



IEA Technology Collaboration Programme
on Energy Efficient End-Use Equipment

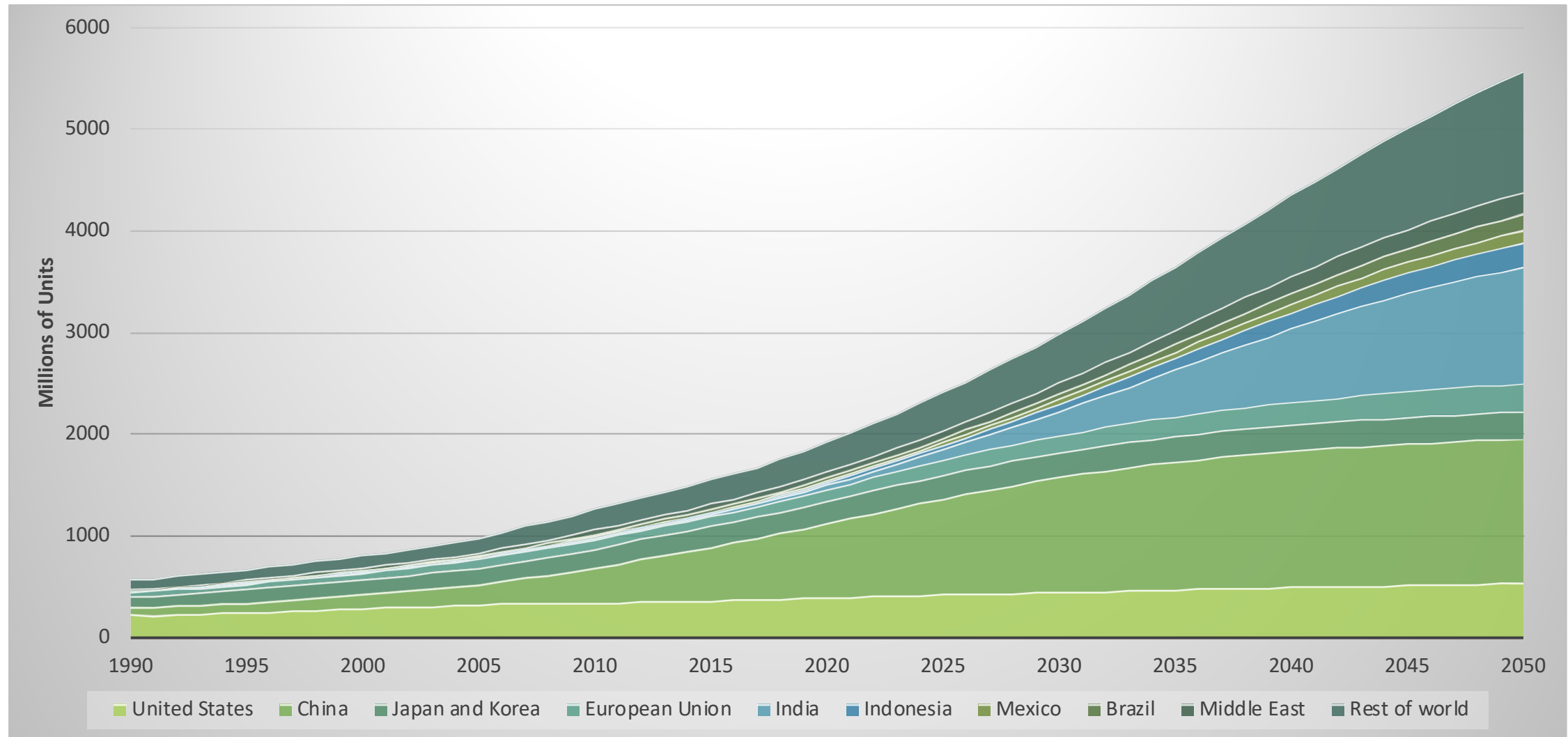
Residential Test Methods for Air Conditioners

The Importance of Robust Test Methods for Energy Efficiency

John Cymbalsky, US Department of Energy

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The Global Air Conditioner Stock: 1990 - 2050

