Qualitative Perspectives of Air to Water Heat Pumps in Multifamily Buildings

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ABSTRACT

The multifamily building segment presents significant yet complex opportunities in electrification and decarbonization because it accounts for 19.3 billion MMBtu or 15% of Massachusetts' state-wide natural gas consumption. Buildings with aging boiler-chiller plants in particular offer compelling opportunities for air-to-water heat pump retrofits as part of a broader decarbonization effort.

This paper presents a field study on a senior housing multifamily building in New Bedford, Massachusetts, where a 120-ton end-of-life air-cooled chiller was replaced with an equivalently sized air-to-water heat pump (AWHP). The existing boiler was retained to support heating during below-design-day conditions with a switchover outdoor temperature reset control. This study explores key challenges and considerations in deploying AWHPs in multifamily buildings, including code compliance, electrical capacity constraints, customer expectations, equipment sizing relative to design-day heating loads and efficiency, optimization of switchover temperatures in respect to decarbonization and customer utility bill savings, and overall cost implications.

Findings from this field study provide insight into the feasibility and scalability of AWHPs as drop-in replacements for aging chiller-boiler plants in multifamily buildings, including implications for policy, design practice, and market transformation.

Introduction

Mass Save® is a collaborative of Massachusetts' electric and natural gas utilities and energy efficiency service providers including Berkshire Gas, Cape Light Compact, Eversource, Liberty, National Grid, and Unitil (collectively known as the Mass Save Sponsors or, sometimes, as the Program Administrators), who jointly administer the Mass Save programs. Mass Save is the brand name for a comprehensive set of programs, administered by the Sponsors within each of their own service territories. Eversource, as one of the Mass Save Sponsors, is responsible for equitably delivering energy and greenhouse gas emissions savings for residents, businesses, and communities in its service areas, which includes New Bedford, Massachusetts.

In the Massachusetts 2025-2027 three-year energy efficiency and decarbonization plan, the Program Administrators (Pas) committed to investing $4.5 billion in program funds to support statewide decarbonization goals (MassSave 2024). With these incentives and goals in mind, the PAs pursued multifamily projects in partnership with vendors seeking to perform transformative electrification work in multifamily. Both a partner in this field study and a long-standing national leader in advancing energy efficiency, WinnCompanies (Winn) play a significant role as one of Massachusetts largest affordable-housing developers and managers. With a portfolio of more than 125 communities and housing that serves nearly 300,000 residents across the Northeast, Winn provides stable homes for vulnerable populations including seniors and military veterans (Winn n.d).

Winn's development strategy includes extensive adaptive reuse of existing buildings like historic mills, former schools, hotels, and government structures paired with new construction techniques to meet modern standards. Their commitment to sustainability is reflected in projects that incorporate Passive House design principles, deep energy retrofits, onsite distributed energy resources such as solar generation, and ongoing energy and water conservation practices across their portfolio (Winn n.d). Therefore, this developer has the ideal skillset to increase the availability and efficiency of the aged Massachusetts building stock.

In better understanding the nature of the Massachusetts multifamily building stock, Table 1 retrieved from the American Community Survey summarizes the number of multifamily buildings across the state. It is interesting to note that 75% of the 115,309 multifamily buildings were constructed prior to the year 2000, with peak development occurring between 1960 to 1979 (U.S. Census Bureau n.d). Statewide adoption of a building construction standard was formerly codified in the 1970's and are now revised on a three-year cadence with minimum requirements for energy efficiency and building façade performance.

Table 1. Multifamily building inventory characterized by number of units, growth, and allocation based on year built.

Year Built	5 – 19	20 – 49	50+	Total	Cumulative	Growth	Cumulative Allocation
2020+	1,214	1,689	1,235	4,138	115,309	4%	100%
2000 – 2019	8,284	6,869	9,431	24,584	111,171	22%	96%
1980 – 1999	13,700	6,065	10,736	30,501	86,587	35%	75%
1960 – 1979	10,604	5,768	8,633	25,005	56,086	45%	49%
1940 – 1959	3,369	1,341	700	5,410	31,081	17%	27%
1939 & earlier	15,753	5,157	4,761	25,671	25,671	-	22%

Study Objectives

This field study aims to discuss the planning and execution of air-to-water heat pumps (AWHPs) as a drop-in retrofit solution for aging chillers and boiler plants. The research presented in this paper discusses the qualitative considerations of AWHP retrofit from a step-by-step program perspective that includes identifying suitable building characteristics, proposed costs in the competitive bidding process, technical sizing for equipment selection, and project timeline delays in respect to ongoing implementation challenges unique to older buildings. Although early measurement and verification data collection activities are pending completion, this paper serves as a guide for other program administrators and implementors to understand the technical risks, barriers to adoption, level of program support, and other topics at each project step, to support the development of a more comprehensive program offering and decarbonization strategy. Overall, this study seeks to answer the following questions.

- What are the barriers that arise when deploying AWHP in income-eligible and market rate multifamily buildings?
- What program design considerations in equipment eligibility, building selection, and model assumptions are required to support the scalable adoption of AWHPs?

