SEAD SUPER-EFFICIENT
EQUIPMENT & APPLIANCE DEPLOYMENT

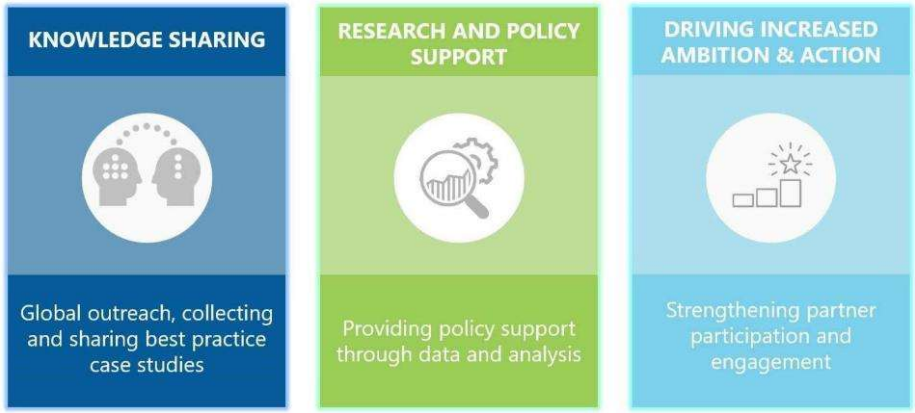
SEAD Webinar
Cooling Solutions: Global Insights for Policy and Practice

Part 1 - July 22nd, 2026

cem Energy Efficiency Hub

SEAD SUPER-EFFICIENT EQUIPMENT & APPLIANCE DEPLOYMENT

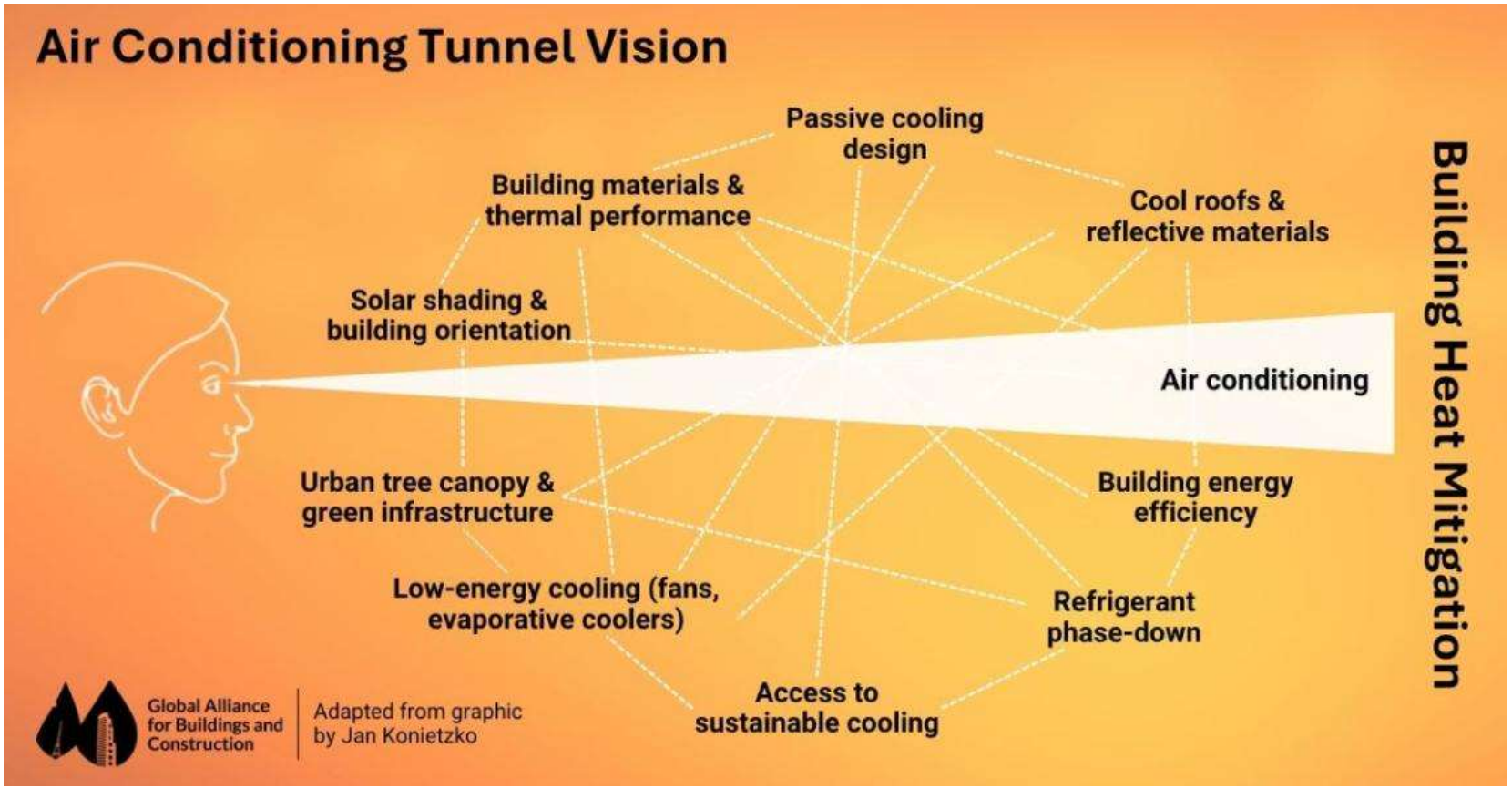
- Voluntary collaboration: 23 governments
- Promote energy efficient appliances, lighting and equipment worldwide
- SEAD is both a Clean Energy Ministerial Workstream and an Energy Efficiency Hub Task



