

C01

Residential Space Heating Opportunities in Cold Climate Regions

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ABSTRACT

This paper's objective is to present an overview of testing and energy conservation standards regulations in the U.S. for single-phase heat pumps with a cooling capacity of less than 65,000 Btu/h, and how such provisions can be further revised to alleviate possible barriers to heat pump adoption in cold climate regions. While new federal provisions for heat pumps will be implemented starting January 1, 2023, and are expected to yield metrics that are more representative of the average use cycle of a covered product installed in the field, several opportunities continue to exist on improving the performance metrics for heat pumps installed in cold climate regions, including but not limited to a controls verification procedure at a lower ambient temperature point prescribed in a recently finalized ENERGY STAR® specification. Such opportunities include but are not limited to the following: test procedure revisions to address heating mode tests in lower ambient outdoor temperatures that are repeatable and reproducible in laboratory environments, impacts of refrigerant transition on performance ratings, accounting of fan energy consumption for air handlers and crankcase heaters in certain outdoor ambient conditions not addressed in upcoming or existing federal test procedures, performance criteria more relevant to cold climate regions, approaches to demand response in both heating and cooling modes, equipment sizing considerations, controls solutions to minimize the usage of auxiliary heating, and standardized reporting of expanded ratings in technical literature. Addressing these factors will improve HSPF2, the heating seasonal performance metric for heat pumps.

The paper will also seek to make a case for regional heat pump energy conservation standards using fractional bin hour weather data for multiple representative cold climate cities. Heat pumps are currently subject to national standards in the U.S. whereas single-phase residential central air conditioners with similar cooling capacities are subject to regional standards.

INTRODUCTION

Renewables Portfolio Standards (RPS) policies on retail electric suppliers and zero-carbon electricity targets have been established in several jurisdictions in the United States (U.S.) per Berkley Lab (Barbose 2021, 9). With the prevalence of a wide variety of climate zones in the U.S., cold climate air-source heat pumps (ccASHPs) offer a pathway to complement ambitious jurisdictional targets. Organizations such as Northeast Energy Efficiency Partnerships (NEEP) have led market transformation efforts in the Northeast region for several years. According to NEEP, in 2021 alone, the sale of residential central air-source heat pumps (ASHPs) increased by approximately 29 percent when compared to sales in 2020, and a significant portion of the sales were NEEP qualifiable ccASHPs (NEEP 2022, 2). The U.S. Environmental Protection Agency (EPA) and Consortium for Energy Efficiency (CEE) have issued specifications in recent years to address the performance of ccASHPs. The U.S. Department of Energy (DOE) is currently partnering with the manufacturing industry (industry) to

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improve performance of ccASHPs at cold temperatures, increase heating capacity at lower ambient temperatures, increase energy efficiency across a broader range of operating conditions, and ensure demand flexibility to adjust usage on demand (DOE 2021). Industry is also dealing with a variety of regulatory actions impacting the design of ASHPs such as new energy efficiency metrics in 2023, a transition towards low global warming potential (GWP) refrigerants due to the 2020 American Innovation and Manufacturing (AIM) Act of 2020 (EPA 2022), and potentially diverging testing and reporting provisions at 5°F (−15°C) in Canada relative to the U.S. Despite these ongoing actions that will yield societal benefits from the perspective of direct and indirect greenhouse gas emissions reductions, efforts are simultaneously underway to consider test procedure improvements for ASHPs that will improve the representativeness of metrics while not impeding design innovation, ensure tests are repeatable and reproducible in current laboratory environments, and provide sufficient utility to consumers when ASHPs are identified as a viable space heating option in purchasing decisions.

CURRENT METRICS AND OPPORTUNITIES TO CONSIDER ON HEATING PERFORMANCE

This section discusses existing metrics in the U.S. federal test procedure linked to a compliance date starting January 1, 2023, and issues that should be considered in upcoming test procedure revisions: Heating Seasonal Performance Factor 2 (HSPF2), Seasonal Energy Efficiency Ratio 2 (SEER2), and Energy Efficiency Ratio 2 (EER2).

