Super-Efficient Room Conditioners as a Multifamily Market Mover

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ABSTRACT

In December 2021, a coalition of New York State organizations—New York City Housing Authority (NYCHA), New York State Energy Research and Development Authority (NYSERDA), and New York Power Authority (NYPA)—launched the Clean Heat for All (CH4A) Challenge, a market competition for manufacturers to design and develop an efficient, easy-to-install, packaged, window-mounted heat pump to serve space conditioning needs in NYCHA buildings. The competition was designed to support New York State, City, and NYCHA decarbonization goals and help facilitate the transition away from fossil fuel-based heating, while enabling the development of a new heat pump electrification product category suited to existing multifamily buildings.

In July 2022, two manufacturers, Gradient and Midea America, were awarded seven-year contracts to produce 30,000 window heat pump units. These units are saddle-style window-mounted heat pumps capable of 9,000 BTU heating and cooling performance and operation down to -13°F without the use of electric resistance heating. Additional product features include compatibility with a standard 120VAC/15A outlet, use of low global warming potential refrigerant, a self-contained condensate management system, and smart controls with BACnet compatibility.

This paper reports results thus far from the Demonstration Phase of the Clean Heat for All Challenge, with a focus on observed usage, tenant satisfaction, performance against CH4A challenge specifications, and energy and cost savings. These key findings from the Demonstration Phase are reported in addition to projected impacts as additional housing authorities, utilities, and other end-use stakeholders adopt, incentivize, and/or install these window heat pumps. This paper also details related market transformation efforts including an Efficiency Vermont pilot program and ongoing work by the Consortium for Energy Efficiency to develop a performance specification for window heat pumps.

Background

New York State's nation-leading climate agenda calls for an orderly and just transition to clean energy that creates family-sustaining jobs, continues to foster a green economy across all sectors and ensures that at least 35 percent, with a goal of 40 percent, of the benefits of clean energy investments are directed to disadvantaged communities.

With an overarching state goal to reduce emissions to 40 percent below 1990 levels by 2030, and then 85% by 2050, the Climate Leadership and Community Protection Act (CLCPA) guides New York on a strict and impactful trajectory (NY State 2019). Part of this plan includes a mandate of a zero-emission electricity sector by 2040, including 70 percent renewable energy

generation by 2030, and to reach economy wide carbon neutrality. The plan also includes certain stipulations to direct no less than 35 percent of the program's benefits to historically disadvantaged communities based on several determinants related to "public health, environmental hazards, and socioeconomic factors" and decided by the newly created Climate Justice Working Group.

In 2019, New York City passed local law 97 (LL97) which committed NYCHA to reducing its greenhouse gas emissions (GHG) 80 percent by 2050 (New York City Council 2019). This goal can only be realistically achieved through rapid space and water heating electrification, which account for most of NYCHA's emissions. NYCHA's current five-year capital plan commits approximately $1.9 billion to heating system replacements and upgrades. Many of these replacements are still in-kind steam plants; however, NYCHA is also allocating a significant portion of this commitment to electrification and intends to greatly expand this effort in the next 5-year capital cycle beginning in 2024.

NY Clean Heat for All Challenge

In support of New York State's climate goals, state authorities have joined forces to collaborate on initiatives to incentivize and aid surrounding communities taking part in reaching these goals. One of these efforts, the New York Clean Heat for All Challenge (CH4A), was created by NYPA, NYSERDA, and NYCHA and aimed at developing a new electrification product that could better serve the heating and cooling needs of existing multifamily buildings and hasten the transition to fossil-fuel free heating sources (NYSERDA 2022).

As multifamily buildings across New York state consider converting to air source heat pumps (ASHP) from steam boiler systems, many will hesitate to do so because of the high cost and major disruption associated with installing split systems. The need to penetrate the exterior walls, roofs, and floors to run refrigerant line sets and condensate drains, the additional cost of soffits for the interior line set runs, the exterior space required for outdoor units, and the requirement of 208 VAC operation are just a few of the many barriers to conversion. Add to these the likely future shortage of capable HVAC technicians, and the potential for refrigerant leaks (and their corresponding GHG harm) the problem becomes almost impossible to address cost-effectively in multifamily applications.

