ENERGY STAR® Room Air Conditioner Draft Heating Mode Test Procedure

Stakeholder Webinar

December 12, 2023

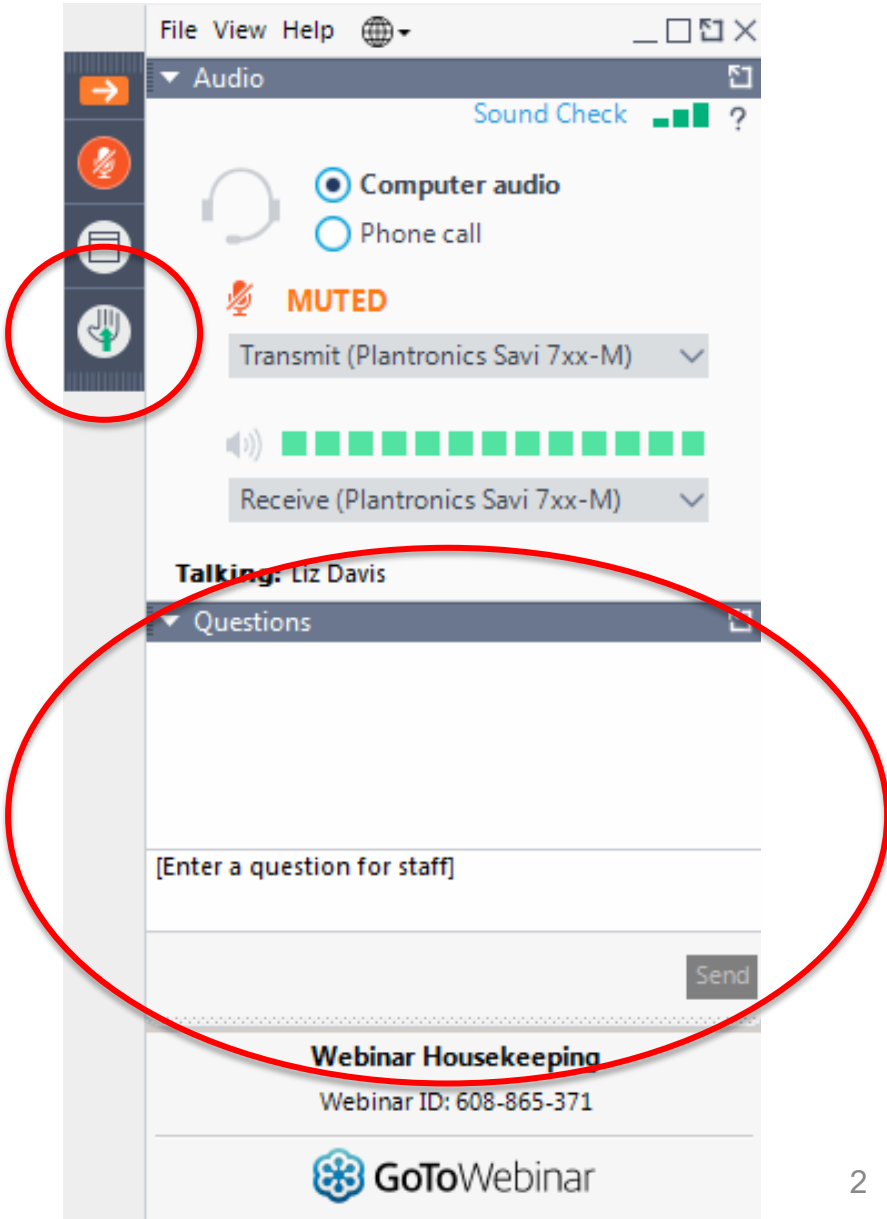
Meeting Details

- Slides and related materials will be available on the Room Air Conditioners Product Development Web page:
  - https://www.energystar.gov/products/room_air_conditioner_specification_version_5_2

- Audio provided via teleconference:

