heating System Options

All-electric options

Individually Metered

Centrally Metered

Central Gas

Electric Resistance Storage

Residential HPWH

Clustered (Semi-Central)
Residential HPWH

Clustered (Semi-Central)
Split HPWH

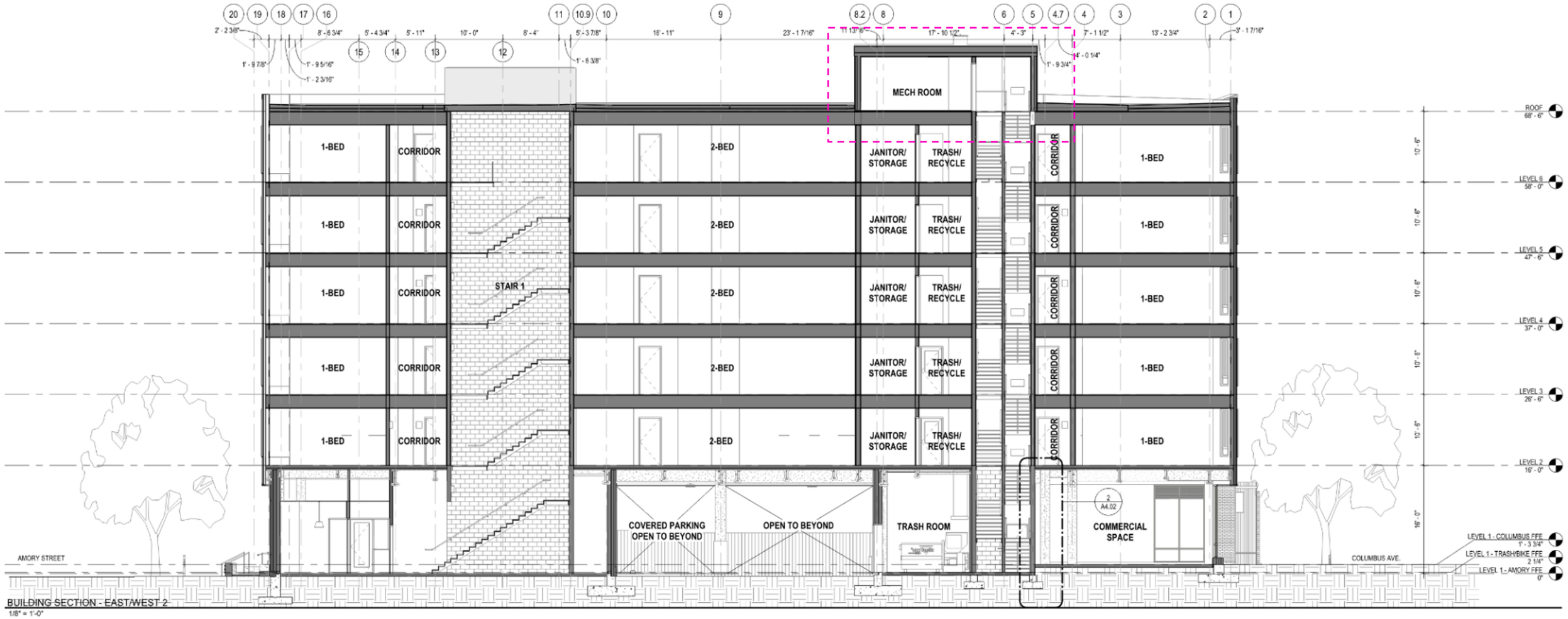
Central ASHP DHW

MEP Systems - Summary Pros/Cons Matrix

	Space Conditioning		Water Heating		
Recommendation	**Central VRF**	**Individual Mini-splits**	**Central Gas DHW**	**Individ. Elec. Storage**	**Heat Pump W.H.**
Case 1	X		X		
Case 2	X			X	
Case 3	X				X
Case 4		X	X		
Case 5		X		X	
Case 6		X			X
First Costs	- Slightly higher first cost	+ 1:1 system slightly lower first cost than VRF	- Slightly higher first cost	+ Lower first cost	- Higher first cost
Utility Costs	Apt. space conditioning on Owner's meter	Apt. space conditioning on Tenant's meter	All DHW on Owner's meter + Low operating cost	All DHW on Tenant's meter - Highest utility cost for tenant	All DHW on Owner's meter + Less operating costs than Elec. Storage
Passive House Feasibility	+ Feasible for Passive House	+ Feasible for Passive House	+ Feasible for Passive House	- Could prevent building from achieving Passive House certification. Requires PV array on roof to meet PHIUS Core	+ Feasible for Passive House
Maintenance/ Other Concerns	- More complex system relative to mini-split - Less redundancy as maintenance and downtime occur on centralized equipment + Less equipment to maintain + Takes up less roof space + Offers ability for additional efficiencies via heat recovery and operating diversity + Central control/monitoring of all indoor equipment	- More outdoor equipment requires more maintenance - Takes up more roof space (less room for PV) - No option for heat recovery capabilities + Simple system and relatively easy to install/service/replace + Some level of heating/cooling redundancy as equipment failures and downtime are localized	- Some on-site fossil-fuel combustion (challenge to decarbonizing the building) - Heat loss from hot water circulation (Could be converted to electric option in the future with proper planning.) + Minimal DHW equipment, less to maintain + Familiar to contractors	- Indiv. equipment requires more ongoing maintenance and replacement costs - Takes up floor space within residential units + Eliminates on-site fossil-fuel combustion + Familiar to contractors, easy to install/replace	- Equipment is noisy - Potentially takes up floor space for apartments - More equipment than Gas DHW + Eliminates on-site fossil-fuel combustion + Minimize/possibly eliminate hot water recirculation piping