sead@iea.org

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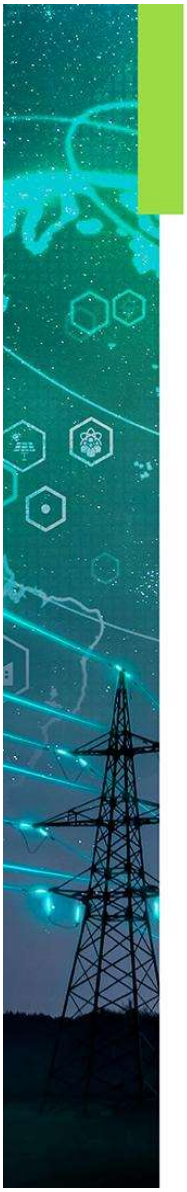
AC essential: Metrics and Standardisation

July 22nd, 2026

4E TCP – Kevin Lane

CLASP – Hu Bo

IEA – Federico Callioni, Sophie Attali

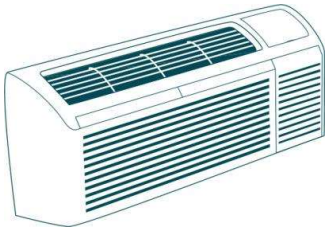


Overview

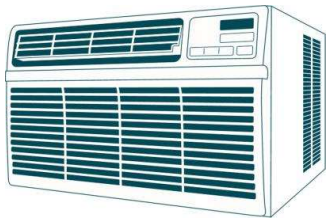
- Types of equipment
- Refrigerants
- Methods of testing efficiency
- Efficiency metrics
- Future testing methods (to reward well controlled AC units)
- Recommendations, resources

Equipment types: the form factors

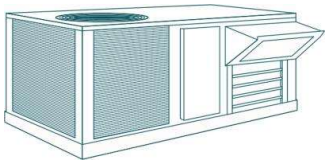
Four dividing lines define the equipment: AC or heat pump · ducted or non-ducted · variable capacity or constant speed · split or packaged.



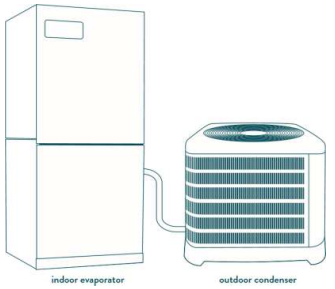
Packaged terminal (PTAC)
Fig 1 — through-the-wall, non-ducted



Window unit
Fig 2 — not permanently installed



Packaged ducted
Fig 4 — evaporator + condenser in one



Ducted split
Fig 5 — separate indoor evaporator



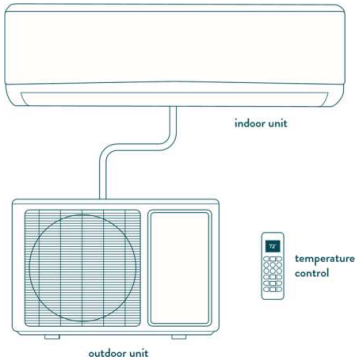
Portable AC

A packaged unit must be ducted — it sits outside and moves air in through ductwork. PTACs and window units are the exception: mounted through the building envelope, they are packaged but non-ducted.

None of these are the scope of today. The scope is permanently installed, non-ducted split system (next slide) — so window and portable units are excluded, as are central packaged systems that condition a whole dwelling.

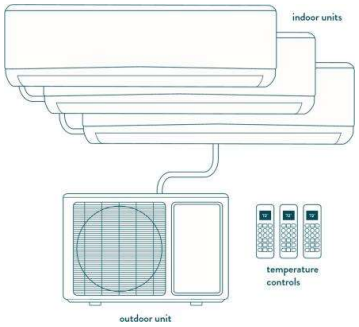
Equipment types: non-ducted split — scope

The flexibility of the non-ducted split has made it the dominant form in many countries. Four configurations, distinguished by refrigerant loops and thermostats:



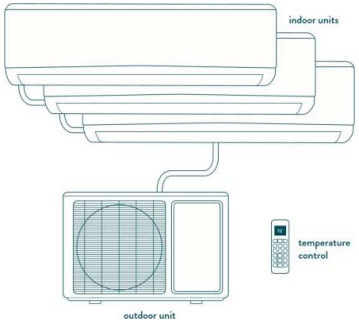
Single split

Fig 6 — one indoor unit, one loop



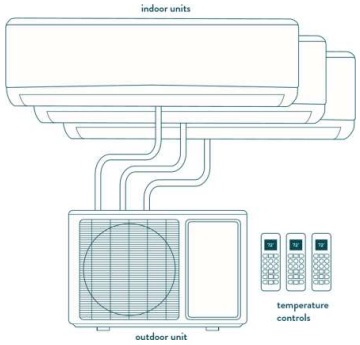
Multi-split

Fig 7 — one loop, indoor units run independently



Multi-head

Fig 8 — one loop, all units on one thermostat

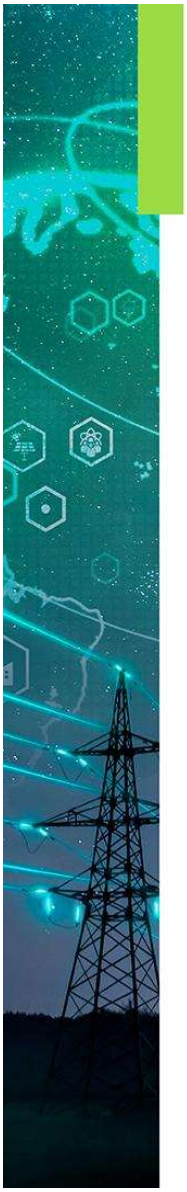


Multi-circuit

Fig 9 — a dedicated loop per indoor unit

Single split is both the most common non-ducted type and the only configuration all ducted splits use.