Site Selection Process

The Mass Save® income eligible program operates using a lead-vendor model who is responsible in overseeing sub-contractors, installers, and other firms to conduct the initial audit, model energy savings, install measure-specific equipment, perform post-inspection, and conduct other activities to support customers such as Winn in their sustainability projects. Program administrators support projects by leveraging market-rate dollars[1] to claim customer energy savings that are reported to the states greater decarbonization goals. Eversource, the program administrator serving this study's multifamily project, is collaborating closely with a sub-contracted project manager from the lead vendor to ensure provision of extent project support in alignment to the lead-vendor's responsibilities

To begin the multifamily project process, a thorough site-selection effort was performed with the sub-contractor, who shared their knowledge and insights on similar multifamily chiller-to-AWHP conversion projects. Table 2 compares four Massachusetts projects that have installed AWHP systems in respect to relevant metrics including the number of apartments, square footage, and total project cost with key performance indicators expressed as cost per apartment ($/Apt), and cost per square footage ($/ft^2). Table 2 serves as a rudimentary scale for anticipated cost range in early-stage project planning for multifamily AWHP conversion projects being pursued in Massachusetts.

Table 2. Total installed cost per apartment and square footage from other residential multifamily air-to-water heat pump projects in Massachusetts.

Project	Apartments	Building ft^2	Cost	$/Apt	$/ft^2
1	56	44,892	$572,725	$10,227	$12.76
2	45	43,618	$716,550	$15,923	$16.43
3	71	32,304	$994,575	$14,008	$30.79
4	58	63,000	$1,200,000	$20,689	$19.05

Among the listed projects shown above in Table 2, Project 1 appears to be the most cost-effective because both the cost per square foot and the cost per apartment ($/Apt) are the least. While Project 4 reflects the highest overall project and dollar per square foot cost. Although project 3 shows a lower cost per apartment than Project 4, its cost per square foot is 2.82 times higher, which is likely due to inaccurate or incomplete floor-area reporting. A further correlation analysis between total project cost and $/Apt and $/ft^2 yields R^2 values of 0.68 and 0.32 respectively, which unsurprisingly suggests a weak correlation given a small sample size.

Despite this result, values provided in Table 2 can be used to set expectations on the estimated project cost range at a high level for multifamily projects in Massachusetts. Similar tables could be developed based on $/ft^2 and $/Apt for other programs assuming that scope of work for each project is comparable.

Identifying Site Selection Barriers

In early discussion in site selection, it was imperative that an aging boiler plant or end-of-life chiller was strongly preferred in this field-study to prove out the feasibility of an AWHP as a drop-in replacement. In addition, older systems may present unique challenges, barriers, and opportunities to better understand customer, contractor, and program implementation perspectives to develop a more comprehensive program offering. So, the project team had no

[1] Supported as a charge on customer energy bills to support decarbonization and energy efficiency projects

immediate preference for the equipment's location in the building, provided it remains accessible by conventional equipment for installation.

Out of a dataset of 68 potential multifamily buildings, only 12 candidates were identified by the managing sub-contractor with suitable mechanical equipment type identified in Table 3. In addition, suitable building characteristics in Table 3 detail the number of apartments, square-footage, equipment type, location, and installation year. Lastly it should be noted some values in Table 3 are denoted "TBD" for sites that have not confirmed information through a site visit.

Table 3. Candidate site high-level details on building characteristics, equipment type and installation date, and potential barriers assessed during exploration field visits.

Site	Apartments	Building ft^2	Install Location	Equipment Type	Installation Date	Identified Site Barrier
1	75	112,879	Roof	Chiller	2003	None
2	70	34,000	Roof	Chiller	2013 & 2016	Property lines / Noise
3	115	87,626	TBD	Chiller	2006	Transformer
4	41	45,834	Roof	Chiller	2021	New Chiller
5	62	59,546	Ground	Chiller	New	New Chiller
6	150	153,136	Ground	Chiller	New	New Chiller
7	120	135,204	Roof	Boiler	Boiler Plant	Transformer / Riser
8	50	72,000	TBD	Chiller	2017	New Chiller
9	45	80,020	Roof	Chiller	2008	Riser
10	130	122,354	Ground	Chiller	Unknown	New Chiller
11	94	55,400	Roof	Boiler	Unknown	Riser / Switchgear
12	40	37,634	Ground	Boiler	2010	Property lines/ Noise/ Density

In each potential site, various key barriers were identified in Table 3. Addressing the first barrier in each site begins with acknowledging local code compliance and regulatory constraints. Understanding the potential code and regulatory impediments and how they impact project cost and circumstances is essential to the selection of the most auspicious project sites for AWHP installation.

Noise ordinance in some municipalities was one potential barrier noted. Strict decibel limits for mechanical equipment where most AWHP manufacturers may not satisfy these thresholds without the addition of a privacy fence or equivalent sound attenuating barrier. Although exemptions from the noise ordinance might have been granted on a case-by-case basis, they are not guaranteed and introduce uncertainty to early project planning. Therefore, sites located in known municipalities with strict noise ordinances were screened out.

Inadequate onsite electrical infrastructure proved to be another significant and common barrier. Many sites had insufficient capacity at the pad-mount transformer and would require building owners to undergo an expensive process with long procurement lead times in upgrading the equipment. Even at sites where overall electrical service was adequate, incompatible switchgear presented additional challenges where existing electrical infrastructure lacked the physical space, breaker capacity, or bus-bar amperage rating required for the planned equipment. Several creative solutions were proposed by the engineering firms but were later deemed unviable due to space constraints and code compliance concerns:

- Tap into bus bar lugs to a standalone distribution box and breaker
- Install sub-feed breaker, add another distribution section
- Tap the service conductors
- Use a tap box or conductor tap

Rooftop installations introduced another potential barrier. In high-rise multifamily buildings where ample rooftop space is available to install new equipment, challenges in the building's electrical distribution were also identified, especially for boiler plants. The feeder to a roof-top boiler plant is sized with conductors that do not meet the minimum national electrical code (NEC) requirements to sufficiently power the new equipment. As a result, the only solution presented by the engineering firms is to route a dedicated feeder from the main switch gear to the rooftop with appropriately sized conductors. Not only is this cost prohibitive, but this also requires carefully coring through multiple floors while avoiding structural elements such as beams and shear walls and may unveil additional barriers such as asbestos containing material. Initial planning estimates for site 11 yield coring and electrical costs of $22,000 and $39,000 respectively for a 12-story building.