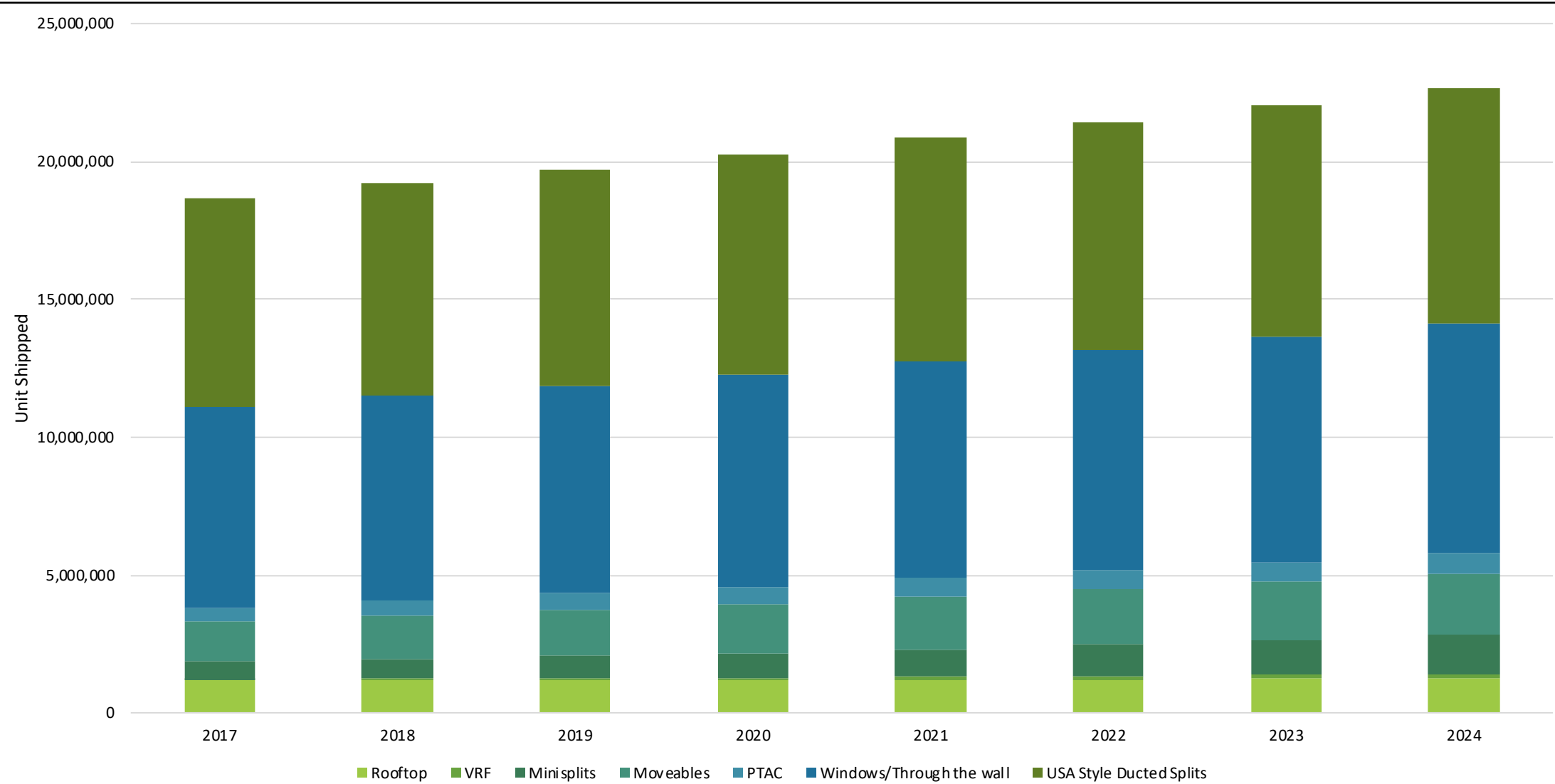


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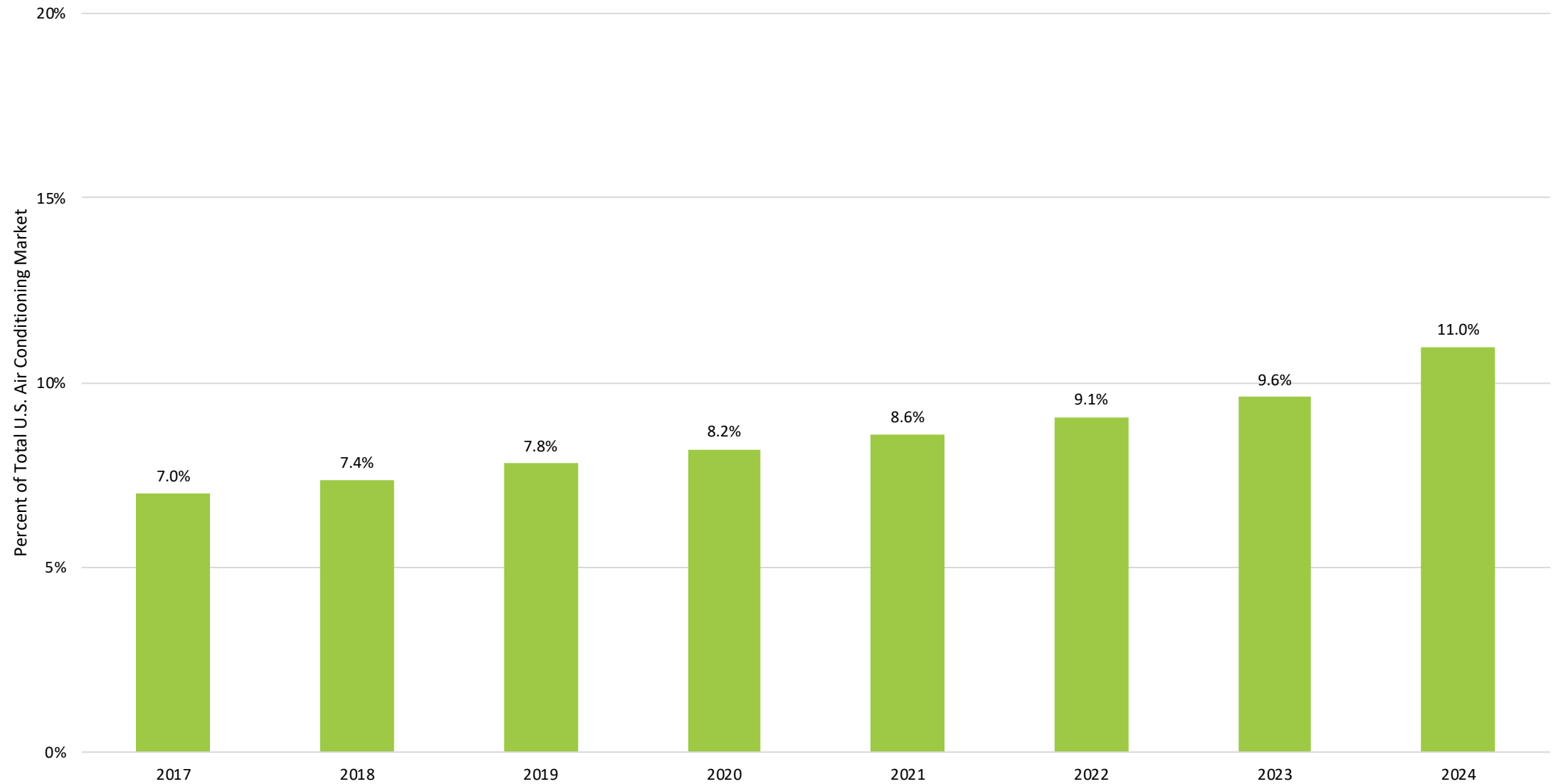
Source: IEA Future of Cooling, 2018.

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U.S. Air Conditioner Shipments by Product



Share of Inverters in the U.S. Air Conditioning Market



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Source: BSRIA: Minisplits and VRF in the USA. 2018, U.S. Department of Energy, Energy Conservation Standards for Small, Large, and Very Large Package Air Conditioning and Heating Equipment, Residential Central Air Conditioners and Heat Pumps, and Commercial Heating, Air Conditioning, and Water Heating Equipment.