1599 Columbus Ave.

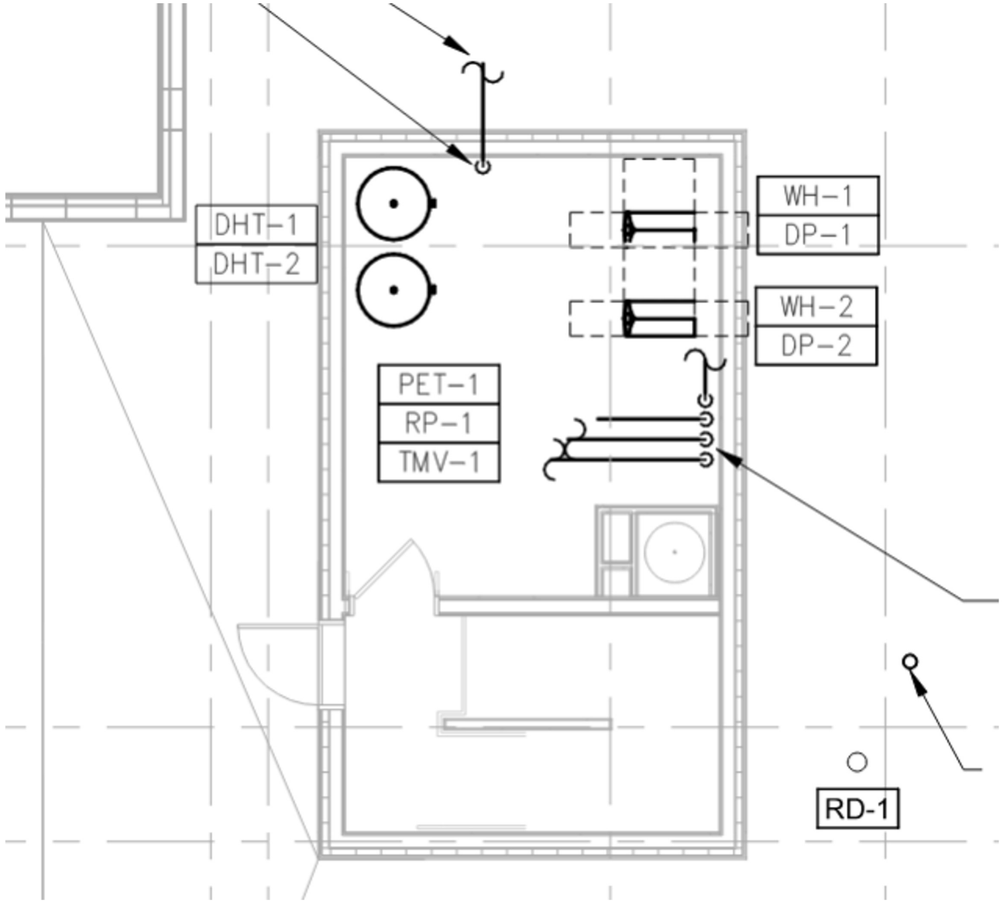
Construction Documents (2021)