While improved Packaged Terminal Heat Pump (PTHP) technology is promising for buildings with existing Packaged Terminal Air Conditioning (PTAC) sleeves, many more buildings do not have this option and will face prohibitively high barriers to installing Variable Refrigerant Flow (VRF) or smaller residential-type split systems. Given these issues, it became clear to NYPA, NYSERDA, and NYCHA that a new type of heat pump solution was needed to ensure that all buildings can afford a heat pump conversion.

To incentivize the creation of this new residential heat pump solution, the state authorities utilized a challenge format for manufacturers to partake in, allowing them to showcase innovative design and efficiency. In doing so, they have sought out a new product to not only minimize these issues but transform electrification markets going forward.

The Clean Heat for All challenge ultimately seeks to improve the performance and value proposition of heat pump technologies by accelerating the development and commercialization of a new-to-market product. The solution NYPA, NYCHA and NYSERDA sought out through

this partnership is a standalone, unitary Packaged Window Heat Pump (PWHP) that can be installed in occupied apartments with limited resident disruption and does not require extensive refrigerant piping, major electrical upgrades, or skilled labor to install.[1] The units developed as part of this challenge are intended to be broadly applicable beyond NYCHA-operated buildings. As another goal of the CH4A, PWHPs are generally well suited for existing occupied buildings in cold climates that must rapidly decarbonize by electrifying their heating systems and replacing existing fossil fuel heating systems.

Costs of electrifying through other retrofit initiatives in New York can be very expensive as building owners mostly choose to implement mini-splits or VRF systems. This equipment requires professional installation and structural change to dwelling units and occupies more physical space in or on buildings. Typically used for larger commercial spaces, the equipment can cost tens of thousands of dollars more per apartment. For example, a recent NYPA project converting a twenty story, 159-unit NYCHA building from a low-pressure steam boiler system to a centralized VRF system cost about $20 million dollars. If this project had utilized PWHPs at a cost of roughly $3,000 per unit and 3 units per apartment, the total equipment cost would be around $1.5 million. As such, PWHPs can serve as a lower cost, turnkey solution for multifamily buildings as most dwelling units and their individual rooms are small. PWHPs require no permanent or professional installation and minimally obstruct rooms and windows.

Project Timeline

The Clean Heat for All Challenge consists of four major phases: the request for proposal (RFP) Phase, Development Phase, Demonstration Phase and Full Purchase Order/Production Phase. The project timeline and a summary of activities included in each phase is summarized in Figure 1.

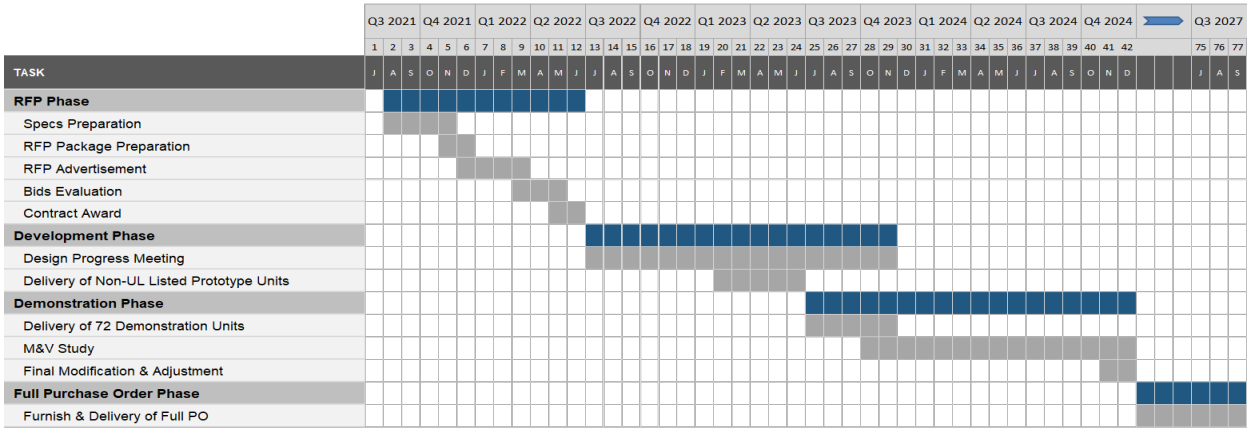

Figure 1. New York Clean Heat for All Project Timeline.