Coverage differs by economy: Korea excludes split systems with multiple indoor units altogether; China covers single and multi-split; ISO 5151 limits splits to multi-splits on a single thermostat, referring the rest to ISO 15042.



Refrigerants in AC equipment: ODP and GWP

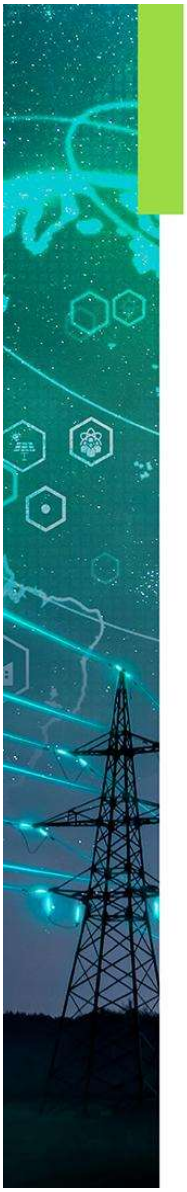
Not covered by the 4E reports — sourced separately. GWP values are IPCC AR4, 100-year: the basis the Kigali Amendment, the EU F-gas Regulation and the US AIM Act are written against.

Refrigerant	ODP	GWP (AR4)	Comments
R-22 HCFC	0.055	**1,810**	The legacy refrigerant. Ozone-depleting, so phased out under the Montreal Protocol — but still in service equipment.
R-410A HFC blend	0	**2,088**	Solved ozone, not climate. The incumbent split-system refrigerant, now being displaced.
R-32 HFC	0	**675**	A 68% cut on R-410A. Mildly flammable (A2L). Widely adopted across Asia and Europe.
R-454B HFO/HFC blend	0	**466**	A 78% cut on R-410A. A2L. The main US replacement for R-410A.
R-290 propane	0	**3**	Natural refrigerant. Highly flammable (A3), which constrains charge size and application.
R-1234yf HFO	0	**<5**	Very low GWP. Established in automotive air conditioning.

The direction of travel is regulatory, not technical

EU — since 2025, new single splits under 3 kg charge must be below GWP 750; from 2029 all splits up to 12 kW must clear GWP 150. · US — since January 2025, new residential AC may not be manufactured or imported above GWP 700.

Note the EU included GWP in its MEPS requirements: the SEER threshold is 4.60 for GWP>150 equipment but 4.14 for GWP<150 — an explicit efficiency allowance for choosing a lower-GWP refrigerant.



Test methods: two ways to measure capacity

Calorimeter room

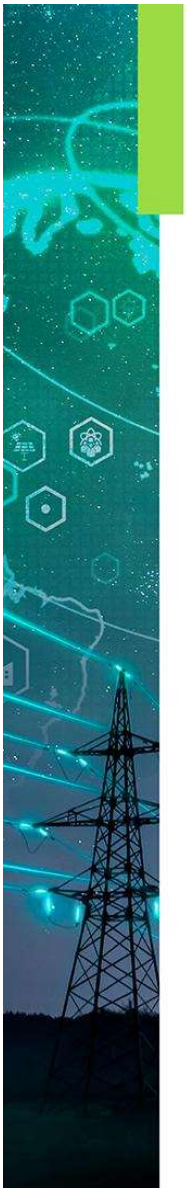
- Measures the energy needed to hold a room at constant temperature. That energy equals the cooling capacity.
- **Very accurate, low risk of error.**
- Slower and more expensive: ~14 hours at two test points, and ~16% more costly than air enthalpy.

Indoor air enthalpy

- Measures air enthalpy entering and leaving the indoor unit. Enthalpy change × airflow = capacity.
- **Cheaper and quicker — the baseline.**
- Less accurate. ~12 hours at two test points.

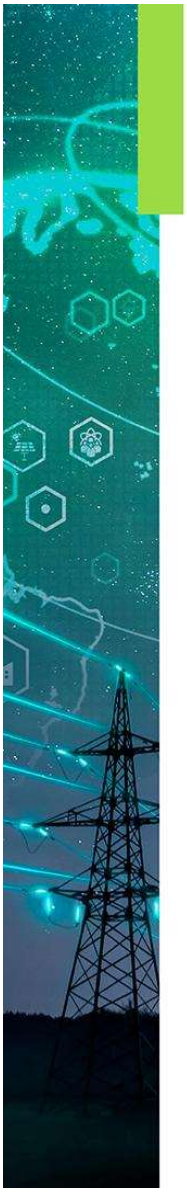
What drives burden

- **Not the method so much as the number of test points.**
- Two points: ~12–14 h (Australia/NZ, China, EU, Korea).
- Five points: ~18–23 h (Japan, US) — roughly 1.5× the cost.