  U.S. Phone Number: (415) 930-5229
  International Phone Number:
  Participant Code: 479-888-872

  - Phone lines will be muted at the start of the presentation
  - Please leave your line on mute unless speaking during the call for questions
  - Press *6 to unmute your line and when you are finished with your question or comment, *6 to mute



Meeting Agenda

Time	Topic
1:00–1:10	**Introductions and Drivers for ENERGY STAR**
1:10–2:10	- Background & Goals - Scope - Test Apparatus - Test Conditions - Test Results - Test Metric - Load Line Analysis - Defrost Tests - Cyclic Performance
2:10–2:15	Request for Feedback
2:15–2:45	Timeline and Open Discussion

Introductions

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Heating Mode Test Procedure Drivers

- Long term, work towards more complete ENERGY STAR criteria including heating performance as well as cooling performance. DOE also interested in heating mode testing in the long term.
- DOE and EPA often work together to release new test methods more quickly through ENERGY STAR.
  - Allows EPA (and others) to use the test method immediately.
  - Added advantage that the market gets to try it out before it becomes a DOE test method.
- Incentives:
  - Interest in Inflation Reduction Act incentives for room heat pumps:
    - Tax credits: CEE needs a heating mode test, and data, to establish Tiers.
    - Home Energy Rebates: A test method for heating performance is required.
  - Some incentive programs from states and utilities would also like to include these products.

⇨ **One test method, developed by DOE and released ASAP through ENERGY STAR, streamlines this group of efforts.**

Heating Mode Test Procedure: EPA Plans

- Manufacturers have expressed interest in updating their model certifications with heating mode efficiency soon after the ENERYG STAR test method is final.
- Heating mode criteria will be considered for ENERGY STAR Most Efficient 2025.
- ENERGY STAR plans to review heating mode data and include heating mode performance criteria in the next ENERGY STAR Room Air Conditioner specification (Version 6.0).
  - Timing for Version 6.0 will be before the next DOE Standards on May 26, 2026.

Working Group Schedule

Below is the schedule crafted by the working group and presented to CEE in September, including the target schedule for the ENERGY STAR heating mode test procedure.

	2023		2024						2025
	Nov	Dec	Jan	Feb	March	April	May		Jan
CEE						Review test data	Set requirements by 12/31/24		
Mfgs.		Provide feedback to ENERGY STAR			Share data to new test method with CEE		Test at certifying lab		Begin selling 25C eligible products
Test Labs		Provide feedback to ENERGY STAR			Accredit new procedure	Accredit new procedure	Upload test data to ENERGY STAR database	. . .	
ENERGY STAR	Publish draft ENERGY STAR test method for comment			Finalize ENERGY STAR test method	Finalize ENERGY STAR database				

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Background

- The current DOE test procedure for room air conditioners (ACs) at Appendix F to 10 CFR 430, Subpart B (Appendix F) measures performance in cooling mode and low power modes (standby/off).
- Room ACs have historically offered heating in some models, some with resistance heating only, and others with reverse-cycle heating (i.e., heat pump).
- There has been recent increased interest in electrification that has led to more room ACs offering reverse-cycle heating, with newer designs capable of operating at colder temperatures (i.e., <47F).
- The Association of Home Appliance Manufacturers and the Consortium for Energy Efficiency have begun working groups focused on addressing room AC heating mode performance.
- The DOE test procedures for packaged terminal heat pumps (PTHPs) and central air conditioners both measure heating mode performance and were consulted in the development of this draft test method.
  - The most recent PTHP test procedure proposal (88 FR 30836, May 12, 2023) was also consulted due to its seasonal rating approach

Goals of this draft Test Method:

- Provide a representative measure of heating mode performance for room ACs that is both repeatable and reproducible
- Offer an overall heating efficiency metric as well as distinguish performance at specific temperature conditions of particular interest, including colder conditions (e.g., <5F)
- Minimize test burden where possible, while achieving a representative measure of performance and efficiency
- Request feedback on key areas of interest

Scope

- Included products: All products that meet the draft definition of a room heat pump

Room Heat Pump:

A room air conditioner, as defined at 10 CFR 430.2, that utilizes reverse cycle refrigeration as its prime source for heating the indoor space.