Further, at ground level, in a dense urban environment, there may appear to be ample space to place mechanical equipment; however, other unique challenges may arise. Land surveying and parcel mapping often reveal that the existing equipment is positioned too close to property lines. In many cases, the proximity of the proposed AWHP would then require an easement adding complexity and risk in early project planning. In other cases, sites that have adequate clearance between property lines lack adequate space for a truck or crane to safely deliver equipment. Although it is possible to develop and issue a stamped engineering lift plan, additional coordination, permitting, and considerations to safety introduce significant risks that are not ideal in demonstrating the market scalability of the technology, and subsequently increase overall project costs.

Eversource and the managing sub-contractor discovered that site 1 was a strong candidate based on fewer potential issues compared to other prospective sites. This was confirmed with an in-person follow-up field visit to ensure that there were no electrical infrastructure limitations or other visible barriers that would impede implementation. In addition, the site features low-temp emitters that are compatible with leaving water temperatures from the AWHPs, making it desirable in an implementation perspective where major re-work of the in-unit hydronic distribution would not be necessary.

Overall, the chiller/boiler to AWHP site selection process began on October 15, 2024, where the first site was identified and confirmed as a viable candidate on November 5, 2024, within 21 days. The search continued for a second site for a similar project until June 17, 2025, lasting 245 days, however a good candidate with minimal barriers in inadequate electrical infrastructure and regulatory code compliance was unable to be identified.

Building Characteristics and Energy Modeling

Originally converted from a historic mill to a multifamily residence, Site 1 features a four-story multifamily building featuring 75 tenant units residing on 123,036 ft^2 of building space. Built in 1910, the building features 70 one-bedroom apartments and 5 loft style two-bedroom apartments. The site is master metered for electricity and natural gas and features onsite renewable generation in the form of a roof-mounted photovoltaic array which is net metered. No delivered fuels are used on site, and there is no emergency generator. The building's heating and cooling are served by a traditional boiler and chiller plant tied to a two-pipe hydronic distribution system with vertical stack riser heat-exchanger fan coil units. The fan coil units provide space conditioning to each dwelling unit. While Gas fired rooftop units (RTUs) featuring direct expansion (DX) cooling serve most of the heating and cooling load in common areas, including some electric resistance heat used in stairways and vestibules.

Overall, the site consumes an annual average of 292,800 kWh of electricity, and 2,413 MMBtu of natural gas. As shown in Table 1 below, apportioning the building's usage for heating[2] and cooling yields an average consumption of 1,731 MMBtu and 71,133 kWh respectively. By weather normalizing metered usage, it is interesting to note that the cooling consumption has decreased 29.7% since 2022 since the customer had reported the chillers failing compressors. Whereas heating usage observed minimal difference with a notably minor 8.2% decrease in 2023.

Table 4. Energy and Gas metered data for Site 1 where heating and cooling are modeled and weather normalized across multiple years.

Year	Energy, kWh	Gas, MMBtu	Heating, MMBtu	Cooling, kWh	HDD	CDD	Heating /HDD	Cooling /CDD
2022	305,400	2,413	1,825	86,500	5,328	751	0.342	115.2
2023	290,700	2,169	1,589	64,500	5,066	632	0.314	102.1
2024	282,300	2,361	1,780	62,400	5,105	771	0.349	80.9
Avg.	292,800	2,314	1,731	71,133	5,166	718	0.335	99.4

In implementing an AWHP the project team estimates an energy efficiency savings of 95% of the buildings' annual heating load yielding 1,642 MMBtu. This fuel displacement incurs an additional electrification penalty of 204,467 kWh yielding an approximate average increase of 497,300 kWh. When considering the spark-spread between electricity (~24 center per kWh) and natural gas (~$27 per MMBtu), this project does not incur any utility savings for the customer (EIA 2024 and 2025). Because the customer initially expressed concerns about increasing their billed heating costs in the long term, they agreed to a three-year measurement and verification plan to optimize and extend the capabilities of the machine in benefit for the programs.

Current and Proposed Configuration

On-site equipment in Figure 1 features an end-of-life Carrier Model 30RBA 120-ton air-cooled chiller and three Lochinvar model FTX850N (850,000 Btu/h) gas-fired fire-tube boilers tied to a two-pipe change-over hydronic distribution system served by two parallel 10 HP pumps. Boiler controls are configured on a lead-lag schedule between two boilers with run-time-based rotation to equalize overall utilization across all three boilers. While the chiller operates as a standalone system with no redundancy in place. Controls between the system enable a series of valves to switch between heating and cooling and ensure that both systems are not operating at the same time.

Upon further inspection of the boiler plants age and operating condition, sufficient justification for early retirement is not possible. However, inspection of the 20+ year-old chiller confirms that two of its five compressors have failed, where increasing costs in maintaining the equipment strongly encourages Winn maintenance staff to pursue replacement options. Especially when considering scarcity of parts and phase-out of refrigerants sold at increasing cost in the market.