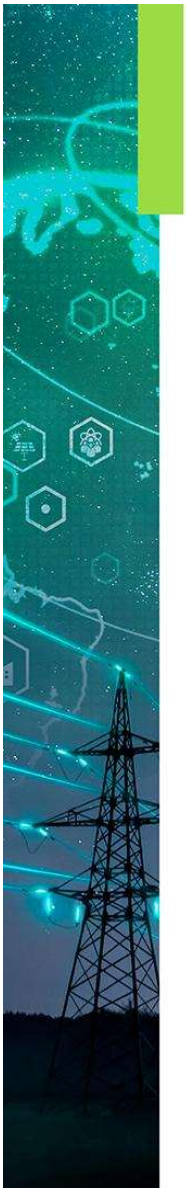
Test conditions — and the variable-capacity problem

- Full load is the easy part. Every economy studied is essentially aligned with ISO 5151: 27°C dry bulb / 19°C wet bulb entering indoor, 35°C entering outdoor. Only the US deviates slightly, on indoor wet bulb.
- **Part load is where they diverge — and it matters more**
  - Cooling test temperatures range from 19.4°C to 30.6°C depending on the economy; seasonal weighted-average outdoor temperature runs from 23.0°C (EU) to 29.3°C (US).
  - Three of the six calculate seasonal performance at temperatures outside their own test range — extrapolating rather than interpolating, which erodes accuracy. Hence the report's recommendation of a standard 20°C low-temperature test condition.
  - Outdoor wet bulb is not controlled for this equipment. Its effect on cooling efficiency is not well defined — a real source of uncertainty, and worse at part load, where dehumidification falls away quickly.
- **The variable-capacity problem**
  - Every established procedure tests variable-capacity units at fixed compressor speeds — which is not how they run in the field. The lab must get the manufacturer to upload software or attach equipment to force a test mode.
  - That opens the door to interference: a manufacturer could in principle bypass features that would lower efficiency. And a 2019 dynamic-testing study found COP at low part-load ratios was over 50% lower when units were allowed to modulate.



Scope: seven procedures, overlapping but not identical

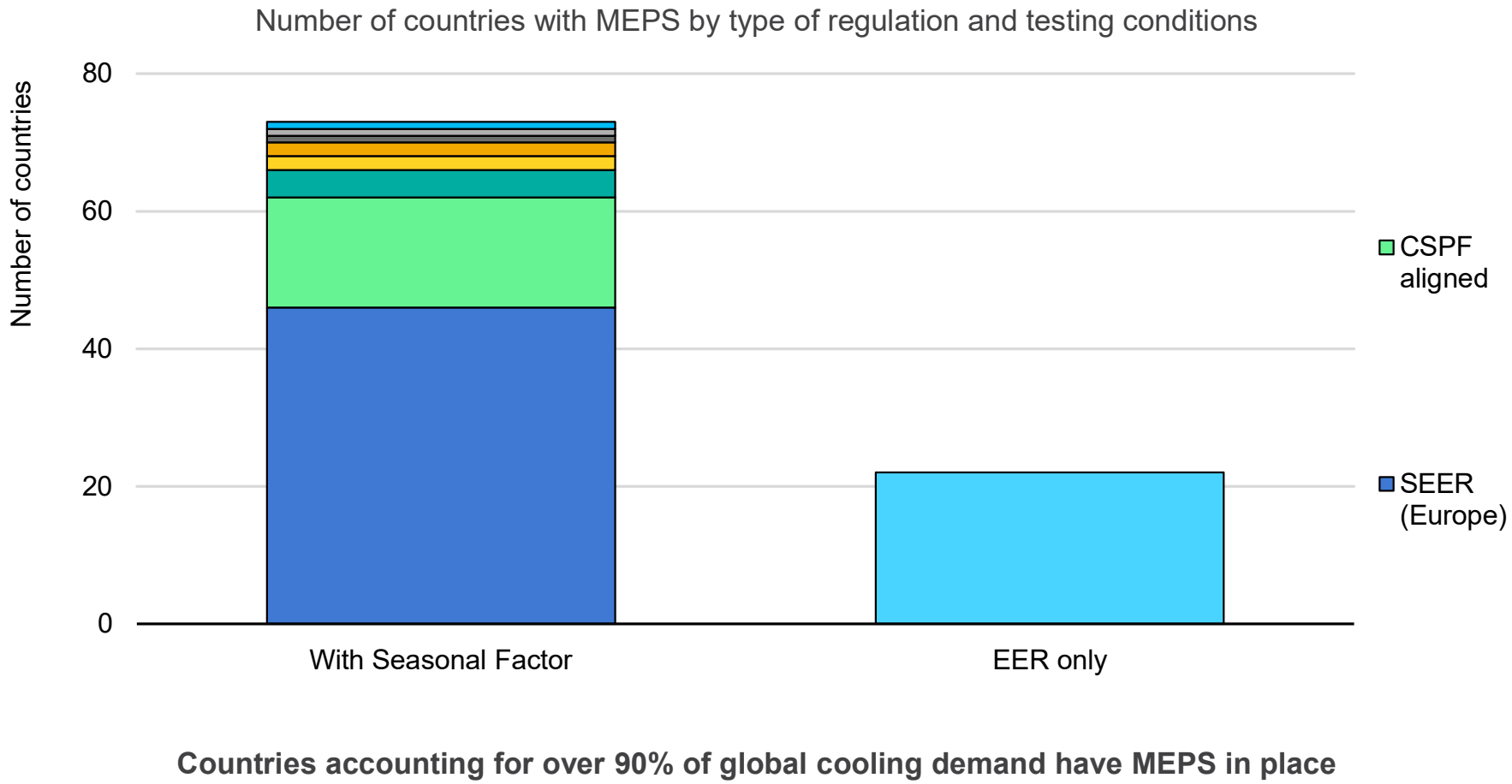
- Each economy tailors its procedure to the products common in its own market — so scope, capacity ceiling and configuration coverage all differ.
  - Australia/NZ — AS/NZS 3823: non-ducted single split, up to 8 kW. Adopts ISO 16358, which pulls in ISO 5151, 13253 and 15042.
  - China — GB/T 7725-2004: non-ducted single and multi-split, up to 14 kW. Water- or air-cooled.
  - EU — BS EN 14511:2018: ducted or non-ducted single split, up to 35 kW.
  - Japan — JIS B 8615-1: non-ducted single split, up to 10 kW. References ISO 5151 with national adjustments.
  - Korea — KS C 9306: ducted or non-ducted single split, up to 35 kW. Excludes multiple indoor units.
  - United States — 10 CFR 430 subpart B, Appendix M / M1: ducted or non-ducted single split, up to 19 kW. Covers multi-head, multi-split (incl. VRF) and multi-circuit.
  - ISO — 5151: non-ducted single and multi-split, up to 10 kW.
- **Every one of them tests by air enthalpy; all but the US also permit calorimetric. All cover both fixed and variable speed. All measure defrost — but only Australia, the EU and the US measure standby or off-mode power.**