[1] This technology will be referred to by several different names in this paper including PWHP, room heat pump, and super-efficient room air conditioner. Other parties have also referred to these products as window heat pumps, micro heat pumps, or portable heat pumps. As of the time of writing, there is not a specifically agreed upon product category name.

During the initial RFP phase, NYCHA, NYSERDA and NYPA collaborated to refine the heat pump specification and evaluation criteria, which provided more details to manufacturers and allowed for flexibility in the proposed solutions. These criteria were made available in the CH4A RFP. While the full specification criteria included in the RFP are expansive, there were several core requirements that proposals needed to meet in order to effectively realize CH4A's goals:

- Full replacement for window AC
- No drilling, running of refrigerant lines, or drainage (internal condensate management)
- No electrical service upgrade required
- No specialized labor needed for install
- <$3,000/PWHP purchase price
- Cold climate HP performance down to 0°F without resistance heat
- Run at 115 VAC +/-10%, single phase, 60 Hz, and plug into a standard 3-prong outlet, 15 amp
- Capacity of 9,000 Btu/hr heating (+ 0 Btu/hr / - 700 Btu/hr, in other words 8,300- 9,000 Btu/hr) at 17 °F outdoor temperature and 70 °F indoor temperature
- Maximum time to install a unit: 2 hours

These core criteria ensure that any winning product could fully electrify the space heating and cooling of an apartment in a NYCHA building in an efficient and minimally invasive manner. One particularly important criterion is the requirement for internal condensate management. Given the intended application of these PWHPs and the RFP requirement that installations will provide no plumbing or drilling, meeting the challenge of internal condensate management was of the utmost importance. Unlike the room air conditioners that the PWHPs are replacing, the condensate could not be allowed to drip outside due to safety and performance concerns during the heating season.[2] While both winning proposals were able to address this need, they chose different ways to achieve the internal condensate management, the exact mechanisms of which are currently confidential.

Outside of the key criteria, the RFP also detailed additional design targets that manufacturers could earn additional points for achieving during the evaluation process. These included points for low GWP refrigerant, BACnet compatibility, and a shape that minimized light obstruction, among other criteria.

The RFP required manufacturers to submit a detailed product narrative, technical submittal, fixed unit price and a schedule for product development. An evaluation committee, composed of representatives from NYCHA, NYSERDA, and NYPA, as well as technical advisors from the energy efficiency industry, was formed to review and score the proposals. The evaluation criteria included Minimum Requirements and Additional Design Targets. In order to be considered, manufacturers had to demonstrate, through their RFP response, that the proposed product met all the Minimum Requirements. Qualified products were then scored by the Evaluation Committee based on the scoring criteria described in the Additional Design Targets.

[2] Safety concerns due to the freezing of condensate on sidewalks below NYCHA buildings and performance concerns due to the freezing of dripped condensate on other units installed in lower floor windows.

During the RFP phase, NYPA also approached the Consortium for Energy Efficiency (CEE) to help solicit manufacturer proposals, a similar role that CEE had played in the late 1990's to secure and promote a new-to-the-market, super-efficient apartment-sized refrigerator through the CEE Super-Efficient Apartment Refrigerator (SEAR) Initiative. The SEAR effort had resulted in the production of a refrigerator that was 30 percent more efficient than standard and at a lower price point, enabling housing authorities across the United States to take advantage of a bulk price purchasing terms under a solicitation administered by NYPA. These efforts resulted in hundreds of thousands of installations of these highlight efficient refrigerators, an outcome that the CH4A challenge is aiming to imitate.