As a necessary first step prior to issuing a request for proposals (RFP) the sub-contracted project manager installed baseline measurement and verification equipment to determine cooling and heating capacities on the warmest and coldest design days. By implementing temperature and flower meters on the boiler and chiller plant, a heating and cooling capacity of 790,759 Btu/h and 625,500 Btu/h were respectively measured. This additional in-field exercise underscores the

[2] Packaged unitary electric and gas heating in the common areas is not accounted in the overall heating load.

importance of baseline performance benchmarking, otherwise the heating capacity would have been assumed to be equal to the maximum firing rate of one boiler, or the combined partial firing rates between the lead-lag boilers, yielding an oversized system. In addition, this further simplifies project complexity for bidding engineers and provide more accurate cost estimations.

Figure 1. End of life Carrier 30RBA 120-ton air cooled chiller (left), and three Lochinvar model FTX850N boiler plant (right)

All engineering bidders proposed replacing the existing end-of-life chiller with an AWHP connected to the existing hydronic distribution system with some additions. The existing hydronic chiller loop features several modifications that place a new plate-and-frame heat exchanger, additional storage tanks, air separator, glycol feeder, and appropriate plumbing valves and fixtures to accommodate the new equipment. The existing boiler plant remains in place to serve as a source of backup heat for below design day temperature hours where the heating load requirements exceed the reduced heating capacity of the equipment. Overall, the proposed AWHP configuration will operate as the primary source of heating and cooling where the boilers are manually enabled only under a specified control sequence. In addition, optimization exercises will be conducted to identify and optimize an economic balance point and outdoor switchover temperature.

Project Bidding Process

Capital improvement projects such as boiler or chiller replacements for commercial and industrial customers often cost millions of dollars. As a necessary component for corporate procurement compliance, an extensive bidding process for an engineering firm, manufacturer, and mechanical contractor is a necessary first step. Without competitive bidding, sole-source procurement in a non-competitive environment may not only yield greater costs but also expose the project and the customer to additional liabilities. In addition, the market ecosystem for large equipment like chillers is well established, so it is both practical and prudent to consult multiple vendors and compare proposals. In identifying an engineering design firm, the managing subcontractor drafted and distributed a request for proposal outlining requirements across three core sections, and coordinated in-person field-visits inviting each engineering firm, equipment representative, and mechanical contractors:

- Proposal Requirements
  - A full equipment quote for the air-to-water heat pump and all required installation components.

- A two-line piping schematic of the new and existing systems for contractor pricing.
  - All proposed product submittals and cut sheets.
  - A description of any equipment discounts or concessions that will be passed through to the contractor/project.
- System Design Constraints
  - The new air-to-water heat pump will be installed on the roof in the existing chiller location connected to a heat exchanger in the mechanical room.
  - The piping between the heat pump and heat exchanger will contain glycol.
  - A switchover strategy between the heat pump and existing gas system must be implemented, updated to better evaluate COP under varying temperatures.
  - Integration with existing building management system capabilities or alternate control solutions may also be considered to support setpoint control, trending, and switch over
- Design Build Services
  - Selects and size equipment to meet the calculated building load.
  - Works with managing subcontractor to validate existing system performance and ensure proper design, sizing, and commissioning.
  - Coordinates with contractors on-site during design and construction.
  - Provides startup support, field question responses, and training for on-site staff.

Selection Criteria

Information from the RFP was then collected and evaluated in selection Table 5, which highlights the key characteristics of the preferred engineering firm. The scoring framework for the selection table prioritizes delivery time with a weight of 30 points, followed by efficiency, customer preference, communication, and prior experience with 20 points; and all remaining categories including price, power, and efficiency below 10 points. A scoring framework for the selection Table 5. Because this study examines the novel application of an AWHP as a drop-in chiller retrofit, the engineering firm's ability to effectively demonstrate and support a successful deployment was prioritized over standard implementation perspectives including initial costs, decarbonization potential, and expandability.

Since each engineering firm had a preferred manufacturer, additional interviews were conducted with the attending firm and manufacturer to understand their working relationship, business model, clarify specific equipment details, and technical merits. In this comprehensive evaluation, which also considered the manufacturer, final scoring reflects that Firm C emerged as a clear leader with a final score of 56, while Firms B and D followed as candidates for consideration on the second site. Despite providing assurances on engineering services, Firm A did not submit a complete and competitive proposal. As a result, their equipment performance and costs in respect to competition were given a lower score in critical categories to deliver, communicate, and manage this project, revealing significant risks that ultimately excluded them from consideration.

Table 5. Site selection weighted scoring matrix and criteria each Engineering Firm.

Weight.	Criteria	Description	Firm A	Firm B	Firm C	Firm D
5	Price	Total installed cost	1	2	4	3
30	Lead Time	Delivery: 8–12-week target	2.5	1	2.5	4

10	Proposal Completeness	Level of detail, missing items	1	2.5	4	2.5
5	Power	Transformer inclusion/pricing	4	4	4	3
0	Expansion	Future capacity/modularity	4	4	4	4
5	Efficiency (IPLV)	Cooling efficiency in respect to ASHRAE 90.1	1.5	3	1.5	4
20	Efficiency (COP Glycol)	Heating COP in respect to ASHRAE 90.1	3	2	4	1
0	Decarb Potential	Relative GHG reduction	4	4	4	4
5	Maintenance	Maintenance detail	4	4	3.5	4
10	Credibility	Experience and partner history	1	3.5	3.5	2
10	Warranty	Strength of warranty offering	4	4	4	4
20	Owner Preference	Alignment with owner priorities and expectations	2.5	4	4	2.5
20	Communication	Contractor/client feedback	1	3	4	2
15	Project Mgmt.	Project mgmt. plan/Gantt	1.5	3.5	3.5	1.5
20	Prior Experience	Installed similar system before	1	1	4	1
Cumulative Weighted Score:			7400	8700	11200	8700
Total Score:			37	44	56	44