Efficiency metrics: full-load vs seasonal

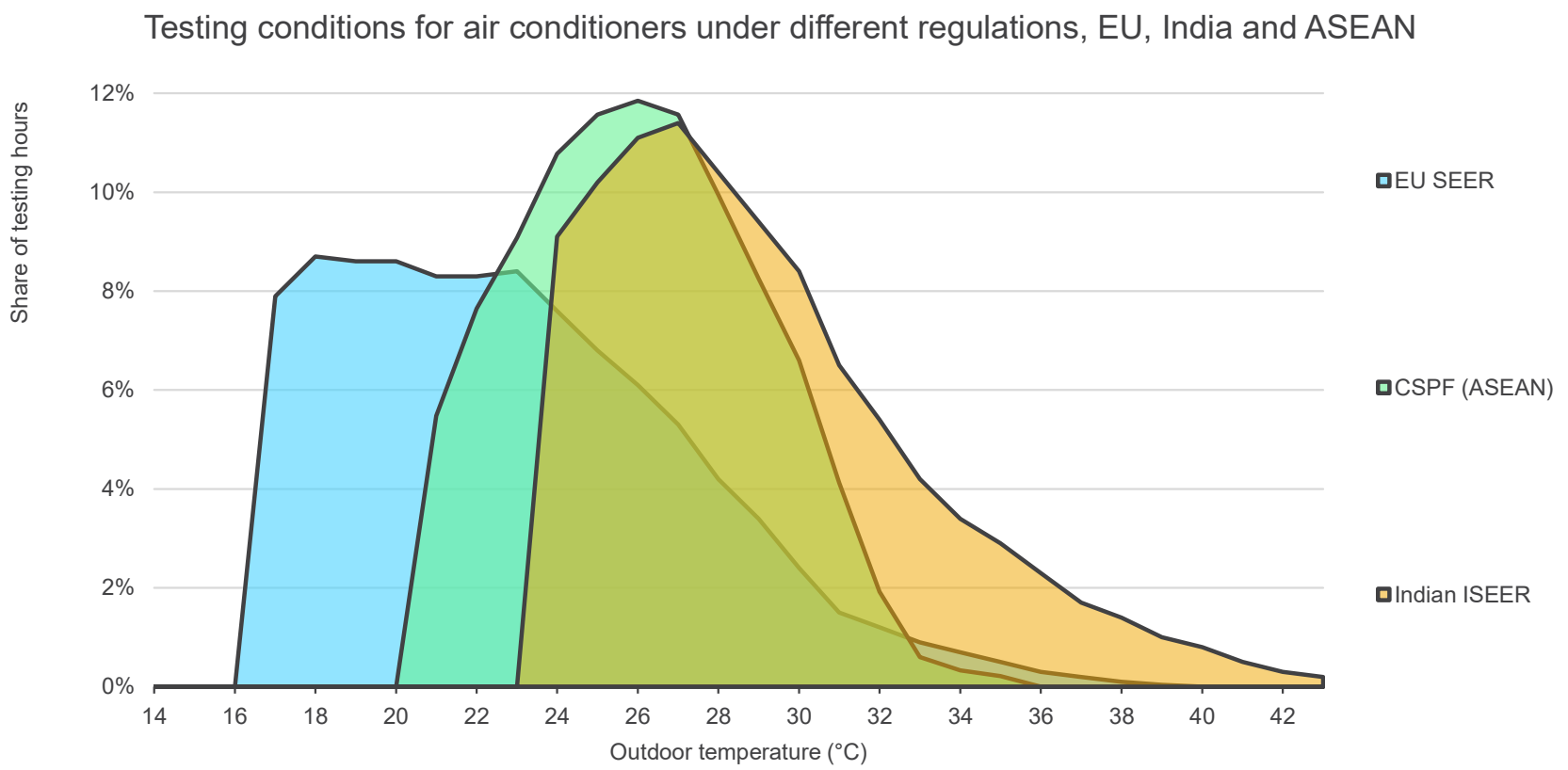
- **Full load — EER (cooling) and COP (heating)**
  - The ratio of capacity to electricity at maximum deliverable capacity, at a single condition (35°C / 24°C). Established, widely used, and well aligned internationally.
  - However, peak cooling conditions occur in under 5% of annual operating hours — and rating on full load alone pushes manufacturers to optimise for it at the expense of part (or seasonal) load.
- **Seasonal — SEER, SCOP, CSPF, HSPF, APF, CEER**
  - A weighted average across a range of outdoor temperatures, intended to represent a whole season. Increasingly replacing EER for MEPS and labelling.
  - Australia EER/SEER/SCOP · China EER/SEER · EU SEER/SCOP · Japan APF (a combined average of CSPF and HSPF — the only single metric covering both modes) · Korea EER/CSPF/HSPF · US SEER/HSPF, moving to SEER2/HSPF2.
- **The catch: same name, different number. Rating conditions are set nationally, and some economies use several climate zones. Seasonal metrics are therefore not comparable between regions even when identically named.**
- Regulation – Energy efficiency requirements - Japan is also the only economy that sets weighted-average efficiency targets across a manufacturer's product line (Top Runner), rather than a minimum any single product must clear (MEPS, EcoDesign, Energy Conservation Standards).