After being approached by NYPA, CEE developed the CEE Super-Efficient Room Conditioner Initiative, which was published in 2022 (CEE 2022). This Initiative is aimed at overcoming heat pump installation barriers in multifamily buildings and enables CEE member utilities across the United States and Canada to encourage the availability and promotion of easily installed, efficient room heating and cooling units. As part of this Initiative, many CEE member utilities have expressed their support for the PWHP product type and may choose to purchase the awarded units, promote the adoption of the units in their own service territories, and partner with local housing authorities to advance equity and electrification in the multifamily sector.

Due to the collective efforts of all parties during the RFP phase, the project attracted a total of six proposals for the new-to-market PWHP. As part of the submission review process, scorecards and slides were created for review by the evaluation committee. Online interviews were also conducted with each manufacturer that submitted a proposal. At the end of the review process, two proposals stood out among the rest: Midea America and Gradient. Each of their proposed products met all minimum requirements set out in the RFP and received the highest evaluation scores, meeting several of the additional design targets as well. As a result, Midea America and Gradient were awarded seven-year contracts to supply 20,000 and 10,000 units respectively.

Upon receipt of the award, the development phase of the project began, in which Midea and Gradient were given up to 12 months to develop the proposed product and produce units for testing and demonstration. Although the proposed products from the two manufacturers have different performance specifications, they share the following product highlights:

- Cold climate inverter heat pump technology with operation below 0°F
- 9,000 BTU/hr for heating and cooling
- No auxiliary resistance electric heater
- Inverted-U configuration[3]
- Variable window depth
- Full functional on a standard 120 VAC 15 A outlet
- Variable speed compressors/fans
- R-32 Low Global Warming Potential (GWP) refrigerant
- Internal condensate pump
- Window seal design that has a minimal impact on envelope performance

[3] Also referred to as saddlebag or saddle style. This design reduces window obstruction and minimizes the internal footprint of the unit.

Following the development phase, the demonstration phase of the challenge officially began in July 2023, with the installation of 36 Midea units in 12 apartments at NYCHA's Woodside Houses in Queens, New York. Approximately five months later, the installation of 36 Gradient units into 12 apartments was completed at the beginning of December 2023. For the typical two-bedroom apartment in the Demonstration Phase, units were installed in each bedroom and the living room, leaving the kitchen and bathroom without units. The installation was completed by NYCHA's maintenance group with the assistance from the manufacturers' technicians. Both manufacturers provided installation and maintenance manuals for the installation process. In preparation for the installation, NYCHA's electrician installed dedicated circuit breakers and outlets for the heat pump units. This ensured that installed units wouldn't overload any circuit that is daisy chained (as some circuits are in NYCHA housing). Each unit is plugged into a dedicated outlet and is being monitored individually. Photos from the installation process can be seen in Figure 2.