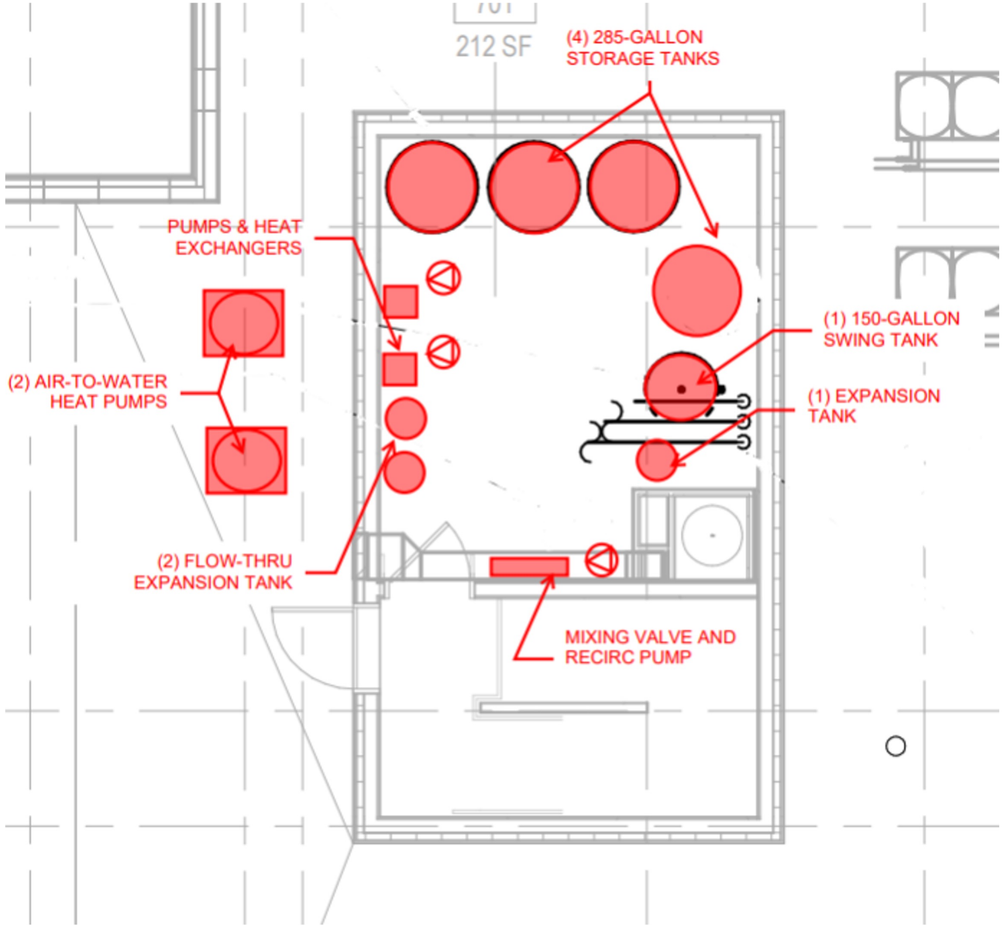
1599 Columbus Ave.