Regulations vary across countries



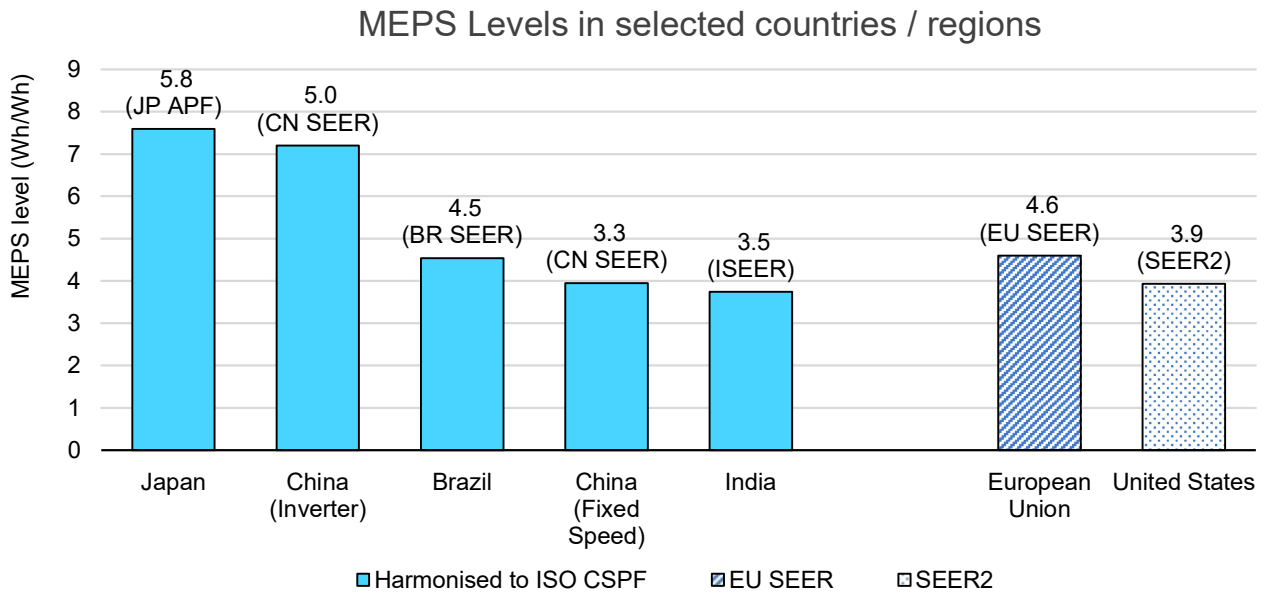
Countries accounting for over 90% of global cooling demand have MEPS in place

Testing conditions shape efficiency levels and define technical design



An AC optimised for European conditions will perform worse in India or ASEAN

Minimum Energy Performance Standards (MEPS) Levels



- **Energy efficiency performance metrics cannot be directly compared**
  Test temperatures, climate bin hours and other assumptions differ.
- **The IEA methodology harmonises to the ISO CSPF metric for comparability**. Label in chart is in original metric.
  The European Union and United States use strongly diverging methods that cannot be directly harmonised in that framework.
- **Brazil and India have updated their levels in 2026** with the new level in Brazil only applying to manufacturing and import and not yet for sales.
- **Japan** uses the Top Runner Methodology that does not prescribe a minimum performance level, but an average level per manufacturer.
  In practice, close to all equipment sold considers this level as minimum.
- In **China**, inverters account for about 98% of the market, but fixed speed ACs are not yet formally phased out.

Towards testing unlocked controls

The problem

Variable-capacity “inverter-driven” ACs and heat pumps are promoted as the most efficient equipment available.

Regulatory tests lock the compressor and fans at fixed speeds. Repeatable — but blind to the native controls that decide real performance.

The 4E work

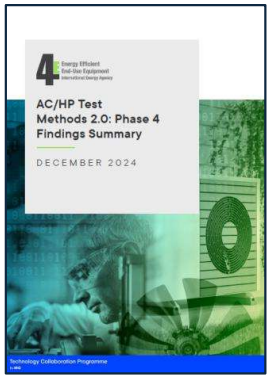
Four phases, September 2020 – December 2024, for 4E by Cadeo Group.

Phase 1 scoped the key issues; Phase 2 ran 439 tests over 11 weeks in two labs; Phase 3 wrote the 4E Test Method; Phase 4 round-robin at four labs in three 4E countries.

The 4E result

A load-based controls verification method: lab-to-lab variance under 10%, and it catches efficiency differences that locked-controls testing hides.

Already embedded in AHRI 210/240-2024 and the US federal test procedure.



Concept - Fixed parameter

Load: balances with the unit’s capacity.

Controls: LOCKED.

Example: US DOE regulatory test.

Reproducible and cheap — but cannot see the native controls at all.