Types of Room Heat Pump

- Room heat pumps can be designed to operate at different operating conditions, ranging from mild conditions (e.g., 47 °F) to cold conditions (e.g., 5 °F).
- "Mild Climate" room heat pumps are intended to operate with heat pump heating (as opposed to resistance heat) where outdoor temperatures remain above 42 °F, and therefore do not actively defrost the outdoor coil if frosting occurs; these units instead cycle off the compressor until the frost is melted (i.e., passive defrost).
- "Cool Climate" and "Cold Climate" room heat pumps are designed to operate with heat pump heating at outdoor temperature below or freezing and implement active defrost (i.e., heating the outdoor coil by operating the refrigerant loop in cooling mode).
- Other room heat pumps may have active defrost but may not operate the heat pump at the low temperatures of cool or cold climate units. These units can be tested in heat pump operation below 42 °F.
- The ENERGY STAR Heat Mode Test Method definitions distinguish room heat pumps intended for different operating conditions. For cool climate and cold climate room heat pumps, the definitions also include minimum heating capacities and efficiencies at the specified conditions to ensure heat pump operation delivers efficient heating.

Room Heat Pump Type	Method of Defrost	Outdoor Temperatures with Heat Pump Operation	Efficiency	Capacity
Mild Climate	Passive	Any	--	
Cool Climate	Active	Below 17 °F but not below 5 °F	$HEER_{17} \geq 5.8$ Btu/Wh	At 17 °F, 100% of 47 °F
Cold Climate		Below 5 °F	$HEER_{5} \geq 5.8$ Btu/Wh	At 5 °F, 70% of 47 °F
Other		Only above 17 °F	--	

DOE and EPA welcome comment on these classifications

Test Apparatus – Calorimeter or Psychrometer

- Appendix F requires a calorimeter for room AC cooling mode tests.
- Water is commonly used as a heat transfer fluid to control the calorimeter chamber temperatures.
- Because water freezes at 32 °F, water-cooled calorimeter rooms are not able to conduct heating mode tests near or below freezing temperatures.
- Psychrometric testing typically uses other cooling fluids and can achieve near or below freezing temperatures.
- Because cooling mode testing must be conducted in a calorimeter chamber, requiring that all heating mode testing be conducted with a psychrometric apparatus imposes an additional test burden requiring two test installations for each model.
- However, for room heat pumps that do not operate at outdoor temperatures below 42 °F, calorimeter chambers may be able to conduct all heating tests required to characterize the unit's heating operation (as discussed in later slides).
- **Therefore, this draft permits heating mode testing in a calorimeter chamber or a psychrometer chamber where applicable. Otherwise, a psychrometric chamber would be required for colder test conditions.**

Test Conditions

- Test conditions were selected to balance representativeness and test burden
  - For units that operate at colder temperatures, it is important to capture the improved performance of heat pump operation vs resistance heating
  - For variable-speed units, it is important to capture the improved performance of the compressor at reduced heating loads
  - For units that are intended for milder climates, especially single-speed units, minimizing the number of tests required to rate the unit is the priority

Test Conditions

- Tests are intended to be dry tests where frost does not form (except for the optional 35/33 °F defrost test), and therefore 60% relative humidity is the maximum allowed during the test.

- Some mild-climate room heat pumps may have passive defrost functionality, where frost and ice on the outdoor coil is removed by cycling the compressor off and continuing to run the outdoor fan (when the outdoor temperature is above 32 °F.
  - The draft test method is not able to account for the proportion of heat pump operation vs electric resistance operation during passive defrost
  - Given the large number of bin hours in the frost region, passive defrosts could impact the calculated efficiency if properly accounted for in the test method.