Consideration of Regional Standards for Residential Central Air-Source Heat Pumps

While a broad range of incentive-related specifications currently exists in the U.S. to sufficiently differentiate ccASHPs from other good, better, and best ASHP product offerings, DOE's federal energy conservation standards for ASHPs are limited to national standards across all U.S. regions. Current regional standards apply only to residential central air conditioners (CACs). The statutory provisions set forth in 42 U.S.C. 6295(o)(6) appear to allow DOE sufficient authority to establish regional standards for ASHPs (United States Code 2020, §6295(o)(6)). This was likely considered when joint stakeholders previously developed a consensus agreement for DOE's consideration and divided the nation into three regions for CACs and ASHPs (DOE 2011, page 37422, sec 2.a.). Although the result was the establishment of national cooling and heating energy conservation standards for ASHPs, this paper's recommendation is for stakeholders to revisit the possibility of regional standards for ASHPs while striving to ensure that the added burden is minimal on market actors such as manufacturers, distributors, and contractors. Potential regions for future energy conservation standards on ASHPs can be either of the following: a) a U.S. North region specific to only ccASHPs and the rest of U.S. applicable to ASHPs; or b) new U.S. North, U.S. Southeast, and U.S. Southwest regions for ASHPs consistent with currently applicable CAC regions (DOE, n.d.). The establishment of regional standards for ASHPs would differentiate ccASHPs from base efficiency models through a regulatory framework, and offer much-needed utility to U.S. North consumers based on sizing practices more typical of the U.S. North, as noted in the next section.

Test Procedure Should Address Variations in Sizing Approaches to ASHPs in the Field

The federal test procedure prescribed in Appendix M1 to Subpart B of 10 CFR Part 430 (Appendix M1) assumes that ASHPs are typically sized for design cooling load rather than design heating load – the inherent assumption of an ASHP sizing based on design cooling load leads to a balance point closer to 30°F (−1.1°C) (DOE 2016, pages 58187-58188). The heating load line equation is a function of the unit's rated cooling capacity with sizing also playing a role in the heating load line equation slope factor (Rice et al. 2016, 1). The heating metric's reliance on the cooling load also establishes a connection with the 10% oversizing approach for the cooling load line equation used for the SEER2 calculation. A regional approach to sizing should instead be considered for ccASHPs in upcoming test procedure revisions to allow for the prioritization of design heating loads and potential oversizing practices in heating, so the pertinent alternate heating load line equation and slope factor are rendered applicable to ccASHPs.

Current sizing approaches in the U.S. Northeast and Canada direct installers to prioritize sizing based on design heating loads at design temperatures as low as −4°F (−20°C) (Natural Resources Canada, 2022). Installers are recommended to match system heating capacity (minus any reliance on auxiliary heat) at design temperatures within 100-115% of the estimated heating load (NEEP 2020, 7). The New York State Energy Research and Development Authority and electric utilities in New

York have designed a tool for residential buildings capable of demonstrating that a ccASHP sized for heating load may be considered to meet an alternate compliance method for the mechanical design requirements under the 2020 Energy Conservation Construction Code of New York State (NYS Clean Heat, n.d.). A ductless ASHP market survey of 156 respondents in Juneau, Alaska, confirmed that owners placed emphasis on design heating loads while prioritizing the climate, reducing fossil fuel usage, and lowering heating costs (DOE 2020, 16). The ability to have air-conditioning was ranked the lowest in terms of priority. About 93% of homeowners expressed satisfaction with their decision to install such a system. Most respondents viewed ductless ASHPs as products that would entirely replace or significantly reduce the use of other heating sources. A small percentage of dissatisfied respondents identified installed cost as the primary reason for dissatisfaction, some of which may be addressed via the following: a) a revised test procedure to better represent field performance of ccASHPs relative to base efficiency products; b) incentive programs to offset the first cost to install the product; c) improved contractor training resources on ccASHPs; and b) use of standardized diagnostic codes to facilitate quality installations.