Adequate for single-speed units, which have no modulating controls to miss.

Concept - Pre-defined load

Load: fixed; not affected by how the unit performs.

Controls: NATIVE.

Example: the 4E Test Method; ENERGY STAR CCHP CVP; DOE CCHP Challenge CVP.

Unlocked controls, still stable enough to reproduce lab to lab. 4E chose this.

Concept - Adaptive load

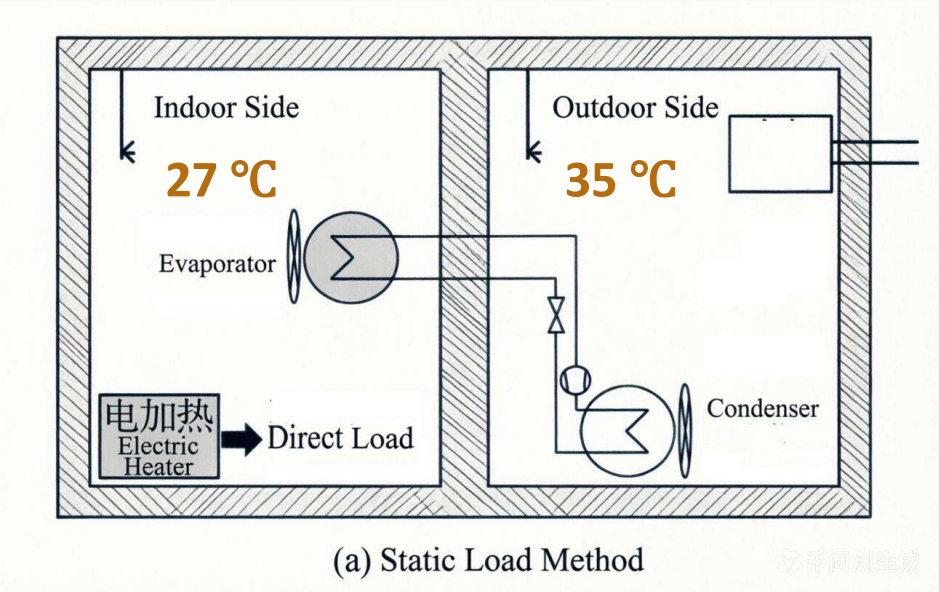
Load: adjusts in response to the unit, usually via a virtual building emulator.

Controls: NATIVE.

Example: CSA SPE-07; Waseda University method; AHRI 210/240 CVP.

Closest to a real house — and the hardest to make repeatable.

Conventional fixed-condition testing



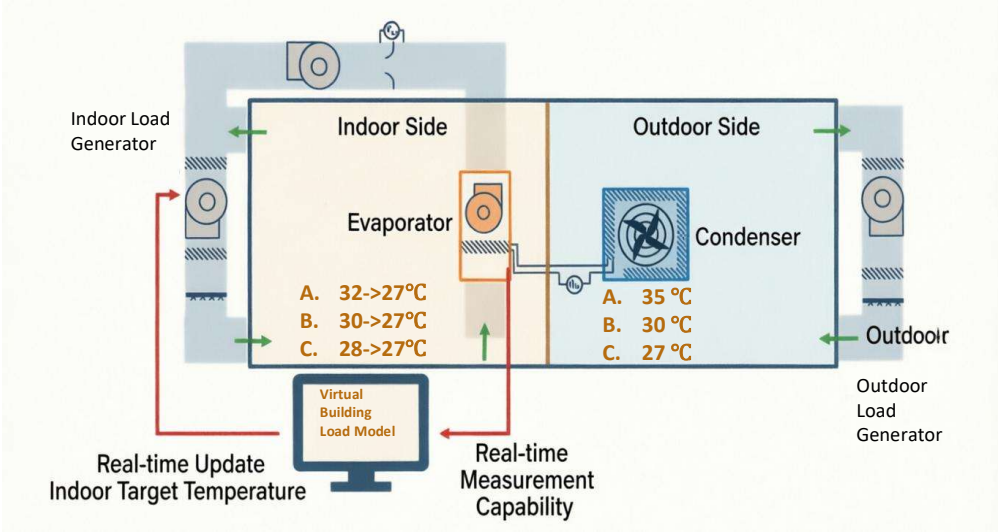
(a) Static Load Method

Two load testing conditions

- Full load at 35°C
- Half load at 35°C

- The indoor and outdoor temperature settings are stable and maintained throughout the test.
- The tested RAC is configured to operate under fixed conditions.

Dynamic load testing method

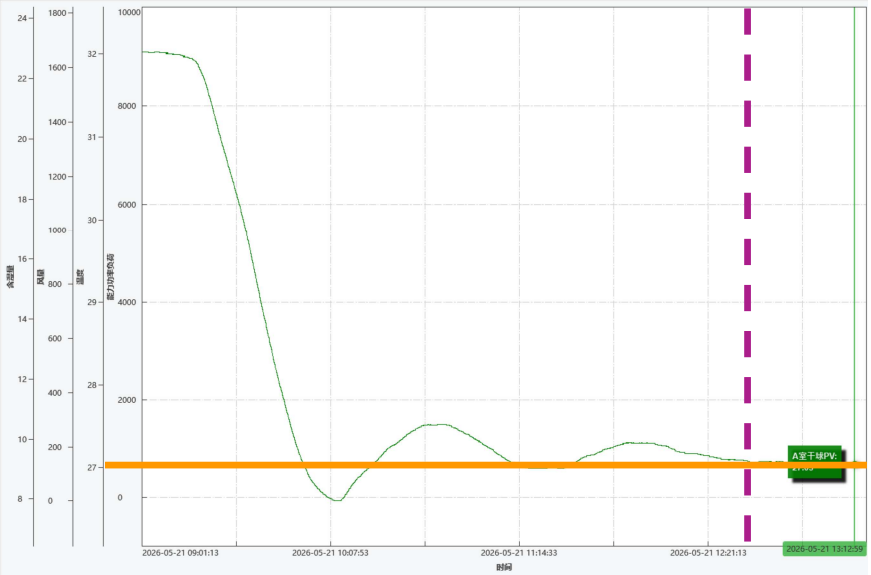


- Testing is conducted under three load conditions (A, B, C as specified on the figure).
- Different indoor and outdoor temperature settings are applied.