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Domestic Air Conditioner Test Standards and Harmonization: Summary of Findings

Jessica DeWitt, Cadeo Group



Overview and Goal of Research Project

- Test procedures are foundational to national regulatory energy efficiency programs.
- This project's goal was to identify key differences to facilitate potential harmonization efforts and areas for improvement.
- Improved harmonization can reduce test burden, share best practices internationally, and allow for better comparison of equipment across countries.
- Cadeo and Stem Integration Services reviewed and compared a selection of international test methodologies for domestic air conditioners designed to provide cooling or heating and cooling.

Test Procedure Review & Findings

This research reviewed and compared the test procedures shown in this table, with primary focus on:

- Scope of Products Covered
 - Ductless Split System Air Conditioners
- Test Method
 - Two test methods allowed in almost every test procedure
- Secondary Energy Uses Tested
 - All test procedures rated some for of secondary energy use
- Ability to Rate Fixed & Variable Capacity Equipment
 - All test procedures had a method for testing and rating both fixed and variable capacity equipment.

Country	Referenced Test Procedure
Australia/ New Zealand	AU/NZS 3823.1.1:2012 AU/NZS 3823.4.1:2014 AU/NZS 3823.4.2:2014
China	GB/T 7725-2004
EU	BS EN 14511:2018
Japan	JIS B 8615-1:2013 JIS B 9612:2013
Korea	KS C 9306 2017
US	10 CFR 430 Subpart B Appendix M/Appendix M1
International	ISO 5151



Efficiency Metrics & Test Conditions Findings

- Most countries require some form of seasonal energy efficiency metric to rate equipment efficiency
- Seasonal metrics rely on multiple temperatures
 - Test condition temperatures
 - High temperature test condition is nearly fully aligned with ISO 5151 across all test procedures studied
 - Low temperature (part load) test conditions vary, with some countries calculating energy consumption at temperatures lower than the low temperature test condition
 - Extrapolation of performance to low temperatures can be inaccurate
 - Local climate rating temperatures
 - Since local climates vary, these temperatures are not standardized
 - Regional weighted temperatures used to calculate SEER don't appear to directly correlate to SEER values



Harmonization opportunities

Standardization of low temperature test conditions represents an opportunity for harmonization.

- May also help seasonal efficiency metrics be more relatable between countries
- A lower test temperature would minimize extrapolation of load curve during seasonal energy efficiency calculation

Standardize secondary energy uses considered

- Results in more comprehensive and consistent assessment of energy performance

Other opportunities for harmonization:

- Standardize refrigerant line length and/or charge
- Standardize equipment nomenclature & terms



Opportunities for Improvement

All countries include Variable Capacity Testing, but approaches could be improved to better characterize performance, especially at part load conditions.

- Current procedure fixes compressor speed at part load condition
 - Does not accurately represent field operation
 - Load-based test procedures have been developed to dynamically test variable capacity equipment
 - Questions about ensuring reproducibility of results
- Current seasonal efficiency calculations vary between fixing degradation coefficient and measuring it
 - Accurately characterizing degradation coefficient is important for correctly anticipating seasonal efficiency



Summary

- Reviewed test procedures from 6 countries + international standard
- Generally aligned, but some opportunities for harmonization of test methods
- Also opportunity to improve testing of variable capacity equipment
- Improved harmonization can reduce test burden, share best practices internationally, and allow for better comparison of equipment across countries

Next Steps: Further evaluating test methodologies for variable speed air conditioners and heat pumps



Summary of the development activities in the EU for testing residential air conditioners

European Commission, DG Energy, Veerle Beelaerts

Energy efficiency requirements for residential air conditioners



Residential air conditioners
and heat pumps (≤ 12 kW)



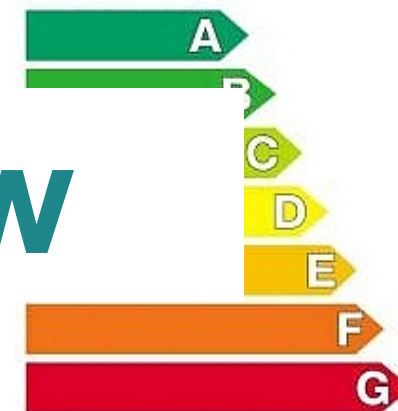
Ecodesign*

Energy labelling**

Energy
efficiency



Under review



*Regulation (EU) No 206/2012

**Regulation (EU) No 626/2011

Basis for setting requirements – seasonal efficiency (SCOP and SEER)