Mechanical Penthouse Comparison

Gas-Fired DHW Configuration



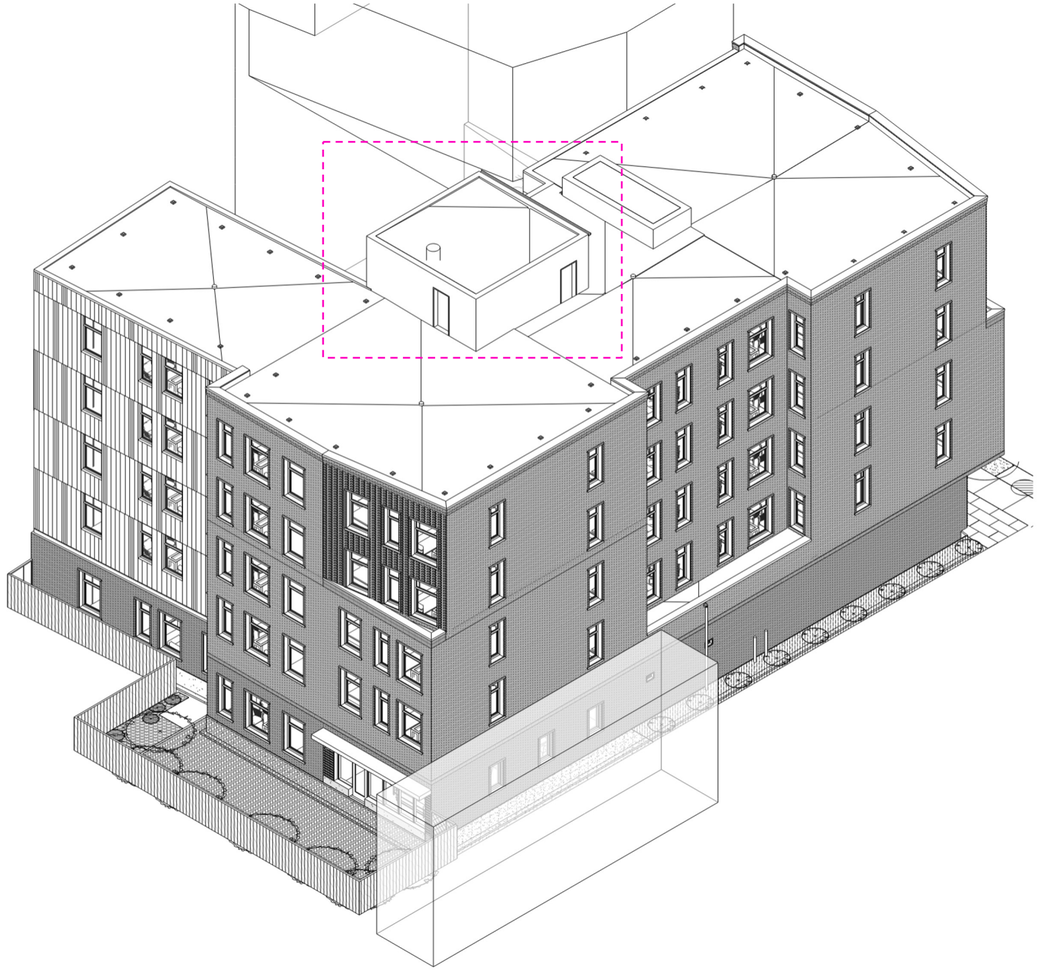
Future ASHP DHW Configuration



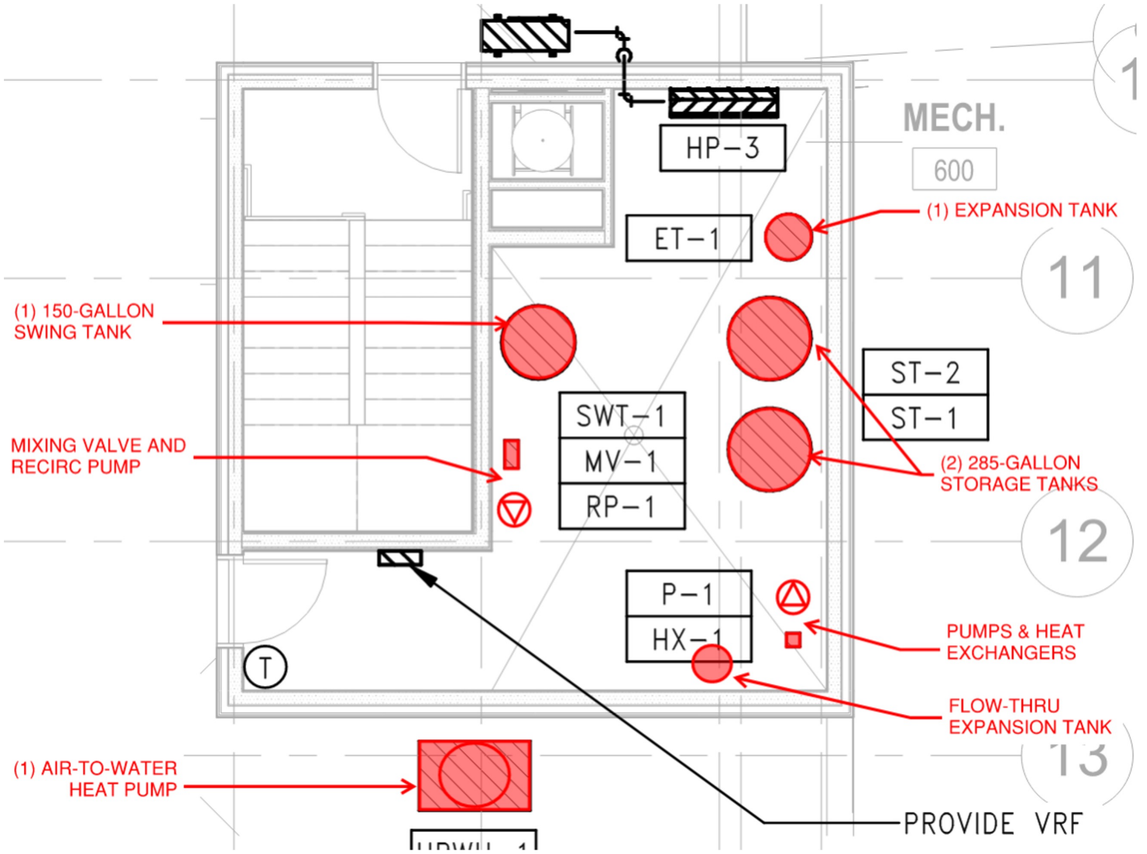
3371 Washington St.