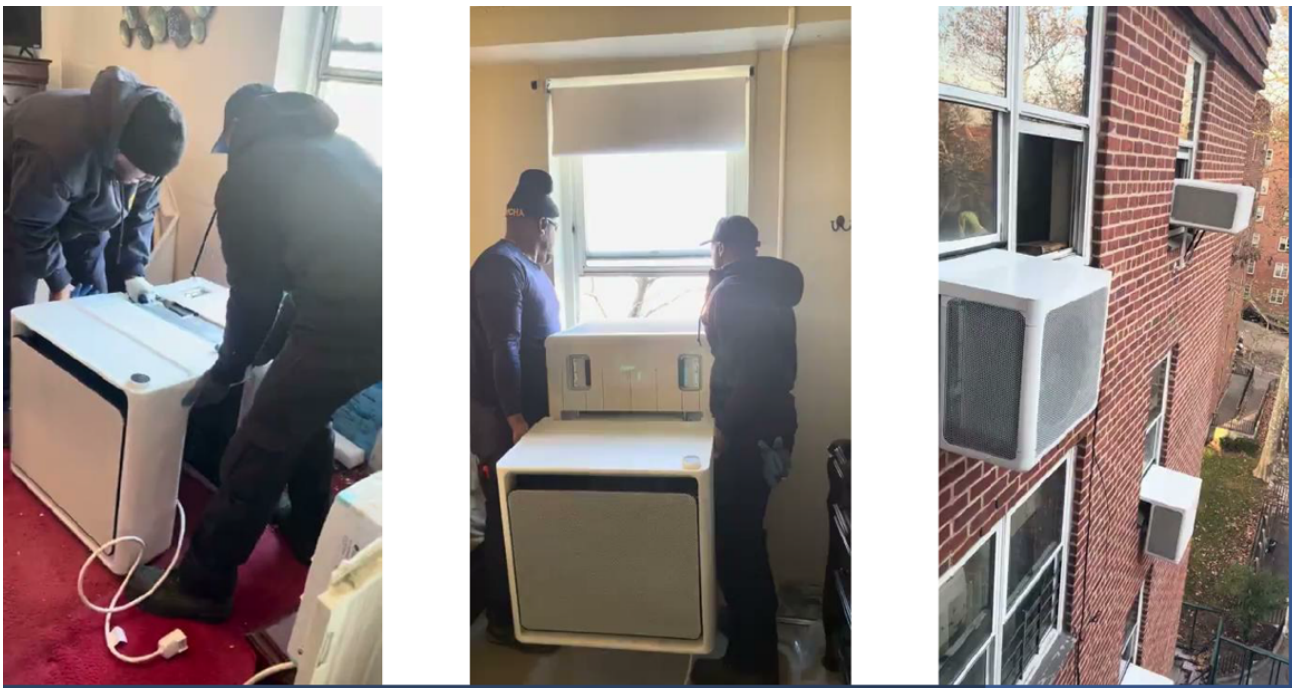

Figure 2. NYCHA maintenance crew installing units and an exterior view of the installed units.

In general, the installation process went quite smoothly for both the Midea and Gradient units. Both companies' units were installed within a 3-day period, averaging about 12 units a day. During the installation, the most common issue encountered was related to ensuring proper insulation around the window. However, these issues were relatively minor and initial tenant reactions to the installation of the units were positive. The most consistent feedback received from tenants was that the units were very quiet and sleek looking. Although the M&V study is still on-going, preliminary data from the installed units shows that the units can consistently maintain the room temperature setpoints, ensuring tenant comfort and health even on the coldest days.

One of the most interesting and unexpected aspects of the demonstration phase so far has been observing how tenants interact with the units. While both Midea and Gradient units have BACnet mesh capabilities and could be controlled via a building management system, the demonstration phase is not assessing the BMS integration of these units and tenants are allowed to control their own units, leading to various usage patterns. Although NYCHA staff have talked to tenants and recommended that units be put in Auto Mode and always kept on, some of the tenants have taken to turning the units on and off based on their needs. The usage patterns are also unrelated to utility bills as NYCHA supplies and pays for all heating and hot water across its portfolio. While other tenants have even utilized the cooling mode during the winter.

As part of the installation process, temperature data loggers were installed in bedrooms, living rooms, kitchen, and bathrooms. These loggers should provide an understanding of how the warm air flows through and permeates the apartments. Of particular interest is how the temperature of the kitchen and bathroom, which have no unit installed, fluctuate. In addition to temperature loggers, eGuage power monitoring devices were installed at the circuit breakers in the apartment to monitor each unit's power consumption. On the building level, the same eGuage devices were installed to monitor the overall power consumption at the electrical riser level to make sure the total peak demand is within safe range. The electrical data shows that the peak demand during the coldest days is higher than the summer peak (cooling has been provided by room air conditioners traditionally) prior to the installation. That said, the peak load is still under the current riser capacity and, when these units are installed in other NYCHA buildings they will not exceed existing capacity.

As the demonstration phase continues and additional data is collected, the data will be utilized by a third-party consultant to conduct a comprehensive Measurement and Verification (M&V) study for both Midea and Gradient units. The M&V study will include air infiltration evaluation, temperature and humidity monitoring, performance and efficiency evaluation, unit noise levels testing, unit condensate management assessment, and a tenant experience survey. PWHP units and their performance will also be fully evaluated against the RFP specifications and manufacturers' proposal specifications. At the end of the demonstration phase or when enough data has been collected to properly assess the performance of the demonstration units, the M&V consultant will submit a final M&V report to NYPA, NYCHA and NYSERDA.