Equipment Manufacturer Technical Considerations

All engineering firms submitted proposals containing equipment and component level engineering cut sheets and performance data at rated conditions with varying levels of technical detail. While each AWHP manufacturer provided COP, EER, water temperatures, heating capacities, and other metrics that are readily available from their respective public-facing technical literature, values in public literature often model optimized scenarios that may not reflect real-world performance. To enable a fair, like-to-like comparison, all firms were asked to provide calculated COP and heating capacity values for site specific outdoor temperatures that model a theoretical hydronic heating system using a 40% glycol mixture and a 130°F leaving-water temperature. This consistent performance data requested eliminates design-specific biases inherent in each of the manufacturer's published data.

It should also be noted that all four manufacturers offer their equipment in modular configurations designed to achieve a total tonnage of 105 to 120 and greater design capacities if needed to serve larger building loads. Manufacturers (MFG) A and D feature four modules, while B and C feature two modules.

Apart from MFG. A, all manufacturers supplied the required supplemental performance data summarized in Figure 2. The results indicate that MFG. D delivers the highest heating capacity but exhibits lower coefficients of performance (COP), making it best suited for buildings prioritizing peak heating output over efficiency. MFG. C demonstrates the strongest COP but offers a lower than anticipated heating capacity, positioning it as a strong option for minimizing overall operating costs. MFG. B has the lowest heating capacity ratio with a performance curve falling between MFG. D and MFG. C, which renders it as a fair general-purpose option for installation consideration.

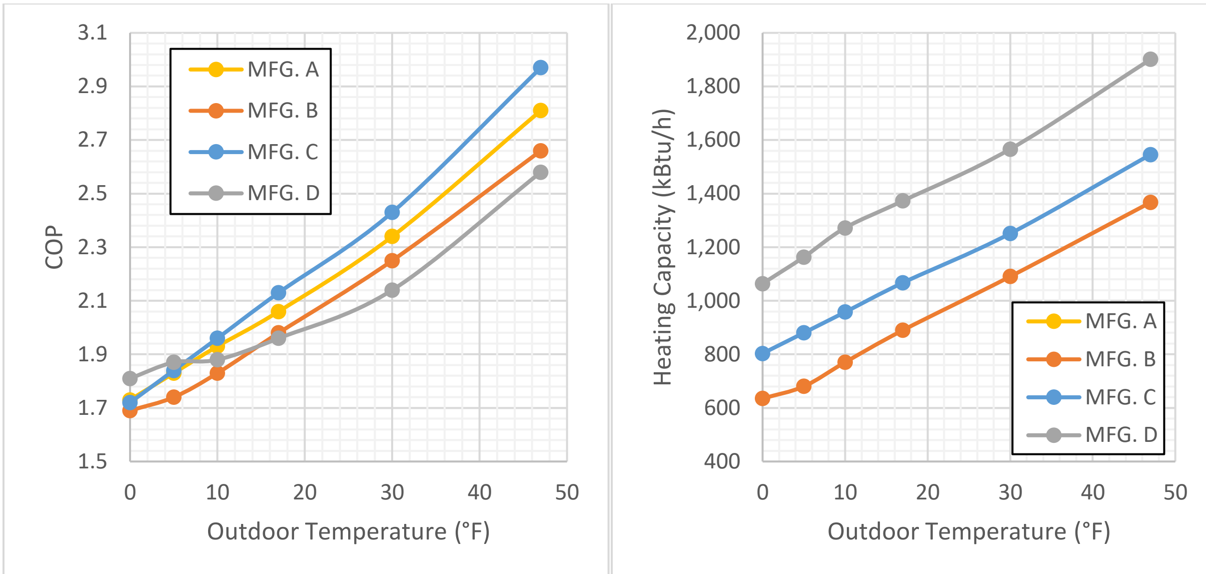

Figure 2. Manufacturer's custom output values for Coefficient of performance and heating capacity at varying outdoor temperatures design with 40% glycol and leaving water temperature of 130°F

By closely examining performance for outdoor temperature conditions below the heating design-day temperature[3] of 16.5°F, all equipment lines converge within a relatively narrow COP band of approximately 2.0 to 1.7. While the heating capacities for each manufacturer follow a linear downward trend. It is interesting to note that the average heating capacity ratio at 30°F, 17°F, 10°F, 5°F, and 0°F as a quotient with respect to 47°F respectively yield 81%, 69%, 62%, 56% and 51%. This trend underscores the importance of proper AWHP sizing, as systems must be selected based on local design-day temperatures to ensure that sufficient heating capacity is available to serve the building load under the coldest expected conditions. Furthermore, projects replacing a 120-ton chiller are not necessarily a 1:1 nameplate replacement with an AWHP when also accounting for the heating load. These design situations often require larger equipment and that may increase overall project cost.