Mechanical Penthouse

Axonometric View Looking East



ASHP DHW (*Add-Alt*) Configuration



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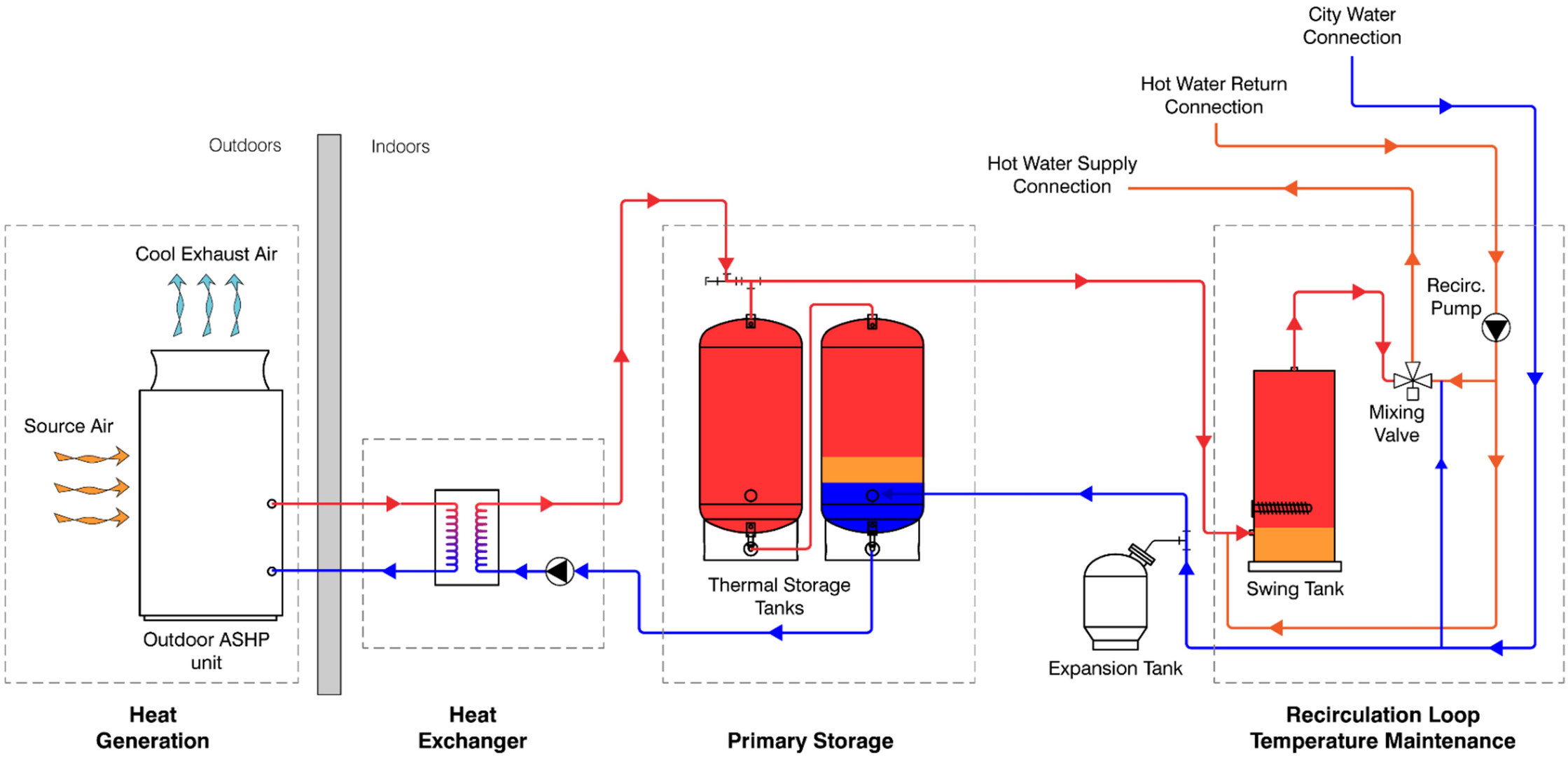
Central ASHP DHW

Components of ASHP DHW System



Adapted from Mitsubishi Electric *Heat2O Domestic Hot Water Heat Pump* Presentation

Energy required to heat hot water for a 2-bedroom apartment per month:

Energy to raise 1 gallon of water to DHW temperature:

$$(55^{\circ}F \text{->} 110^{\circ}F)\left(1\ \frac{BTU}{lb \bullet ^{\circ}F}\right)\left(8.33\ \frac{lbs}{gal}\right)=460\ \frac{BTU}{gal}$$

Gallons of DHW consumption per month:

$$(3\ people)\left(15\ \frac{gal}{PP \bullet day}\right)\left(30.4\ \frac{days}{month}\right)=1368\ \frac{gal}{month}$$

Energy used to heat DHW supply (excluding system losses):

$$\left(460\ \frac{BTU}{gal}\right)\left(1368\ \frac{gal}{month}\right)=629{,}280\ \frac{BTU}{month}$$