Revising the test procedure to account for varied sizing prioritizations based on the region will minimize the resistive space heating contribution within the denominator of the HSPF2 metric, and yield metrics more representative of the average use cycle of installed ccASHPs and ASHPs across a variety of climate zones. In addition to sizing based on the installed region that can lead to an adjustment of the building heating load line equation and slope factor, region-specific bin fractional bin hours should be applied to the heating metric calculation to account for regional variations in outdoor dry bulb temperatures. Region V and Region IV bin fractions could be made applicable to the calculated HSPF2 values for ccASHPs and ASHPs respectively. Tables 1 and 2 summarize these perspectives for three major Alaskan cities using National Renewable Energy Laboratory's (NREL) National Solar Radiation Database (NSRDB) archived weather data (NSRDB, n.d.). Since fractional bin hours in Region V are existent across all bins compared to Region IV, weather data for cities located in climate zones designated as subarctic / arctic by the International Energy Conservation Code (IECC) suggests a Region V HSPF2 is more appropriate for such cities. About 0.8% of the annual fractional bin hours in Fairbanks went beyond heating bin number 18, and were at very low temperatures between -26°F (-32.2°C) and -37°F (-38.3°C). While both HSPF2 and SEER2 are important performance metrics to consider for heating and cooling operation, Table 2 confirms how prioritizing for design cooling load in cities such as Fairbanks, Anchorage and Juneau will not benefit consumers since most of the cooling bin numbers for those cities are unutilized relative to Appendix M1. The lower temperatures in Fairbanks beyond heating bin 18 comprise approximately 0.9% of the overall heating fractional bin hours for the city.

Table 1. Heating Fractional Bin hours for Alaskan Cities Relative to Appendix M1

i, T_i (°F) ¹	DOE M1 Region IV	DOE M1 Region V	Fairbanks ²	Anchorage ²	Juneau ²
1 62	0	0	0.070	0.064	0.048
2 57	0	0	0.089	0.130	0.099
3 52	0.103	0.086	0.089	0.124	0.175
4 47	0.093	0.076	0.066	0.077	0.138
5 42	0.100	0.078	0.056	0.062	0.106
6 37	0.109	0.087	0.051	0.083	0.138
7 32	0.126	0.102	0.052	0.095	0.103
8 27	0.087	0.094	0.052	0.091	0.083
9 22	0.055	0.074	0.046	0.083	0.051
10 17	0.036	0.055	0.050	0.081	0.026
11 12	0.026	0.047	0.064	0.044	0.017
12 7	0.013	0.038	0.055	0.023	0.008
13 2	0.006	0.029	0.061	0.021	0.006
14 -3	0.002	0.018	0.058	0.015	0.003
15 -8	0.001	0.010	0.054	0.004	0
16 -13	0	0.005	0.049	0.001	0
17 -18	0	0.002	0.024	0	0
18 -23	0	0.001	0.004	0	0

¹ Per Table 20 of Appendix M1.

² Heating bin fractions for each city are based on archived weather data downloaded from NSRDB.

Table 2. Cooling Fractional Bin Hours for Alaskan Cities Relative to Appendix M1

j T_j (°F) ¹	DOE M1 Cooling Fractional Bin Hours	Fairbanks ²	Anchorage ²	Juneau ²
1 67	0.214	0.539	0.864	0.581
2 72	0.231	0.287	0.123	0.329
3 77	0.216	0.149	0.013	0.090
4 82	0.161	0.020	0	0
5 87	0.104	0.005	0	0
6 92	0.052	0	0	0
7 97	0.018	0	0	0
8 102	0.004	0	0	0

¹ Per Table 19 of Appendix M1.

² Cooling bin fractions for each city are based on archived weather data downloaded from NSRDB.