Engineering Firm Bid Itemization

Similar to a chiller installation, an air-to-water heat pump may require a level of custom-work based on the existing building's hydronic system design, which results in project-specific cost variability. Additions to the hydronic system, electrical infrastructure, buildings structural framing, and other costs not common to a drop-in replacement are considered custom work. Therefore, vendors that provide detailed itemized cost proposals immediately indicate a deeper understanding of the associated material, labor, and scope of work involved in AWHP drop-in installations. In addition, this level of scope detail enhances their credibility by reflecting stronger installation experience and more reliable project management capabilities.

In reviewing each proposal, Engineering Firms B and C provided comprehensive itemization for each line item in Table 6, including optional costs and services. While required project expenses such as the transformer were needed, other common costs such as removal, setup, and accessories were grouped into broader categories. Firms B and C's costs were within a narrow range of $401,952 to $450,315, which are subject to increase in a separate controls scope

[33] ASHRAE 1% Heating Mean-coincident dry bulb temperature for New Bedford, MA yields 16.5°F

listed as “TBD”. Firms A and D did not supply complete cost breakdowns, citing an engineering services consultant agreement contingent upon a field-visit prior to pricing. While this approach reduces the risks in presenting a blind proposal, it shifts the installed cost estimation exercise later in the process and may ultimately result in higher-than expected project costs due to unanticipated barriers. To account for this risk, Firm D assigned conservative allowances of $80,000 for controls and $138,000 in distribution and pumping components directly in the AWHP line item. This yields a total allowance of $210,000, which is technically greater than the costs provided by Firms B and C that yield respective subtotals of $72,563 and $84,500 across comparable line items respectively.

Table 6. Itemized bid review for each engineering firm representing their respective manufacturers that detail the AWHP material quote and other common costs in alignment to the statement of work for Site 1.

Engineering Firm	Firm A	Firm B	Firm C	Firm D
Manufacturer	**MFG A**	**MFG B**	**MFG C**	**MFG D**
Engineering Services				$34,900
AWHP Quote		$377,950	$317,452	$305,300
Transformer			$11,635	
Controls	$51,000	TBD	$415 + TBD	$80,000
Heat Exchanger		$22,075	$31,820	
Chiller Pumps		$20,447	$11,356	
Buffer Tanks		$8,926	$11,291	
Air Controls		$11,371	$6,236	
Magnetic Filter		$3,264	$5,729	
Glycol		$6,479	$6,018	
Total	-	$450,513	$401,952	$465,300

Ultimately Firm C was selected primarily based on its competitive cost and proven installation experience with a similar site within Eversource territory. Although Firm D provided fewer itemized details, received a lower overall score, and had a higher total cost relative to Firm B, it was selected for the second site due to product availability. This is because delivery timelines were deemed more critical to ensure that data during the 2025 heating season can be collected for measurement and verification.

Mechanical Contractor Bid Itemization

After selecting engineering firm C and manufacturer C with Site 1, a mechanical contractor specializing in plumbing, electrical controls, and other value-added services were procured through a similar competitive bidding process. The managing sub-contractor for the project solicited three vendors who detailed the itemized bid pricing in Table 7, yielding bid ranges from $899,050 to $995,500. The base cost of labor and material is consolidated in the first line item and represents approximately 80% of the total project cost for each bid. Additional expenses associated with non-standardized work scopes added to the overall costs indicated in the subsequent line items.

When considering that the engineering firm’s costs range from $401,952 to $465,300 as shown in Table 6, the magnitude of the mechanical contractor bids represents a two-fold increase. The largest variance between each mechanical contractor’s bid is the modifications to the steel dunnage, roof repairs, pipe insulation, glycol, and the three-year maintenance agreement. Each varies according to the respective mechanical contractors’ preferred materials and quality labor procurement practices. Where rigging, dunnage modifications, and roof work are specifically sub-contracted to specialty firms on a not-to-exceed basis. When considering that labor hours and material are well understood, the large variance in the other items including pipe insulation, glycol, and three-year service agreement are likely to account for hidden ancillary costs including profit, overhead, and safety allowances.

Table 7. Itemized bid review of mechanical contractor bids that include the base material and labor cost in line 1, and other unique costs and that are quoted based on time and material or procured through subcontracted services.

Description of Work	Contractor 1	Contractor 2	Contractor 3
Base: Labor and Material	$874,670	$861,500	$940,000
Pipe Insulation	$32,000	$21,500	$35,000
Electrical and Controls	$39,450	$40,100	$38,500
Structural Engineer Initial Evaluation	$9,800	$10,900	$8,500
Stamped Drawing for Dunnage Redesign	$11,000	$10,366	$9,500
Modifications to the Steel Dunnage	$4,800	$10,740	$5,000
Coring and Roof Repairs	$5,900	$9,660	$4,880
Removal + Rigging New Equipment	$26,660	$28,660	$23,500
Glycol System	—	$13,500	$19,500
Permit	$425	$500	$500
Add #1: Three-year maintenance agreement	$36,000	$27,550	$40,500
Add #2: Roof Drain	$13,620	$10,000	$15,000
Total With Maintenance	$910,670	$889,050	$980,500
Total With Maintenance and Roof drain	$924,290	$899,050	$995,500

Because the competitive bid results showed minimal cost differentiation between the mechanical contractors, contractor 2 was ultimately selected primarily based on their cost competitiveness. This selection results in a total anticipated project cost of $401,952 (from Firm C in Table 6) + $899,050 (from Mechanical Contactor 2 in Table 7) = $1,301,002. Based on manufacturer C's equipment tonnage of 105.2, this equates to $12,336 per ton,

By using the low and high $/Apt values in the Site Selection Process (Table), an estimated total cost range of $767,025 and $1,551,675 suggests that the proposal is 16% below the higher end of the scale. Which also indicates that the bids align within a reasonable margin but are at the higher end due to the identified barriers in the early project planning stage. Moreover, identifying buildings with minimal barriers and compatible hydronic equipment may improve overall project costs and subsequently cost-effectiveness.