Central DHW system **operational cost** per month by type:

Gas: $\frac{\left(629{,}280\ \frac{BTU}{month}\right)}{100{,}000\ \frac{BTU}{therm}} = \frac{\left(6.3\ \frac{therms}{month}\right)}{(0.85\ comb.eff.)(0.75\ sys.\ eff.)} = \left(9.9\ \frac{therms}{month}\right)\left(\frac{\$1.25}{therm}\right) = \frac{\$12.40}{month}$ Lowest

ER: $\frac{\left(629{,}280\ \frac{BTU}{month}\right)}{3{,}412\ \frac{BTU}{kWh}} = \frac{\left(184.4\ \frac{kWh}{month}\right)}{(COP\ 1)(0.75\ sys.\ eff.)} = \left(245.9\ \frac{kWh}{month}\right)\left(\frac{\$0.22}{kWh}\right) = \frac{\$54.10}{month}$ Highest

ASHP: $\frac{\left(629{,}280\ \frac{BTU}{month}\right)}{3{,}412\ \frac{BTU}{kWh}} = \frac{\left(184.4\ \frac{kWh}{month}\right)}{(COP\ 2.75)(0.75\ sys.\ eff.)} = \left(89.4\ \frac{kWh}{month}\right)\left(\frac{\$0.22}{kWh}\right) = \frac{\$19.67}{month}$ +60% over gas

Central DHW system **energy use** per month by type:

Gas: $\left(9.9\ \frac{therms}{month}\right)\left(29.3\ \frac{kWh}{therm}\right)=290\ \frac{kWh}{month}$ Highest

ER: $\frac{\left(184.4\ \frac{kWh}{month}\right)}{(0.75)(COP\ 1)}=246\ \frac{kWh}{month}$ Lower (-15% than gas)

ASHP: $\frac{\left(184.4\ \frac{kWh}{month}\right)}{(0.75)(COP\ 2.75)}=89\ \frac{kWh}{month}$ Lowest (-70% than gas)

ASHP DHW - Barriers and Countermeasures

Barrier	Countermeasure
First cost *(can be 2x to 3x the cost of central gas)*	• Raise awareness of (and advocate for) federal, state, and local utility incentives • Consider economy of scale for larger buildings
Lack of contractor familiarity	• Increase installer awareness • Training for installers + facilities maintenance staff • Quickly evolving industry w/ increasing demand; more mature markets overseas
Lack of available mfrs.	
Unproven market track record	
Potentially higher operational cost	• Minimize hot water demand through design • Raise awareness of policy-based fossil fuel compliance penalties

ASHP DHW - Design Considerations

Component	Recommendation
Right-sizing	• Ensure proper sizing of water heating and storage capacity • Carefully design distribution piping and ways to reduce demand
Mechanical room location + configuration	• Locate room directly adjacent to outdoor heat pump (typically on upper floor or penthouse) • Room size large enough for components, e.g. tanks • Wider doors to accommodate larger storage tanks • Allocate space on roof for ASHP compressor units, including clearance requirements
Floor structure	• Ensure sufficient structural capacity for tank storage
Electrical service	• Evaluate impact on electrical service capacity