DOE and EPA welcome comment on creating a passive defrost test method to better represent the energy efficiency of systems utilizing that functionality and further differentiate technologies for mild-climate room heat pumps.

DOE and EPA also welcome comment on the test conditions and whether the 60% relative humidity maximum will be sufficient to prevent frosting in typical tests.

Test Conditions – Single-Speed and Variable-Speed

		Single-Speed				Variable-Speed		
Outdoor side temperature (°F)		Mild Climate	Cool Climate	Cold Climate	Other	Mild Climate	Cool Climate	Cold Climate
Dry bulb	Wet Bulb	Test Required?				Test Required/Compressor Speeds		
62	56.5	*Optional*				Low	Low	Low
47	43	Yes	Yes	Yes	Yes	Nominal, Intermediate, Low	Nominal, Low, *Optional Full*	Nominal, Low, *Optional Full*
35	33		*Optional*	*Optional*			Intermediate	Intermediate
17	15		Yes	Yes			Full	Full
5	4			Yes				Full
Cut-In/Cut-Out Temp	60% RH			*Optional*	Yes			*Optional Full*
Total Required Tests		1	2	3	2	4	5	6

Note: To minimize test burden, some tests are optional and results for those test points are interpolated using the required tests or, in the case of the 35/33 °F defrost test, a standard factor is used. Manufacturers may conduct the optional tests if desired, to demonstrate higher efficiency than determined based on the interpolation and standard factors.

DOE and EPA welcome comment on whether multi-speed (i.e., not single-speed or variable-speed) room heat pumps are available or likely to become available.

Test Results

- Heating capacity and power are measured at each test condition.
- Measured heating and capacity values are extrapolated or interpolated to create equations that relate capacity and power to outdoor temperature.
- From these equations, the energy use in each bin due to the heat pump and the electric resistance heater can be calculated with the following additional steps:
  - Determine whether the resistance heater or heat pump would typically operate in a temperature bin
  - Determine the speed at which the compressor is operating
  - Account for energy lost due to cycling

Heating Performance Metric

- The heating capacity of a unit is measured at the 47 °F outdoor temperature test condition, with a nominal compressor speed if applicable.
- The efficiency of the unit is expressed by the Heating Energy Efficiency Ratio (HEER), a seasonal metric:
  - Accounts for performance across a variety of temperatures expected to be encountered during the heating season
  - Performance at these temperatures is weighted by the heating load line, which relates heating load to outdoor temperature

$$HEER = \frac{Total\ Heating}{Total\ Energy\ Consumption} = \frac{\sum_{j=1}^{14} Fractional\ Hours_j \times Building\ Load_j}{\sum_{j=1}^{14} Heat\ Pump\ Energy_j + Resistance\ Heat_j}$$

- The test method also provides means for evaluating efficiency at temperatures of interest, as applicable to the unit under test: 17 °F, 5 °F, and at the lowest temperature a unit operates (single-temperature efficiency $HEER_{17}$, $HEER_5$, and $HEER_x$, respectively)
- The HEER equation does not account for energy use in standby mode, while the room heat pump is plugged in during the heating season but is not actively providing heating and is not defrosting.

DOE and EPA welcome comment as to whether the HEER metric should account for standby power associated with the heating season.

Load Line and Temperature Bins

- The heating load line relates the outdoor temperature to the required heating load in the conditioned space and the operating hours at each condition.