Tested &
rating

EN 14825



- energy efficiency representative of the cooling and heating season (seasonal efficiency, i.e. SEER and SCOP)
- uses same basic principles as standard series ISO 16358 (ISO TC86 SC6)

Concerns with the current testing method (1)

The current test method doesn't require manufacturers to take into account ***thermal comfort***:

- In cooling mode ***45% of the units do not dehumidify*** (data from calculations from an EU manufacturer) -> dehumidification is necessary to ensure thermal comfort
- In heating mode the ***temperature of the air*** that blows out of the heat pump is ***as low as 27°C and commonly lower than 32°C*** -> the temperature of the air that blows out of the heat pump (supply air temperature) should not be below 32 °C (temperature of the skin) and probably closer to 40 °C to ensure thermal comfort.

In reality, when thermal comfort is not ensured, the end-user will change the set point. This will increase cooling/heating loads, and will lead to ***lower real life performances***.

Concerns with the current testing method (2)

The current test method:

- requires *manufacturers to give the settings of the unit* during test
- *bypasses the control*
- *locks the compressor* during test

This is a *worldwide practice*

However, the *performance of units in real life may differ* from the performances measured in standard test conditions

Looking for solutions – ensuring thermal comfort

- **Heating:** set parameters (e.g. set values for air flow rate) such that the *temperature blowing* out of the heat pumps is *between 32°C and 40°C* (under discussion)
- **Cooling:** set parameters (e.g. max sensible heat ratio or limitation on the air flow rate) such that the:
 - *minimum sensible heat ratio is 70% at 35°C ambient temperature, and 95 % at 30°C* (proposal stakeholder), or alternatively
 - *minimum sensible heat ratio is 80 % at 35°C ambient temperature, and 85 % at 30°C* (US AHRI 1230 VRF)

Looking for solutions – independent test method (1)

2 alternative methods have been proposed by stakeholders:

1) The compensation method

- Thermal load imposed to the machine, the unit has to maintain the set point, the compressor and outdoor fan are unlocked, real life control
- Same test conditioners as EN 14825

=> Round robin test is ongoing in cooling mode, for heating more tests might be needed

2) The dynamic method

- Same test method as the compensation method
- 21 times steps of 2.5 hours covering the whole load curve and outdoor air conditions

=> Further work is needed

Proposal currently being discussed

Based on the above, a possible way forward that is currently being discussed:

- Tier 1 (1 year after entry into force, tentatively Mid-2023): improve the thermal comfort and set resource efficiency requirements
- Tier 2 (5 years after entry into force, tentatively Mid-2027): mandatory application of an independent method that doesn't fix the compressor and which fulfils the requirements for a method fit for regulatory purposes
- Review (7 years after entry into force, tentatively Mid 2029)

Thank you



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Improving thermal comfort

HEATING MODE

POSSIBLE SCENARIOS: PRINCIPLES

1. Constant indoor air flow rate, T_{supply} equal to 32 °C at an outdoor air temperature equal to the bivalent temperature (T_{biv});
2. Constant indoor air flow rate, T_{supply} equal to 40 °C at T_{outdoor} equal to T_{biv} ;
3. Variable air indoor flow rate, T_{supply} equal to 40 °C at T_{outdoor} equal to T_{biv} and T_{supply} equal to 32 °C at T_{outdoor} equal to 12°C (rating point D).
4. *New: Variable air indoor air flow rate in line with water based fan coil intermediate temperature regime (variable water temperature outlet) in EN14825 (40/45 @ -10 °C down to --/28 °C @ 12 °C), calculated here based on water outlet temperature with coil effectiveness of 0.85*

Improving thermal comfort

COOLING MODE

POSSIBLE SCENARIOS: PRINCIPLES

1. Ensure minimum SHR of 70 % in A condition, and 95 % in B condition (Daikin proposal)
2. Ensure minimum SHR of 80 % in A condition, and 85 % in B condition (US AHRI 1230 VRF)