August 7, 2023

Ms. Abigail Daken,
ENERGY STAR HVAC Program
United States Environmental Protection Agency
Washington, DC 20460

(Submitted electronically to HVAC@energystar.gov)

Dear Ms. Abigail Daken:

## I. Introduction

The Daikin Group is one of the largest heating, ventilation, and air conditioning ("HVAC") manufacturers in the world. Daikin Comfort Technologies North America ("Daikin"), Inc. is headquartered in Waller, Texas, and employs thousands of workers across the United States. The company manufactures residential and light commercial heating and cooling equipment, and its products are sold and installed by contractors in every American state, as well as in Canada.

Daikin is respectfully submitting the following response to the questions raised in U.S. Environmental Protection Agency's ("EPA") ENERGY STAR Residential Boilers Discussion Guide, June 2023. Daikin supports establishing an ENERGY STAR criteria for AWHP products using the appropriate test procedures, performance metrics, and related thresholds. We appreciate the opportunity to provide information to the EPA.

## II. Daikin response to questions raised in the Discussion Guide:

***Question 1:* Is the name "ENERGY STAR Heat Pump Boilers" for the new specification preferable to "ENERGY STAR Air-to-Water Heat Pumps"? Is there another name that would better align with customer expectations of the product?**

Daikin recommends that EPA adopt the widely used terminology from global regions where these products have a robust market presence[1]. The European market also certifies Air to Water Heat Pumps under the Eurovent's Certification program. Additionally, the 'heat pump' name describes the method of heat transfer from one space to another, whereas a boiler creates heat by burning a source of energy (typically a fossil fuel) or boiling water with electric heat – typically up to 210°F or higher with water pressures up to 160 PSIG or higher on high pressure boilers. For simplicity and in congruence with established markets, we recommend the agency continue to call this product type: *Air to Water Heat Pumps (AWHP).*

[1] https://www.rehva.eu/rehva-journal/chapter/european-heat-pump-market Last opened August 6, 2023

***Question 2:** Are there broadly accepted industry definitions of air-to-water heat pumps or heat pump boilers?*

We believe that a definition must include the following descriptors*:

| | |
|---|---|
| Source of energy | electricity, |
| Method of heat transfer | a refrigerant vapor compression cycle, |
| Application | Primary: space heating,<br>Optionally: space cooling, domestic (potable) hot water. |
| Thresholds for consumer vs commercial application | single phase, *output heating capacity ≤ 65,000 Btu/h* = consumer application*<br>*three-phase (any output heating capacity) and single-phase, output heating capacity >65,000 Btu/h = commercial application* |
| Arrangement of the equipment | Evaporator in heating mode, Condenser in cooling mode shall be located outdoors. Electric resistance heating may be included as a back-up heat source. |
| Shall exclude | *Air to water Heat pumps primarily exclusively for DHW,*<br>*Air to water Heat pumps used to heat swimming pools/spas.* |

e.g.
See definition of AWHP in Energy Technology List, part of the Department for Business, Energy & Industrial Strategy in the UK: https://etl.beis.gov.uk/products/heat-pumps/air-water-heat-pumps
*The US Department of Energy adopts this descriptor to reflect that AWHP solutions fall under the scope of consumer Central AC/HP product category[2].

***Question 3:** Is there any need to distinguish boilers that are used with hydronic coils in a forced air distribution system from those used with hydronic distribution? Are the same products used in both situations?*

We recommend that EPA consider classification criteria for AWHP equipment also include leaving water temperature (LWT) conditions. The LWT needed to operate a hydronic coil air handler is different to LWT required for hydronic distribution system, e.g. underfloor radiant panels. The variances of heating energy required to operate different heat emitters are reflected in the respective LWT performance ratings. LWT is also used as a rating condition in EN standards[3].