Standby Mode and Crankcase Heater Operation

The zero-load point in Appendix M1 was lowered to 55°F (12.8°C) relative to the previous test procedure. Outdoor dry bulb temperatures between 55°F (12.8°C) and 64°F (17.8°C) in heating bins 1 and 2 of Appendix M1 now contribute to zero fractional bin hours in regions IV and V. The HSPF2 calculation does not incorporate standby mode energy consumption of ASHPs and ccASHPs in the 55°F-64°F (12.8°C-17.8°C) range. The term “Standby mode” is defined in 42 U.S.C. §6295(gg)(1)(A)(iii) (United States Code 2020, §6295(gg)(1)(A)(iii)). Future test procedure revisions should consider the incorporation of a new standby mode energy consumption provision in this temperature range. Standby energy consumption can be pronounced in regions where the contributions of fractional bin hours are high across heating bins 1 and 2. Table 3 confirms that in Atascadero, California, approximately 45.2% fractional bin hours are comprised in heating bins 1 and 2. (The composition is even higher at 80.1% for San Diego.) An ASHP is likely to be in standby mode in those conditions. A case study on multifamily buildings located in Atascadero, California, found that uncontrolled crankcase heaters contributed to the daily energy consumption of installed ASHPs (Dryden et al. 2021). The associated report confirmed that data collection periods included the shoulder season. While equipment runtimes were significantly less during the shoulder season, the crankcase heater operated continuously even when there was no call for space conditioning. Further to the data presented in the previous section, Table 3 confirms that while a Region IV HSPF2 is appropriate for cities located outside of the U.S. North region, a region V HSPF2 is more practical for cities such as Rochester (Minnesota), Great Falls (Montana), and International Falls (Minnesota).

Appendix M1 appears to address standby mode and off mode energy consumption for scenarios outside of the 55°F-64°F (12.8°C-17.8°C) range. (Standby energy consumption is appropriately addressed within the HSPF2 and SEER2 metrics.) Off mode provisions in Appendix M1 address the following crankcase heater energy consumption scenarios for ASHPs during the shoulder season: a) products with no compressor crankcase heater; b) products with non-self-regulating crankcase heaters lacking controls; c) products with self-regulating crankcase heaters; d) products with sound blankets on compressors; and e) products with a crankcase heater turn-on temperature higher than 71°F. Assuming the worst-case scenario where a crankcase heater consumes energy even during a compressor-on operation, the crankcase heater energy consumption would be captured during the electrical measurements prescribed in Appendix M1 for a variety of components including auxiliaries such as controls, transformers, crankcase heater, integral condensate pump on non-ducted indoor units, etc. Any further improvements to the crankcase heater energy consumption provisions should weigh the significance of energy savings potential relative to added testing burden.

Table 3. Heating Fractional Bin Hours¹

j T _j (°F) ²	San Diego (CZ 3C)	New York (CZ 4A)	Albuquerque (CZ 4B)	Seattle (CZ 4C)	Buffalo (CZ 5A)	Denver (CZ 5B)	Rochester (CZ 6A)	Great Falls (CZ 6B)	International Falls (CZ 7)	Atascadero
1 62	0.366	0.121	0.118	0.115	0.127	0.123	0.116	0.092	0.090	0.208
2 57	0.435	0.130	0.125	0.145	0.099	0.109	0.092	0.099	0.099	0.244
3 52	0.171	0.113	0.132	0.163	0.103	0.107	0.081	0.095	0.091	0.232
4 47	0.028	0.120	0.140	0.176	0.110	0.112	0.085	0.089	0.065	0.184
5 42	0	0.089	0.098	0.158	0.064	0.080	0.067	0.071	0.039	0.074
6 37	0	0.152	0.161	0.175	0.108	0.126	0.084	0.132	0.066	0.052
7 32	0	0.179	0.170	0.064	0.184	0.182	0.169	0.207	0.128	0.006
8 27	0	0.052	0.046	0.003	0.098	0.084	0.088	0.111	0.076	0
9 22	0	0.025	0.008	0	0.052	0.029	0.039	0.033	0.054	0
10 17	0	0.019	0.001	0	0.040	0.023	0.048	0.043	0.066	0
11 12	0	0.002	0	0	0.013	0.011	0.036	0.017	0.061	0
12 7	0	0	0	0	0.001	0.008	0.039	0.004	0.058	0
13 2	0	0	0	0	0.001	0.004	0.029	0.002	0.047	0
14 -3	0	0	0	0	0	0.001	0.011	0.001	0.020	0
15 -8	0	0	0	0	0	0	0.012	0.003	0.019	0
16 -13	0	0	0	0	0	0	0.005	0.001	0.009	0
17 -18	0	0	0	0	0	0	0.001	0.001	0.008	0
18 -23	0	0	0	0	0	0	0	0	0.003	0