At the time of writing, the demonstration phase is still ongoing and, while the M&V report is not finalized, preliminary feedback and results have been largely positive. Assuming this trend is reflected in the final M&V reports, the project will move to its final phase, the Full Purchase Order Phase. In this final phase, the remainder of the agreed number of units will be procured with NYPA reserving the right to procure more units at the contract price. The full purchase order agreement will also include a price match guarantee, whereby other entities not in privity to the agreement can purchase units from the Vendor at the same price offered to NYPA. This clause allows for utilities and housing authorities to secure PWHPs for their own service territories and buildings, a substantial opportunity to electrify and decarbonize multifamily buildings across the United States and Canada.

Supportive Market Transformation Efforts

Efficiency Vermont Pilot

As the CH4A Challenge began its work with this new product type, it quickly caught the attention of several parties and jurisdictions who have been working on similar heating electrification challenges to New York. One such entity - Efficiency Vermont, Vermont's Energy Efficiency Utility, became extremely interested in this innovative solution and developed a parallel pilot to CH4A to test the viability of PWHP in low-income multifamily rental housing. The goal of this pilot is to test how this product category performs in this population from a DIY perspective, truly negating the need for professional installation and its associated costs.

Residential rental properties have long been a difficult to serve population in demand side management programs (Rotmann et al. 2020). Building owners are often apprehensive about making electrification improvements to their properties as they often do not result in increased profitability from these properties. Renters are also unlikely to make these improvements. Even if building owners provide permission for renters to make improvements, renters are apprehensive to make significant improvements to a property they do not own. As a result, rental properties have long lagged behind owner-occupied properties. Combined with the fact that a high percentage of low to moderate income people live in rental housing, this additionally becomes an equity concern.

Efficiency Vermont saw the PWHP product category coming out of the CH4A as a potential solution to this issue. These products' portable nature creates an opportunity for renters to invest in electrification without making permanent modifications to the building and enables the tenant to take their investment with them when they move. PWHPs also appear to be a relatively inexpensive electrification option. However, the bulk of the cost savings compared to ductless mini-splits (the predominant heat pump equipment type being installed in Vermont housing) is from eliminating the need for a professional contractor for installation (a substantial portion of the cost associated with heat pumps). Efficiency Vermont therefore saw the portability and DIY components of the PWHP as potentially transformative to this market.

Efficiency Vermont is in discussion with both Midea and Gradient, the two awardees of the CH4A Challenge to install 30 PWHP units in low-income multifamily rental housing. Selected participants for the pilot are sent a PWHP unit at no cost. The product is drop-shipped to the customer as any other product from an online vendor would arrive. Participants are then responsible for completing the installation on their own. They can use friends and family (encouraged as these units are heavy, requiring two people to lift), but not professional help. Following installation, a representative of Efficiency Vermont will visit the home to check on the installation and to install a plug-load meter to capture energy consumption and usage patterns of the unit. Participants will be surveyed/interviewed twice during the pilot. The first will occur within two weeks of the installation. The focus of these questions will be to understand how the installation went and gauge initial customer reaction. The second round of questions will occur toward the end of the pilot (12 months from installation). These questions will be focused on how the participants felt about the PWHP and how they used it.

Pilot Participant Characteristics:

- Renters (required)
- Building has single/double hung window in living space to outdoors (required)
- Renter pays for their own heating (required)
- Low Income (preferred, moderate income considered)
- Multi-family (preferred, single family considered)

Establishment of a Test Procedure for Heating Mode Performance

While other utilities aside from Efficiency Vermont are planning PWHP pilots, other market players have also been similarly intrigued by the CH4A PWHPs and have been actively working to address other aspects of the emerging PWHP market. Specifically, ENERGY STAR and CEE have both been actively looking to assess and specify the efficiency of these new-to-market units.

In previous iterations of federal test procedures for room air conditioners (RACs), the relative lack of RACs with reverse cycle capabilities led the US Department of Energy (DOE) to set room air conditioner energy conservation standards based on the Combined Energy Efficiency Ratio (CEER) metric in accordance with the DOE test procedure for room air conditioners at Appendix F to 10 CFR 430 (DOE 2023). As such, current standards referencing Appendix F for RACs only capture the cooling mode energy consumption including ENERGY STAR RAC Specification Version 5.0 (ENERGY STAR 2023). While these current standards set out CEER performance levels for units with reverse cycle, there is no current methodology to assess the heating efficiency of these units.