It is possible that the same AWHP equipment will supply a range of LWT, depending on product design and intended end use. We recommend the following classification using LWT (leaving water temperature):

| Temperature Profile | Application Range* | For reference: Related Performance Rating LWT (EN Standards) | EPA's concerned application |
|---|---|---|---|
| Low Temperature | up to 130F | 95F | Hydronic distribution |
| Intermediate Temperature | | 113F | |
| Medium Temperature | 130-150F | 131F | Hydronics coil |
| High Temperature | above 150F | 149F | |

Table 1. Available Leaving Water Temperature (LWT) Range

[2] Federal Register, 81 Fed. Reg. No. 110, on June 8, 2016.
[3] EN 14511:2022 + 14825:2022- Standards for Air conditioners all parts. Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling

***<u>Question 4:</u> EPA believes that products that can serve as domestic water heaters or as air-to-water heat pumps for space heating could simply be tested and rated for each use. Is there any need for a definitional distinction between heat pump water heaters and air-to-water heat pumps for space heating? If so, what would the distinction be?***

We believe that a Heat Pump Water Heater (HPWH) is clearly distinguished by its application and the location of its evaporator coil. Please see Table 2 and Figure 1, a visual aid to understand types of AWHP and compare to a HPWH in the last row of the table. Additionally, HPWH are rated with UEF and FHR only, whereas a AWHP will have a space heating capacity and related seasonal efficiency ratings. We strongly recommend excluding HPWH from scope of the intended AWHP specifications.

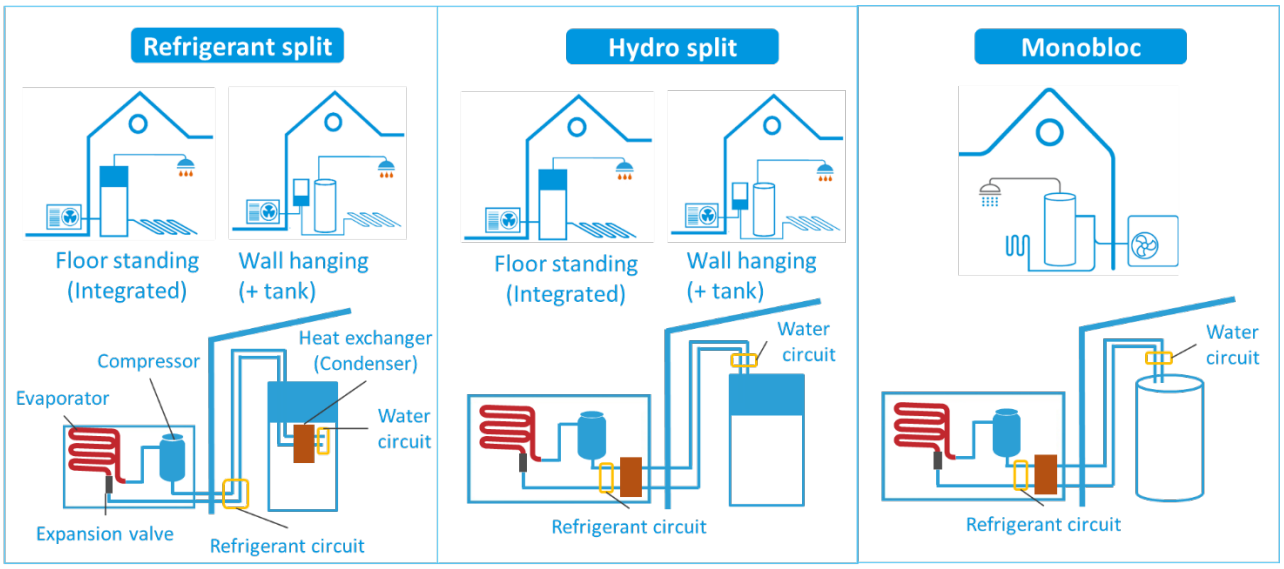


Figure 1. illustrations for Typical AWHP Systems

***<u>Question 6:</u> As the evaporators are likely to be located outdoors, what range of outside air conditions are most representative to determine overall performance?***

The outdoor unit of an AWHP will be subjected to the same conditions as would a central AC/HP product rated per 10 CFR Appendix M1 to Subpart B of Part 430, in cooling and heating mode. Both AWHP and Central AC/HP transfer heat using refrigerant vapor compression cycle and are designed to provide different heat output because of differing heat emitters or end use. The outdoor conditions may range from 5°F to 95F per AHRI Standard 210/240-2023, covering heating, cooling and domestic hot water operations.