¹ Climate zone numbers for each city are based on Pacific Northwest National Laboratory's Energy Savings Analysis on the 2021 IECC for Residential Buildings (PNNL 2021, 5). Heating bin fractions for each city are based on PSM v3 TMY weather data downloaded from NSRDB (NSRDB, n.d.).

² Per Table 20 of Appendix M1.

Incorporation of a Controls Verification Procedure for ccASHPs

A test procedure final rule issued by DOE in October 2022 increased the wet bulb test condition in the optional H4 heating mode tests for all ASHPs to a maximum of 4°F (-15.6°C) (DOE 2022, page 64552, sec II). The previously prescribed condition was at 3°F (-16.1°C). A variety of stakeholders including industry supported this revision from the perspective of achieving reasonable test results while also reducing overall test burden and increasing the number of facilities capable of performing tests at such low outdoor temperature conditions. The outdoor dry bulb temperature prescribed in these tests was left unchanged at 5°F (-15°C). While more laboratories are expected to be capable of running tests at the H4 condition due to this test procedure revision, validation of performance with controls shipped with units is still needed in the test procedure.

The U.S. Environment Protection Agency's (EPA) ENERGY STAR® Version 6.1 CAC/HP specification prescribes the following key low ambient performance criteria for ccASHPs that also seek to ensure the comfort of building occupants during low outdoor temperatures: a) a heating capacity maintenance of at least 70% at 5°F (-15°C) relative to 47°F (8.3°C) for cold climate HPs; and b) a minimum coefficient of performance at 5°F (EPA 2022, 5). EPA collaborated with DOE (EPA 2021, 2-3) to develop a controls verification procedure (CVP) for ccASHPs so that certified low ambient performance can be validated in laboratory environments with native control settings specified for field use (EPA 2021).

The industry has also carefully considered the importance of delivered heating capacity in other standards impacting ASHPs. AHRI Standard 1380-2019 on demand response limits the use of auxiliary heating elements during a critical peak event unless the indoor temperature goes below 62°F (16.7°C), at which point the comfort of building occupants takes precedence over load curtailment (AHRI 2019, pages 5 and 10).

Several stakeholders are currently evaluating load-based testing using a virtual building model to emulate indoor conditions. The following issues are being evaluated from the standpoint of test repeatability and reproducibility while

endeavoring to limit test burden: a) variation of thermal inertia across laboratory test chambers; b) field-based tests to validate laboratory-based tests; c) laboratory-to-laboratory round-robin tests; d) variation in the use of calorimetric versus psychrometric test chambers; and e) establishment of an uncertainty analysis for dynamic testing approaches involving a unit's embedded controls and a thermostat. Approaches to load-based testing should also fully consider the current market state, and not preclude coil-only combinations from the method of test. Existing federal certification provisions set forth in 10 CFR Part 429.16 for products with single-speed and two-stage compressors should be factored into any load-based test methods prescribed for CACs and ASHPs. ASHRAE's TC 8.11 Unitary Next Generation Test Procedure Subcommittee is currently evaluating approaches that may facilitate a practical transition from traditional steady-state tests to dynamic tests.