Overall, the bid process began on December 3, 2024, and ended on March 11, 2025, for a duration of 98 days.

Project Timeline and Implementation Barriers

The project site selection effort was initially launched on October 15, 2024, with an anticipated installation window during the spring shoulder season of program year 2025 to enable heating and cooling operational data collection by year's end. However, installation did not begin until November 18, 2025, and completion is now expected in the spring shoulder season of 2026. This was due to numerous project delays and setbacks during the selection process for both the building and vendors, as well as delays in the construction process, and shipping the product overseas. As a result, total costs to date have added $149,355 for a total cost of $1,450,357, which equates to a 11.5% increase, and placing the project 6.5% below the higher end on the initial project estimation scale. If the step-up transformer and the dunnage reinforcements were not identified in early project planning, this would then equate to new cost to date of $192,996, representing a 15.3% increase. Some of the key factors that increased costs and delays are described as follows:

Voltage Requirements

Although a thorough site-selection process was conducted to avoid major electrical barriers, Site 1 had a minor voltage mismatch identified early in the project planning phase. The building utility connection provides 120/230-volt service, but the AWHP equipment requires 460-volts. The solution to this mismatch was to install a dedicated step-up transformer downstream of the customer's switch gear. This should not be mistaken with a utility transformer upgrade which involves replacing the building's primary transformer on the utility service line.

The material and labor costs were anticipated early in the project and were included in the initial RFP. Table 1 lists the Transformer's material cost at $11,365, while Table 2 outlines the mechanical contractor's overall electrical and controls wiring allowance of $40,100. Where final installation costs and labor hours will be available upon project completion.

Structural Modifications

The existing dunnage for the old chiller was measured at 8 feet in length, which is insufficient for the new AWHP equipment footprint measuring 9 feet and 6 inches. To accommodate the larger footprint, an additional 1 foot 6 inches of structural dunnage is required. To improve upon the inadequate existing structural support, the mechanical contractor procured a structural engineering firm to perform the necessary inspection and evaluation of the dunnage. They provided a stamped engineering design for the support, and the mechanical contractor subcontracted steel workers to purchase materials and build the modification to the existing dunnage. Table 1 lines 4 through 7 detail a total dunnage structural reinforcement allowance of $41,666. Although these costs were originally anticipated early in the project planning phase, modifying and inspecting the dunnage underscores a critical barrier that most stakeholders are unaware of, and can be cost-prohibitive depending on current building conditions.

Given that the building served as a historic mill, it was assumed that the existing floor structure would provide sufficient load bearing capacity, with some minor reinforcements. However, following an assessment with the sub-contracted structural engineer, it was identified that the second-floor mechanical room required significant reinforcements to accommodate the additions to the new hydronic equipment supporting the AWHP. The wet weight of the buffer storage tanks (3,900 lbs.) and heat exchanger (4,200 lbs.) total 8,100 pounds. Therefore, a change-order was requested and approved at an additional $63,015 and the project was further delayed by an additional 5 weeks.

Although the existing equipment has a gross weight of 7,690 lbs. and the new AWHP equipment weighs in at 8,420 lbs., this marginal increase did not initially raise concerns relative to the roof support in early planning and did not lead to consideration for additional structural reinforcements; as the building had been supporting the previous load. However, after completing structural reinforcements in the mechanical room, structural engineers discovered that the original dunnage footing did not align with the building's supporting structural columns. As a result, the roof support for the new AWHP equipment then required further structural evaluation, redesign, reinforcements, and an entirely new structural dunnage would need to be constructed to ensure proper load transfer and compliance with building code requirements.

Therefore, an additional change-order was approved for an additional $55,590, and the project was further delayed.

The total cost for the additional structural engineering, inspection, and additional construction amounts to $149,355.

Project Communication

The mechanical contractor did not coordinate effectively with the steel worker's schedule. As a result of the poor coordination, when the equipment was ready to be placed on the roof, the project was delayed for an additional week because the steel workers were not yet available to perform their work. In the interim, both the mechanical contractor crew's and the subcontracted crane lift service waited idly incurring $2,520 per day to the project, pending the steel worker arrival.

Mechanical Affidavit

Although the mechanical contractor provided allowances for the project and performed all construction related activities within the statement of work in parallel, a critical permitting step further delayed progress. Within jurisdiction of the city officials and building inspectors office, they had requested a mechanical affidavit be issued after significant work has been performed. It is uncertain as to what triggered this additional regulatory requirement and how this critical step was not identified by the mechanical contractor in early stages of planning. As a result, the cost of issuing and filing this document required an approved change order of $15,000, and the project was delayed by an additional week.

Conclusions

The field study presented in this paper demonstrates both the promise and practical complexity of deploying (AWHPs) as a drop-in or minimally invasive replacement for aging chiller and boiler systems in multifamily buildings. While the technical performance of AWHPs is well understood in similar studies, this process revealed a wide array of market barriers that must be addressed before this technology can scale meaningfully in multifamily buildings across the income-eligible and market-rate programs in Massachusetts.