  The outdoor temperature is stabilized at its initial setpoint.

  The indoor load is dynamically adjusted by an indoor load generator, determined by a virtual building load model using real-time inputs.
- The tested RAC is configured to operate in free cooling mode.

DLT results: efficiency scores reflect real-world performance



Test duration

4 hours

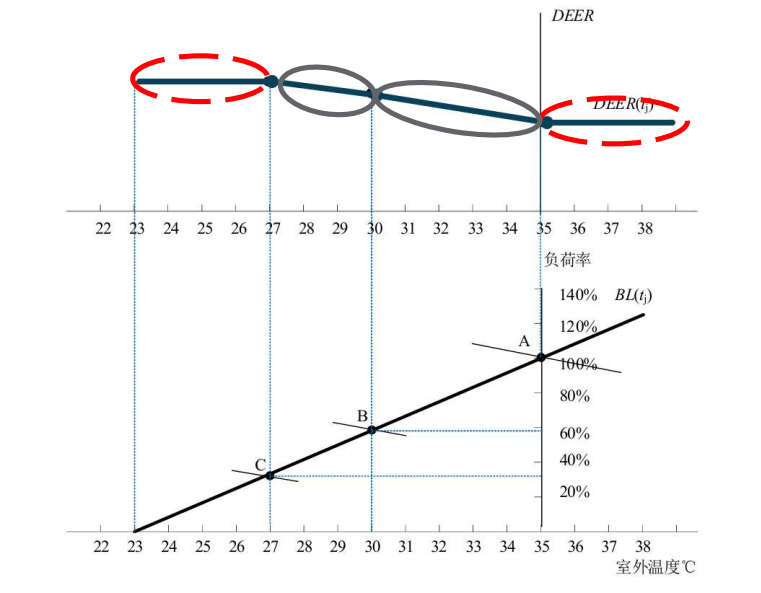
DEER

The ratio of total cooling capacity to total cooling power consumption over the 4-hour dynamic load test period.

DSEER

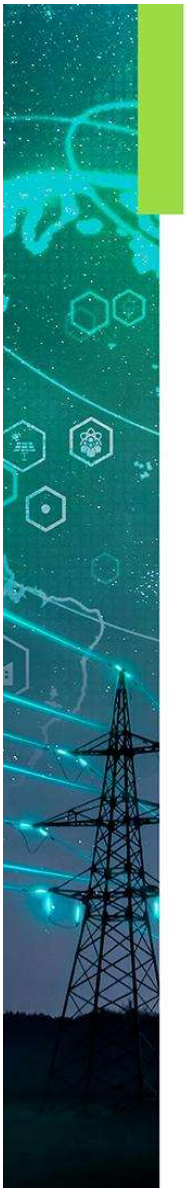
Calculated based on the DEER values obtained at three different load settings and temperature bins.

New method to calculate DSEER



- DEER values within the range of outdoor load temperatures are calculated using **linear interpolation**.
- For temperatures outside this range, the value is taken as a **flat rate** based on the nearest load point.

This approach replaces conventional extrapolation with boundary-point values for temperatures outside the defined load range.



Where harmonisation could actually help

- The report's conclusion is not "align everything". Test methods are already reasonably aligned, and metric differences largely reflect genuine climate differences that are worth keeping.
- **Four practical opportunities**
  - Test conditions — adopt a standard 20°C low-temperature condition, so seasonal efficiency is interpolated rather than extrapolated.
  - Standardised reporting — report performance at each test temperature and the interim variables (standby, degradation coefficient), so one metric can be translated into another transparently.
  - Installation — refrigerant pipe length varies from 5 m upwards between economies; standardise it, or verify charge before testing.
  - Nomenclature — room ACs and their metrics go by many names. Standard naming would make comparison possible at all. Recent IEA developments on Heat Pump taxonomy.
- Beyond those four: for economies without their own procedure, guidance on calculating seasonal metrics for their region or climate zone would do more for harmonisation than any of the above.
- **The longer game: representativeness**
  - Fixed-speed testing of variable-capacity units is the real weakness. Load-based testing is a fix — but the burden must be shown to be worth it, and reproducibility proven. That work is the 4E AC/HP Test Methods 2.0 project (published December 2024).
  - Balance any transition against the harmonisation and rating infrastructure already built on current methods.

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Thank you

Further information:

- IEA
  Cooling a hotter world: El Niño meets strong growth in global electricity demand – Analysis – IEA
  Staying cool without overheating the energy system – Analysis – IEA
  Energy Efficiency 2025 – Analysis - IEA
- 4E TCP www.iea-4e.org/projects/air-conditioners/
- CLASP Air Conditioners - CLASP
- UNEP - U4E
  Country Savings Assessment
  Model Regulation Guidelines for Energy-Efficient and Climate-Friendly Air Conditioners and Air-to-Air Heat Pumps - United for Efficiency

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