| Designation* | Split Type | Arrangement Indoors | Arrangement Outdoors | End Use | End Use (Temperature) |
|---|---|---|---|---|---|
| Monobloc | Water | - | • Outdoor Fan<br>• Compressor<br>• Condenser<br>• Evaporator Coil<br>• Pump | • Space Heating & Cooling | • High,<br>• Medium,<br>• Low Temp |
| Split System (Single split) | Refrigerant | • Condenser<br>• Pump | • Outdoor Fan<br>• Compressor<br>• Evaporator Coil | • Space Heating & Cooling | • High,<br>• Medium,<br>• Low Temp |
| Monobloc with Tank | Water | - | • Outdoor Fan<br>• Compressor<br>• Condenser<br>• Evaporator Coil<br>• Pump | • Space Heating<br>• Space Heating & Cooling<br>• Space Heating + DHW<br>• Space Heating & Cooling + DHW | • High,<br>• Medium,<br>• Low Temp |
| Split System with Tank | Refrigerant | • Condenser<br>• Pump | • Outdoor Fan<br>• Compressor<br>• Evaporator Coil | • Space Heating & Cooling,<br>• Space Heating & Cooling + DHW | • High,<br>• Medium,<br>• Low Temp |
| Monobloc Hydro Split | Water | • Controls &<br>• Distribution Pump<br>• Integrated Backup Heat | • Outdoor Fan<br>• Compressor<br>• Condenser<br>• Evaporator Coil | • Space Heating & Cooling,<br>• Space Heating & Cooling + DHW | • High,<br>• Medium,<br>• Low Temp |
| Multi-Split | Refrigerant | • Multiple condensing units | • Outdoor Fan<br>• Compressor<br>• Evaporator Coil | • Space Heating & Cooling | • High,<br>• Medium,<br>• Low Temp |
| Multi-Split with Tank | Refrigerant | • Multiple condensing units | • Outdoor Fan<br>• Compressor<br>Evaporator Coil | • Space Heating & Cooling,<br>• Space Heating & Cooling + DHW | • High,<br>• Medium,<br>• Low Temp |
| Heat Pump Water Heaters | n/a | • Condenser fan<br>• Compressor<br>• Condenser<br>• Evaporator Coil<br>• Pump | - | • DHW (only) | • Medium,<br>• Low Temp |

*Heat Pump Pool Heaters are excluded from this table because they are air-to-water heat pumps also but specifically used to heat swimming pools/spa, while the AWHPs being discussed are either space heating, space heating/space cooling and/or domestic hot water only.

Table 2: Types of Air to Water Heat Pumps

***<u>Question 7:</u> At very low outside temperatures, the compressors for ATWHPs and dual fuel HPs may no longer provide useful efficient heat. We assume ATWHPs will include backup heating for this circumstance. Ideally, the test method would capture this behavior and incorporate it into an estimate of annual energy use. What is the best way to include backup heat in the test method? What other testing considerations should be evaluated for performance in cold climates?***

In our experience and a quick survey of product specifications of products sold in the EU market, equipment has published operation range down to -18°F. They can also deliver nominal heating capacity down to 5°F.

Some AWHP could still be equipped with supplementary backup heat. The heating test conditions in the EU are different than the typical rating conditions in the US, heating capacity and sCOP at 5°F, vs HSPF2 at 47°F and 17°F respectively. This could potentially increase the reliance on backup heat because if the test procedure does not test the equipment at lower conditions, then manufacturers may be incentivized to design around the higher temperature design conditions. We recommend that the performance of back up heat be reflected in the energy consumption and efficiency ratings if it's use is initiated during the conducting of any ratings test with normal control settings. A specific method of calculation will require the industry to develop a consensus standard applicable in the US. Ideally - all systems should be tested with their native controls to represent actual in-situ operations, without disabling any backup heat.

***<u>Question 8:</u> How often are air-to-water heat pumps applied in combination systems that also provide domestic hot water? For these applications, can they use the test and metric for domestic hot water delivery efficiency found in 10CFR Part 430 Subpart B Appendix E? Would this test fully capture the performance of the product in space and water heating modes?***

We are not aware of US market data that estimates how often AWHP are applied in combination systems. However, Daikin manufactures AWHP products for the EU market where most of the product lineup is capable of providing both space heating and domestic hot water.