Although the market for reverse cycle RACs is still largely nascent, the vastly improved heating efficiency of the units created for CH4A has caught the attention of both DOE and ENERGY STAR as well as the Consortium for Energy Efficiency and its members. As these products are assessed during the CH4A demonstration phase and are likely nearing larger market availability in the next calendar year, ENERGY STAR and DOE are working to create a new heating mode test procedure for room air conditioners with reverse cycle (room heat pumps).

As this paper is written, ENERGY STAR has released the final draft of their heating mode test procedure (ENERGY STAR 2023a). This draft was released in April of 2024 and details a test procedure to assess a unit's Heating Energy Efficiency Ratio (HEER), a new metric that captures the heating efficiency of room heat pumps (room heat pumps are defined as RACs with reverse cycle capabilities in the test procedure). HEER is a seasonal metric, and the test procedure also allows for testing at specific temperatures, capturing the coefficient of performance (COP) at 47ºF, 17 ºF, and 5ºF (renamed from $HEER_{47}$, $HEER_{17}$, and $HEER_5$ in the first draft). _

In addition to establishing the HEER metric, the ENERGY STAR draft also establishes various definitions for room heat pumps. In the final draft test procedure, there are four types of room heat pumps that are defined: Type 1, 2, 3, and 4. A type 1 RHP is defined simply as a unit that does not have active defrost or for which the specified compressor cut-in and cut-out temperatures are not both less than 40°F. A type 2 RHP is defined as a unit that has active defrost, and for which the specified compressor cut-in and cut-out temperatures are both less than 40°F but not both less than 17°F. A type 3 RHP is a unit that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less than 17°F but not

both less than 5°F. Finally, a type 4 RHP is defined as unit that has active defrost and for which the specified compressor cut-in and cut-out temperatures are both less 5°F. These definitions largely correlate with the original mild, cool, and cold climate definitions in ENERGY STAR first draft (with the addition of the type 2 distinction) and describe the regions and climates that RHPs are best suited for.

As ENERGY STAR and DOE work to incorporate comments on the final draft test procedure, the Consortium for Energy Efficiency has been actively involved in discussions with its members to establish a performance-based specification for room heat pumps. CEE intends to reference the finalized ENERGY STAR test procedure, which is anticipated in June of 2024, in its specification, establishing a heating efficiency standard utilizing HEER. As such, CEE's specification will likely be released for industry comment in the weeks following the publication of the final ENERGY STAR test procedure with the goal of finalizing the specification in the summer of 2024.

CEE Development of a Binational Voluntary Specification for Room Conditioners

A large aspect of the impetus for CEE's work on this specification is to meet the timeline established by the Inflation Reduction Act which establishes 25C tax credits (Energy Efficient Home Improvement Credits) linked to CEE's residential energy efficiency specifications. For a model to receive tax credits in a given calendar year, they need to meet the CEE specification that is in effect on January 1st. Given the market potential for these room heat pumps and CEE member interest in the technology, particularly for electrifying and decarbonizing the multifamily sector, CEE and its members are working to help accelerate the market adoption of these units by establishing a performance-based specification that will likely enable these units to receive tax credits in 2025. Additionally, this CEE specification can be adopted by any of its utility members to establish additional incentives for these units on top of the tax credits, reducing the overall costs significantly and improving the value proposition for renters and low to moderate income consumers. While there are several factors at play and this specification is not guaranteed to be approved by CEE's Board or in effect by 2025, the specification development process is progressing as expected so far. As these efforts continue, utilities, housing authorities, renters, and other interested parties will have increased confidence in the technology and increased access to rebates and incentives, drastically improving the value proposition of these packaged window heat pumps.