Energy Codes and Standards

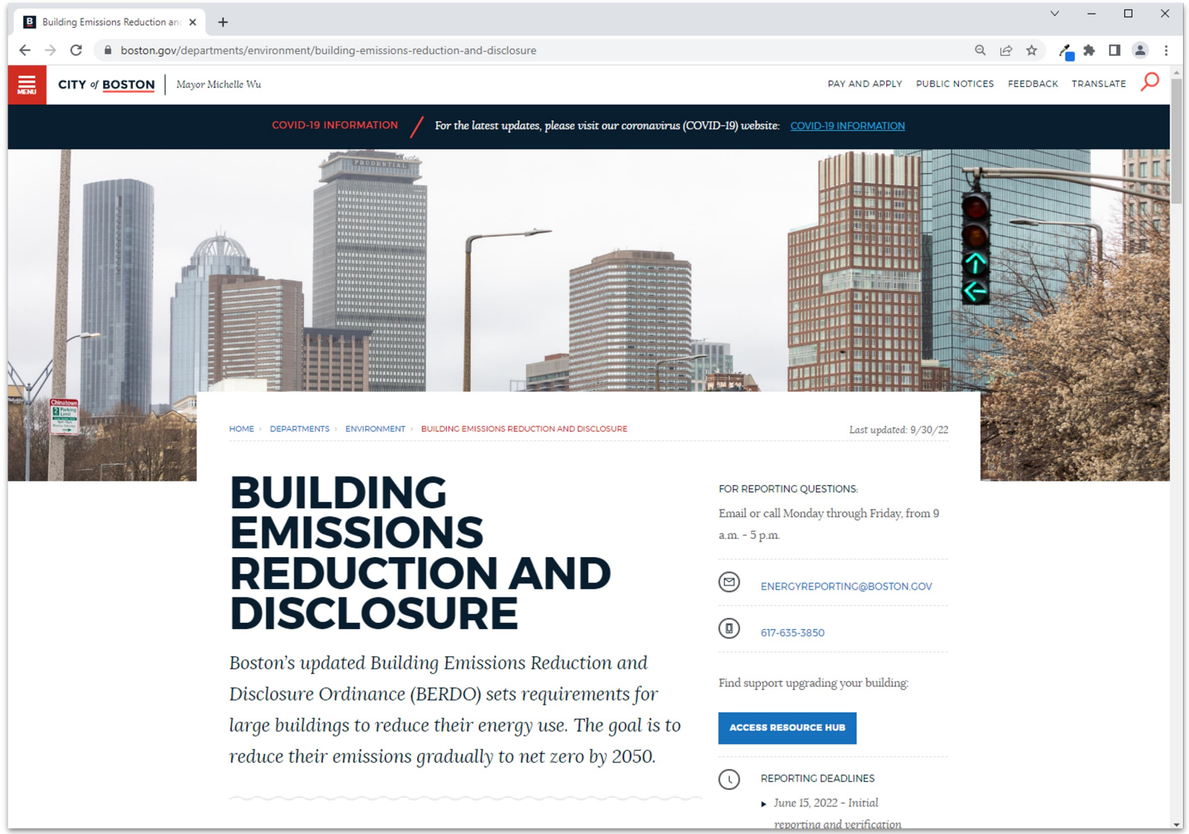
Seattle Commercial Energy Code

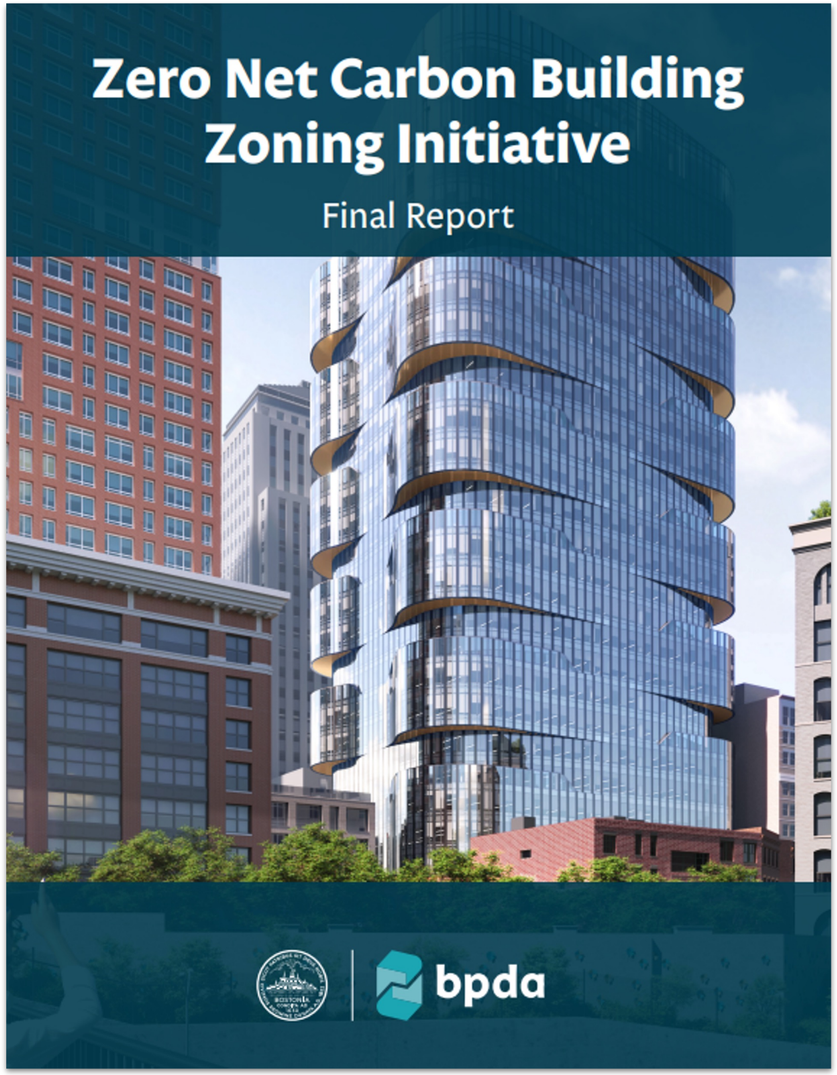
C404.2.3 Group R-1 and R-2 occupancies with central water heating