AWHP systems with storage tanks can be tested to the 10 CFR 430 Subpart B, App E., test procedure, however the rating conditions will not be appropriate to determine its operation range or performance in DHW applications. Additionally, we believe the following type of changes will be necessary to appropriately revise Appendix E test method, such as, appropriate ambient temperature conditions to reflect outdoor conditions in winter, refrigerant and hydronic piping lengths, pump operating conditions and reflecting the use of external or in-built pump systems.

The DOE test procedure referenced above can only cover performance related to DHW operation. It is crucially different than space heating operation and performance measurements. DHW performance depends on storing and drawing hot water routinely for a pre-determined period and frequency, whereas space heating function requires the system to maintain LWT conditions in a closed loop hydronic coil, or distribution, over a period in response to the heating demanded for thermal comfort. We recommend

that space heating and DHW performance metrics continue to remain separate because DHW is an optional feature of AWHP. Using a combined metric is not advisable as DHW will not necessarily be installed in every application.

Daikin will support AHRI in establishing a Standards Technical Committee (STC) to write an industry consensus standard to determine applicable ratings and conditions for AWHP product categories.

***Question 11:** Do air-to-water heat pumps generally use multiple speed, variable speed, or inverter-driven compressors? For these products, do part-load tests in AHRI 550/590 reflect field operation?*

In Daikin's experience in manufacturing AWHP for the EU market, inverter technology is extensively used, particularly for cold climate conditions. The control systems for systems using variable speed or inverter driven compressors are very different than a fixed speed compressor, thus allowing a wide range of capacity modulation and resultant energy reduction. The intended specification should reflect the inherent advantage of using an inverter system, i.e higher efficiencies can be achieved in part-load operation, as opposed to fixed full load tests that only reflect a small part of the operation range.

We don't believe that AHRI Standard 550/590 is able to accurately measure the part load performance of AWHP over an annual period. AHRI Standard 550/590 only covers the full-load heating (COP), full-load cooling (EER), part-load cooling only (IPLV) - typical part load tests at 25%, 50%, 75%. The standard does not present a part-load heating metric. Even the part-load cooling metric is dissimilar from AHRI Standard 210/240's SEER2 metric. We believe that a bin method calculation is more applicable to define AWHP's seasonal heating and cooling performances.

***Question 12:** If units are sized for design conditions, what does that mean for their part-load heating performance? What have users' experiences been in the field?*

Equipment should be sized based on design conditions and resultant heating, cooling loads, including factors identified in the Manual J load calculations. The equipment sizing also depends on the heat emitters discussed in response to Question 13. Since design conditions can represent the upper or lower limits or the 1% temperature conditions, AWHP are anticipated to operate in the part-load conditions for the majority of its operation. Inverter systems or variable capacity AWHP will excel in those operating conditions leading better COP and higher energy reductions. See Figure 2. derived from Daikin's published product specification data in the EU, showing the system COP when used in combination with outdoor reset.

There is no large enough sample size in the US to reflect user experience. However, AWHP are predominantly used, widely accepted with satisfactory performance in the EU. PG&E found in a thermal comfort survey from its recent study[4], *Assessment of Residential AWHP coupled with Thermal Storage*,

[4] https://www.etcc-ca.com/reports/assessment-residential-air-water-heat-pumps-coupled-thermal-energy-storage Last Opened August 6, 2023

2021, that radiant panels provided better comfort than the reference AC during precooling and load shifting hours.