Market Opportunities

The CH4A PWHP solution presents a cost-effective electrification approach for multifamily and single-family buildings that currently have window air conditioners for cooling and steam or hot water systems for heating. This is a common building-type in New York State and especially in New York City, where 75% of multifamily units have window air conditioners and central hydronic heating systems. The CH4A PWHP would allow these units to electrify for $6,000-$12,000 per apartment, depending on number of rooms, and would not entail specialized labor or contractors to install. The PWHP presents a promising alternative as opposed to current

electrification solutions (mini-splits and VRF), which can cost up to $50,000 or more per apartment and for which installation is disruptive to tenants, entails extensive installation work, and sometimes involves asbestos and lead abatement when installation involves drilling through walls.

Looking ahead at future demand, NYCHA estimates a need for approximately 156,000 units over the next five to ten years in its efforts to meet New York City and State mandated emissions targets. NYCHA provides affordable housing to 358,675 authorized residents in over 168,100 apartments throughout the five boroughs of New York City through the conventional public housing program. Together, NYCHA public housing residents and Section 8 voucher holders (low-income residents in the Federal Housing Choice Voucher Program) occupy 11.6% of the city's rental apartments. Of NYCHA's 285 developments, 60% are fifty years old or older and 100% of NYCHA's cooling is currently provided by resident-owned window air conditioners.

As these products begin to proliferate in the market, their potential impact is substantial. New York State alone offers a large market of both low-to-moderate-income and market-rate housing with several million multifamily units, as well as potential applications for these units in commercial buildings. Additionally, these new type of heat pumps could be used for net zero carbon retrofits under NYSERDA's Affordable Housing Agency partnerships and "direct injection" incentive programs with NYS Dept. of Homes and Community Renewal (HCR) and NYC's Dept. of Housing Preservation and Development (HPD). Through the RetrofitNY Pledge, building owners have already pledged to install cost effective net zero retrofit solutions in over 400,000 dwelling units when they become available.

Beyond NYCHA and New York State, such a product would be broadly applicable to existing occupied buildings in cold climates that must rapidly decarbonize by electrifying their heating systems, particularly for large portfolio managers and owners. According to a survey conducted by the Department of Housing and Urban Development and the U.S. Census Bureau (2021), approximately 38.5 million residences, or approximately 30 percent of housing in the U.S. today, are multifamily and would likely benefit from these PWHPs. Buildings that lack central cooling, and which presently meet cooling needs using window ACs would also be well suited for electrification using this type of packaged heat pump. According to the 2020 Residential Energy Consumption Survey (RECS) fielded by the US Energy Information Administration (EIA), a total of 24.1 million residences (20 percent of all residences) in the US had individual air conditioning units including window, wall, or portable units installed as their primary method of air-conditioning (EIA 2024). Another 7.2 million households utilize these units for secondary air conditioning. On the heating side, 42 percent of US households supplement their heating with secondary equipment with 25 million households utilizing portable electric heaters for secondary heat. Another 3 million households utilize portable electric heaters for their primary heating.

PWHPs can also play a crucial role in enabling a more equitable climate transition. In multifamily buildings, utility costs are often the largest variable operating expense and efficiency measures are far less likely to be installed in multifamily rentals than in any other type of housing, leaving significant energy savings unrealized and excluding millions of tenants from the clean energy transition. If cost-effective energy efficiency upgrades were performed in the top 25 percent of multifamily energy users, it is estimated that multifamily sector energy usage across

the United States could be reduced by 17 percent and save around $3 billion in total utility costs (Samarripas and Tanabe 2020). Across all residential buildings, space heating accounts for around 42 percent of energy usage, further amplifying the transformative potential of PWHPs (EIA 2023).

Conclusion

As local, state, and federal regulations increasingly strive for decarbonization through efficient electrification, various heat pump solutions and configurations can help support the transition to a carbon neutral economy. The CH4A PWHP emerges as a promising turnkey solution for both single and multifamily buildings to help achieve these greenhouse gas emission reduction targets in several building applications throughout the United States and Canada. Across the entire energy industry, utilities, housing authorities, non-profits, and federal organizations are already taking steps to incorporate this new technology into the market, laying the groundwork for the rebates, incentives, and programs that are crucial to adoption. In this market landscape, PWHPs are poised to revolutionize the space conditioning sector and play a pivotal role in advancing electrification and decarbonization efforts.

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