> Service hot water shall be provided by an air-source heat pump water heating system (not fossil fuel combustion or electric resistance)

Adapted from Ecotope *Central Heat Pump Water Heating: Engineering Deep Dive* Presentation
Accessed from: https://www.lightingdesignlab.com/sites/default/files/pdf/CHPWH_Deep_Dive_Part1_01112022.pdf

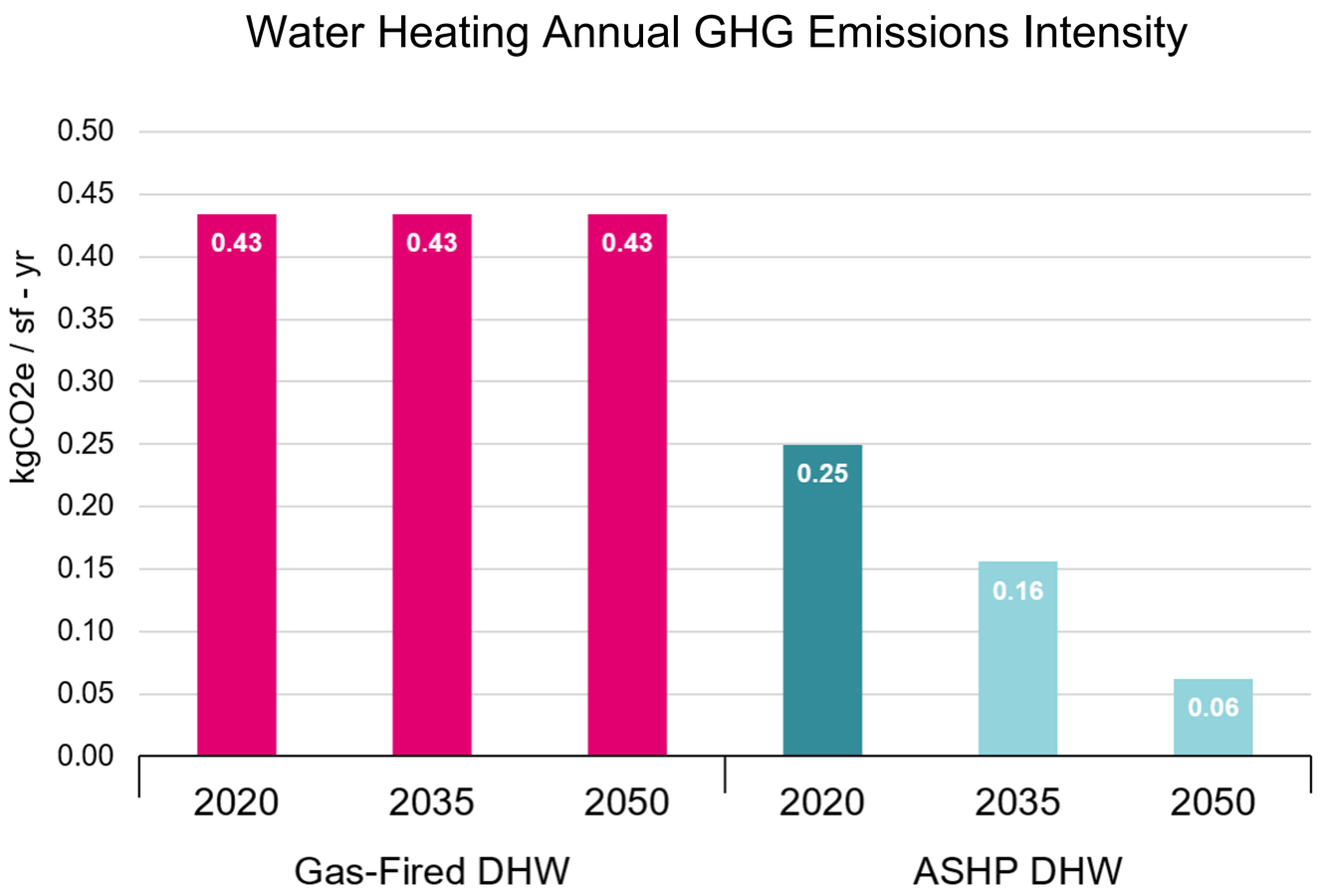
Boston’s Carbon Emissions Standards





DHW Operational GHG Emissions Comparison

3371 Washington St.



Key Takeaways

- Understand and communicate operational cost implications
- Right-size DHW system design to reduce cost
- Raise awareness of state and local decarbonization policies and standards
- Identify and advocate for incentives

Thank you!

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utile

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