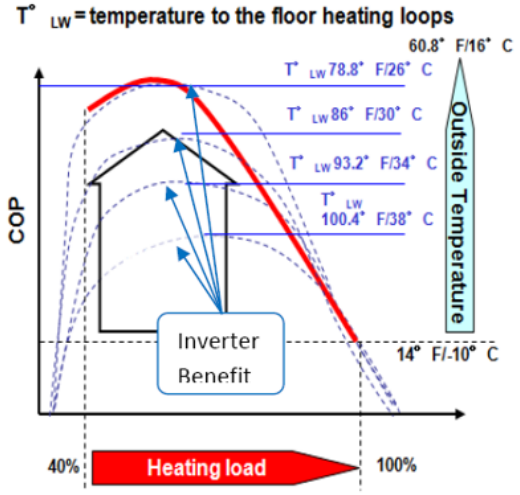


Figure 2. Inverter System Efficiencies for AWHP under Heating Load and Range of Outdoor Temperatures

***<u>Question 13:</u> This test defines performance with 110F leaving water temperature. This will not provide sufficient heat when used in legacy heat exchangers, typically designed for 160-180F water. Do manufacturers recommend using these products in retrofit situations? If so, is there anything special they recommend making sure residents have enough heat?***

LWT rating conditions that were used in the ENERGY STAR Emerging Technology Aware from 2019-2020 may have been appropriate to measure performance at an applicable rating condition in the absence of a national consensus standard for AWHP. However, those conditions do not represent capacity, temperature, or performance limits of the available AWHP in the global market. Daikin's AWHP product specification data[5] for its products sold in the EU demonstrate variable LWT conditions, and steady state LWT at 160°F at outdoor temperature -15°F without backup heat, and LWT at 160°F at outdoor temperature -18°F with backup heat.

We recommend that equipment selection should be based on the required flow and temperature of the connected heat emitters. Performance of 110°F, from EPA's example, is appropriate for under-floor radiant panels applications and some DHW applications. Other applications, such as fan coils, fan convectors and radiators, would require higher LWT to emit sufficient heat and prevent system pressure rise (see Table 3 and Figure 3). Retrofitting is possible and likely. We recommend retrofitting appropriate heat emitters to ensure sufficient heat transfer, where needed. Additionally, legionella would also become a concern at 110°F limitations, requiring LWT to rise up to 140°F to kill any harmful germs[6].

[5] https://daikintechnicaldatahub.eu/en-GB/ Last opened August 6, 2023
[6] https://www.cdc.gov/legionella/downloads/fs-legionnairesvacationrental-508.pdf Last opened August 6, 2023

| Type | Minimum LWT scope | Maximum LWT scope |
|---|---|---|
| High Temperature Radiators | 149°F | 194°F |
| Low Temperature Radiators | 104°F | 149°F |
| Fan Coil Units | 86°F | 122°F |
| Under Floor Heating | 77°F | 113°F |

Table 3. Different types of heat emitters and LWT requirements

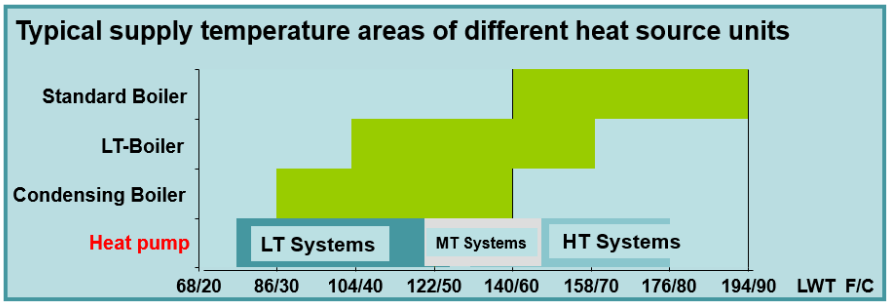


Figure 3. LWT determines the match between heat emitter and heat source

***<u>Question 14:</u> Many hydronically-heated homes are located in cold climates in the US. Is there a need for separate criteria for cold climate ATWHPs?***

AWHP products are widely used in cold climate conditions in the EU. The test standards used in that market, i.e. EN Standard 14511 & 14825, and EN 16147, also include rating conditions for the colder regions. We recommend that the US standards also include relevant operating and performance rating tests in colder climate.

## III. <u>Conclusion</u>

Daikin appreciates the opportunity to provide these comments. If you have any questions regarding this submission, please do not hesitate to contact me (lee.smith@daikincomfort.com) or Anuj Mistry (anuj.mistry@daikinus.com).

Sincerely,

Lee Smith
VP – Strategic Marketing & Environmental Technology Solutions
Daikin Comfort Technologies North America

*cc-Anuj Mistry*