- DOE and EPA developed a room heat pump heating load line and hours spent at each temperature during heating operation by analyzing an equally weighted combination of national building load data for mid-rise apartments and single-family homes, with the following assumptions:
  - At -15 °F, heating load is equal to the typical cooling load at 95 °F
  - Unit cooling capacity typically meets the cooling needs of the space at 95 °F (i.e., no oversizing)
  - At 63 °F, heating load is zero

- The number of hours spent at each temperature were separated into temperature bins and divided by the total number of hours in the heating season to arrive at the fractional bin hours n_j/N

Bin number, j	Bin temperature range °F	Representative temperature for bin °F	Fraction of total temperature bin hours, n_j/N
1	64-60	62	0.017
2	59-55	57	0.044
3	54-50	52	0.077
4	49-45	47	0.136
5	44-40	42	0.181
6	39-35	37	0.177
7	34-30	32	0.133
8	29-25	27	0.081
9	24-20	22	0.062
10	19-15	17	0.038
11	14-10	12	0.023
12	9-5	7	0.013
13	4-0	2	0.008
14	(-1) - (-5)	-3	0.01

DOE and EPA welcome comment on the approach to deriving the load line and fractional bin hours.

Defrost Factors and Test

- A significant number of hours in the heating season take place at temperatures where frost is likely to form on the outdoor coils of a room heat pump. If frost is not dispelled, ice build-up can lead to damage to the refrigeration system.
- Both active and passive defrost approaches require pausing heating operations to dispel frost, leading to reduced performance. As previously discussed, the draft test method only accounts for active defrost operation at this time.
- To limit test burden, the test method provides two options to account for the losses associated with active defrost operation -
  - Conduct a defrost test *or*
  - Use standard factors to account for defrost performance
- The standard defrost degradation factors are applied to the capacity and power equations for temperatures between 42 °F and 17 °F
  - For capacity, the standard factor is 0.9
  - For power, the standard factor is 0.985
- The standard factors are determined based on data collected for central ACs.
- The defrost test method is based on the DOE test procedure for central ACs in Appendix M1

DOE and EPA welcome comment on the appropriate electrical power frost degradation coefficient for room heat pumps or the submission of any room air conditioner-specific data regarding frost performance.

Resistance Heat Lockout and Controls Verification Procedure

- DOE and EPA are aware that while under test, some mild climate room heat pumps operate the resistance heater at temperatures for which heat pump-only operation is expected.
- The test method acknowledges this behavior and allows manufacturers to provide instructions to disable the resistance heater to better represent typical field operation.
- If instructions are used to disable the resistance heater, a resistance heat controls verification procedure (CVP) is conducted when verifying performance of these models to ensure tested performance reflects typical consumer operation.
- The CVP verifies whether resistance heat would be likely to engage under real world conditions by investigating how the unit responds to changes in indoor room temperature with the unit thermostat set to a temperature near the indoor room temperature.

DOE and EPA welcome comment on the resistance heat lockout provision and the suggested controls verification procedure.

Accounting for Cyclic Behavior

- When compressors cycle on and off in response to low heating load, some heating performance is lost.
- Cycling occurs for single-speed units when the building load is less than the unit capacity and for variable-speed units when the building load is less than the low-speed capacity.
- The calculation of HEER as a seasonal metric accounts for performance losses due to inefficiency of cycling.
- These equations use a heating degradation coefficient of 0.38 to quantify the cyclic performance losses in a part load factor that scales the total energy used in heating mode.
  - Based on data from PTHPs
  - No data are currently available for room heat pumps

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Webinar Wrap-up and Comment Deadline

- EPA and DOE appreciate the opportunity to discuss the Draft 1 Test Method with stakeholders today
- Comments are due on **January 9, 2024**
- Please send all comments to:

appliances@energystar.gov

Unless commenters indicate that written feedback is confidential, all comments will be posted to the ENERGY STAR Room Air Conditioner Version 5 Product Development webpage (https://www.energystar.gov/products/room_air_conditioner_specification_version_5_2)

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Timeline

Event	Date
Draft 1 Test Method Published	December 5, 2023
Draft 1 Test Method Webinar	**December 12, 2023**
Draft 1 Test Method Comments Due	January 9, 2024
Publish Final Draft Test Method	*February 2024*
Publish Final Test Method (effective date is same as the published date)	*February 2024*

Open Discussion

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Thank you!