The industry should consider improving AHRI Standard 210/240-2023 (2020) via the incorporation of EPA's currently established CVP into a new normative appendix, and prescribe low ambient CVP provisions for ccASHPs. Some aspects of the test procedure prescribed in DOE's Residential Cold-Climate Heat Pump Technology Challenge Specification may also be applicable to this effort (DOE 2021, 10-12). A normative appendix CVP precedent is already well established for cooling conditions in Appendix C of AHRI Standard 1230-2021, so an industry standards revision process to prescribe heating mode CVP provisions within AHRI Standard 210/240 is feasible. Discussions on a heating mode CVP should also consider how to address current control schemes that minimize auxiliary heat utilization. While the HSPF2 metric captures the electrical energy consumption of electric resistive space heating components, auxiliary gas-related energy consumption (e.g., dual-fuel ASHPs) is not addressed in this metric and most gas-fired backup options are separately regulated by DOE. Addressing this matter in a heating mode CVP will incentivize an integrated control that optimally locks out an auxiliary heating option within a ccASHP until it is no longer feasible for the ccASHP to heat the space via only the vapor-compression cycle (NYS Clean Heat 2022, 2-3).

FAN ENERGY CONSUMPTION IN AIR HANDLERS

With the 55°F-64°F (12.8°C-17.8°C) outdoor dry bulb temperatures not being relevant to the SEER2 and HSPF2 calculations, it is important to ensure that fan energy consumption at those temperatures is appropriately addressed in a federal test procedure, particularly during constant air circulation through the ductwork. Appendix AA to Subpart B of 10 CFR Part 430 (Appendix AA) estimates 400 national average operating hours in constant circulation mode for furnace fans. DOE has previously noted that provisions in 42 U.S.C. 6295(f)(4)(D) can be viewed to encompass electrically-powered devices used in any residential heating, ventilation, and air-conditioning product to circulate air through the ductwork, and not just furnaces (DOE 2014, 504).

Historical shipments reported by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), indicate that annual shipments for ASHPs in the U.S. have steadily increased over the past two decades and are currently comparable to residential gas-fired furnace shipments (AHRI, n.d.). The corresponding shipments of air handlers are expected to have increased with shipments of ASHPs. Addressing fan energy for air handlers within a federal test procedure would provide consumers a basis to fairly compare fan performance between residential furnaces and air handlers prior to making purchasing decisions.

Verification of airflow requirements should be considered from the perspective of rated cooling/heating capacities rather than nominal capacities as a range of airflows are applicable when systems are certified prior to being distributed in commerce. Certified cooling and heating capacities are associated with rated airflows during a third-party verification process, are displayed on a publicly accessible directory, and provide an increased level of assurance to consumers. The industry has previously expressed support for the rated capacity approach in lieu of nominal capacity in regulatory proceedings, and stakeholders should consider this aspect in ongoing discussions (AHRI 2018, TN#223335, page 7).

OPPORTUNITIES WITH DEMAND RESPONSE-ENABLED PRODUCTS

Outdoor temperatures greater than or equal to 95°F (35°C) were evaluated for California cities such as Los Angeles, Sacramento, and San Francisco. Charge and discharge pattern estimates were developed using RPS as a pathway to generation, and relying on the energy storage perspectives offered in a California Independent System Operator Corporation

(CAISO) report on California and Europe (CAISO 2019, 27). Several high outdoor temperatures within Figure 1 fall within the charge zone associated with lower-price periods and high generation. A small percentage of outdoor temperatures within the discharge zone (i.e., higher-price periods with peak demand) can be managed using the general curtailment and critical curtailment approaches specified in AHRI Standard 1380-2019.