The site-selection phase highlighted that only a small subset of candidates possesses the right building-equipment characteristics in equipment age, hydronic compatibility, electrical infrastructure, structural readiness, and regulatory conditions. Among 12 down selected candidates from a program population of 68, nearly all were limited by inadequate switch gear infrastructure, transformer upgrades, and strict compliance to local ordinances especially in densely urban areas. As a result, the market potential is large but not uniformly accessible. However, the site selected in this field study benefited from low temperature hydronics and adequate roof access which illustrate the importance of building characteristics to reduce the need for invasive and costly upgrades.

In the competitive engineering and contractor bidding process, there were valuable insights into cost structure and market maturity. While equipment pricing across manufacturers was relatively consistent, cost variability in additional work for hydronics, structural reinforcement, controls and other items revealed that AWHP retrofits depend heavily on building-specific constraints. The final project cost was originally estimated at $1,301,002, consisting of the engineering firm's bid of $401,952, and the selected mechanical contractors bid of $899,050. However, actual costs grew to date $1,450,337 due to structural reinforcement challenges that could not have been discovered in the early planning process.

Subsequently, these challenges incurred significant project delays that extended an anticipated installation and commissioning timeline in the spring shoulder season of 2025 to mid-summer season of 2026. While delays in shipping were a major bottleneck, structural related construction delays equally increased timelines. Three separate rounds of structural assessments and stamped engineering drawings were set off like dominoes, where each instance required a 5-week lead time that compounded delays throughout the process. These disruptions underscore the need for an engineering-design build process that combines the engineering firm and mechanical contractors under one integrated team to design and build the AWHP in a more efficient and coordinated manner. In addition, a more comprehensive structural evaluation conducted at the outset of the study would have mitigated many of the unforeseen challenges.

While installation of the selected system is still underway, the lessons learned to date emphasize that AWHP retrofits are feasible but not turnkey. They require careful coordination among engineers, mechanical contractors, manufacturers representatives, and program administrators in conjunction with building owners to align expectations on cost, timelines, and operational performance. Once operational, this system will provide a real-world test case to evaluate heating performance, optimize outdoor switch over temperatures, and monitor efficiency under monitored conditions that will be invaluable in reimagined statewide electrification strategies.

Some best practices for project implementors are considered:

- Locate buildings with
- Identify buildings with a near end-of-life chiller and mechanical room situated on the ground floor or basement of the building, accommodating accessibility for heavy construction and transportation vehicles.
    - Constructed after 1970's to minimize discovery of key barriers including but not limited to lead and asbestos.
    - Adequate electrical infrastructure and front-of-the-meter service capacity.
        - Inspect building electrical infrastructure including switch gears and transformers for, capacity, breaker size, and feeder size at point of audit.
    - Compatible hydronic equipment to reduce project costs in interior remodeling, renovation, and removal of incumbent radiators and fin-tube baseboards.
    - If preferable install equipment on the exterior perimeter of the building while taking into careful consideration local ordinances for noise compliance, proximity to property lines customers' concerns with property aesthetics, and overall public interaction and safety.
    - If installing on the roof with mechanical room above ground level, strongly consider structural inspection efforts for the dunnage and mechanical room before executing implementation schedule.
- Submit a comprehensive bidding plan for engineering-design-build services agreed upon on a not to exceed basis with generous allowances for pop-up service costs. Also instruct vendors and sub-contractors to subsequently bill services based on time-and-material.
    - Require stamped engineering plans, permitting schedules, and implementation schedules with recovery timelines.

- Avoid technical sizing equipment using general-rule-of thumb and utilize baseline measurement and verification to avoid over- under-sizing equipment.
    - Require detailed energy modeling using bin temperature methodology to determine initial project savings and customer utility billing impacts.
- Evaluate project cost in Massachusetts using $/Apt range of $10,227 to $20,689 in early bid assessment where higher costs require greater scrutiny on cost-effectiveness.
    - Upfront planning of additional service cost's for out-of-scope work and change orders due to remediation of key barriers.

References

ASHRAE. n.d. ASHRAE Climatic Design Conditions. https://ashrae-meteo.info/v3.0/

EIA. 2024. Massachusetts Electricity Profile 2024. https://www.eia.gov/electricity/state/massachusetts/

EIA. 2025. Massachusetts Natural Gas Prices. https://www.eia.gov/dnav/ng/ng_pri_sum_dcu_sma_m.htm

Guidehouse. 2022. Census of Multifamily Buildings: MA12E34-B-MFCEN. https://ma-eeac.org/wp-content/uploads/MA21R34-B-MFCEN_Full_Report.pdf

MassSave. 2024. Energy Efficiency and Decarbonization plan. https://ma-eeac.org/wp-content/uploads/FINAL-MA-2025-2027-Plan-09-25-24-v2.pdf

U.S. Census Bureau. n.d. "Year Structure Built," *American Community Survey, ACS 1-Year Estimates Detailed Tables, Table B25034*, https://data.census.gov/table/ACSDT1Y2024.B25034?q=B25034&g=040XX00US25.

U.S. Census Bureau. n.d. "Units in Structure." *American Community Survey, ACS 1-Year Estimates Detailed Tables, Table B25024*, https://data.census.gov/table/ACSDT1Y2024.B25024?q=B25024:+UNITS+IN+STRUCTUE&g=040XX00US25.

Winn. n.d. WinnCompanies Five Years of Impact Report 2025. https://book.winncompanies.com/impact-report-2025

AI Disclosure

AI-assisted tools used: Microsoft Copilot
Used for: Editing
Extent: Light editing on selected paragraphs
Human review: The authors reviewed and verified all content, calculations, and citations.