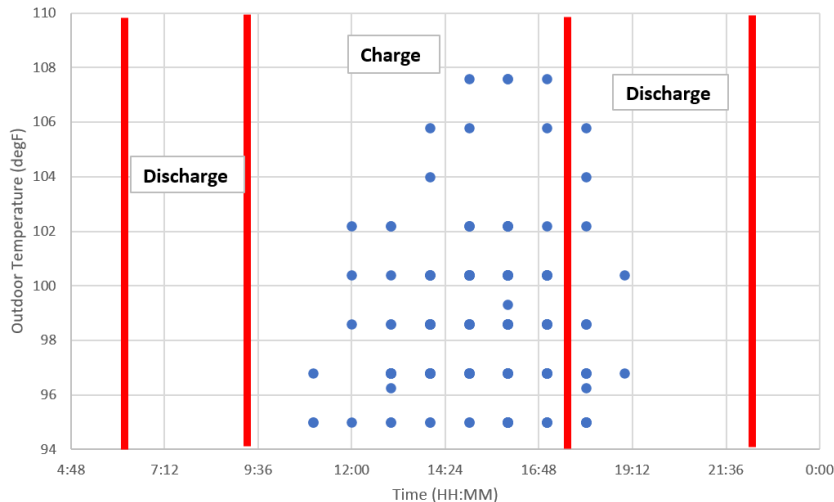


Figure 1 Potential opportunities for load curtailment in California cities using demand response.

Specifications issued by EPA and the CEE prescribe connected criteria for demand response-enabled products. Energy efficiency program administrators may consider offering incentives on connected criteria to strategically manage peak load outside of solely focusing on performance metrics such as SEER2, HSPF2, and EER2.

TRANSITION TO A2L REFRIGERANTS

Several issues are currently being considered as the industry transitions towards complying with the phasedown schedule of the AIM Act of 2020 and state-based regulations specifying end-use prohibitions with GWP thresholds (e.g., California's less than 750 GWP refrigerant mandate in 17 CCR § 95374 for ASHPs starting January 1, 2025).

In a report submitted to the California Energy Commission in 2021, an A2L refrigerant was used as an alternative drop-in replacement to an ASHP with R-410A, currently the most common A1 refrigerant in ASHPs. While drop-ins are not practical in the field since safety standards do not allow changing of refrigerant classes, the project results demonstrated that an A2L could potentially replace an A1 from the perspective of product performance and functionality, and yield a reduced overall refrigerant charge in an ASHP (Amarnath et al. 2021, 2).

While A2Ls are expected to serve as alternatives to A1s in the near term for ASHPs, provisions in acceptable use conditions for certain A2Ls under EPA's Significant New Alternatives Policy regulations, product/application safety standards, and building codes will play a key role in shaping how such products will be appropriately installed in the field (AHRI 2022). ASHRAE convened a roundtable of industry experts in 2021 on this important topic (ASHRAE Journal November 2021). It was mentioned that charge limits are a function of a refrigerant's lower flammable limit. ANSI/ASHRAE Standard 15.2-2022 (Standard 15.2), the safety standard for refrigeration systems in residential applications, prescribes a table summarizing charge levels for a variety of A2Ls that can be referenced by installers to determine installation limitations. The transition to A2Ls will require installers to assess room sizes and the amount of releasable charge at the time of installation. In an event a certain charge limit is exceeded, mitigation methods are expected to incorporate a refrigerant detection system, safety shutoff valves, or continuous airflow to control releasable charge. Standard 15.2 also prescribes pressure and vacuum testing to validate there is no leak in existing or new piping and the associated joints.

While the product safety standard requires manufacturers to provide detailed mitigation steps in product installation manuals, training installers on the mandatory incremental steps relative to today's installation practices is imperative to ensure a smooth transition towards products with A2Ls.

CONCLUSION

ccASHPs provide a unique opportunity towards complementing ambitious zero-carbon electricity targets across jurisdictions. Proposed regional standards for ASHPs and revisions to performance metrics raised in this paper will improve the representativeness of ratings and increase the utility offered by such products to consumers and installers. Improved training resources for contractors with clearly outlined incremental steps on installing products with A2Ls, incentive programs to help lower installed costs, and standardized diagnostic codes will aid in the uptake of ccASHPs as viable space heating solutions.

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NOMENCLATURE

T_j = the outdoor bin temperature, °F. Outdoor temperatures are “binned” such that SEER2 or HSPF2 calculations are only performed based on temperatures within the bin. Bins of 5°F are used.

CZ = Climate Zone

Subscripts

j = cooling or heating bin number, dimensionless

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