International Energy Agency

# Webinar Series on Energy Efficient Cooling - Test Methods for Residential Air Conditioners

*Towards a better way to measure the performance of inverter technologies*

IEA SEAD Webinar, 30 June, 2020
14:00 [CEST]

# Agenda

**Introduction**

- *Emily McQualter, IEA*

**Background**

- *John Cymbalsky, United States Department of Energy*

**Summary of issues in testing variable capacity air conditioners**

- *Jessica DeWitt, Cadeo Group*

**Summary of development activities in EU and North America**

- *Veerle Beelaerts, European Commission*
- *Catherine Rivest, United States Department of Energy*
- *Kimberly Curran, NRCAN Canada*

**Benefits and challenges in achieving international alignment for these products**

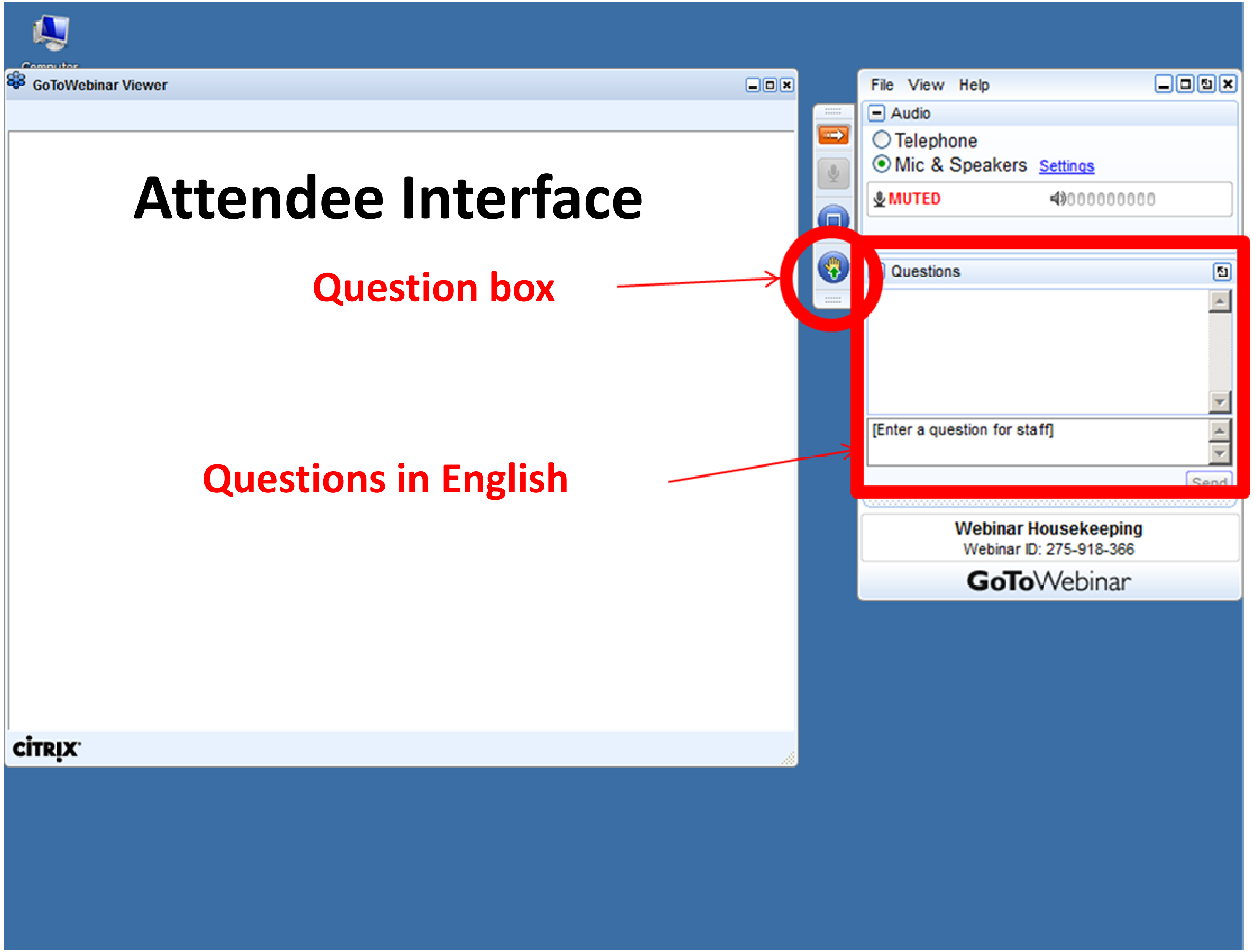
- *Rusty Tharp, Goodman Manufacturing, a member of Daikin Group*

**Q&A Discussion**

**Conclusions & Close**

- *John Cymbalsky, United States Department of Energy*

# How to ask questions



# SEAD: Governments working together to save energy

SEAD SUPER-EFFICIENT
EQUIPMENT & APPLIANCE DEPLOYMENT
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

**Governments working together to save energy, turning knowledge into action, and advancing global markets to encompass energy efficient products**

Operating Agent

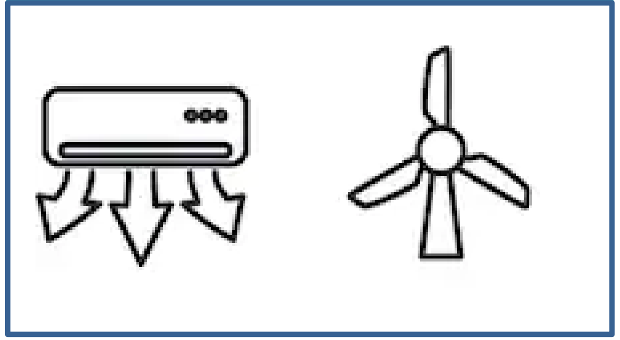
**18** collaborating members

\+ partners

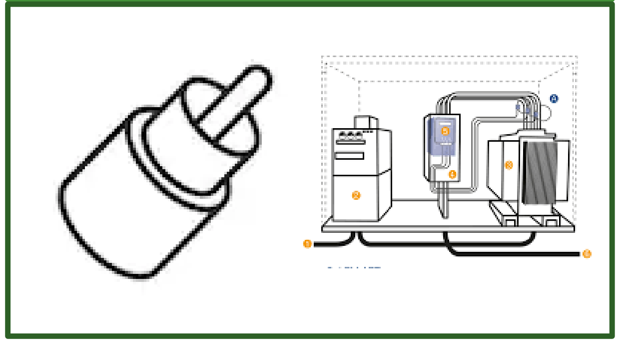
*SEAD is an Initiative under the Clean Energy Ministerial*

# Covering a wide range of equipment and appliances…..

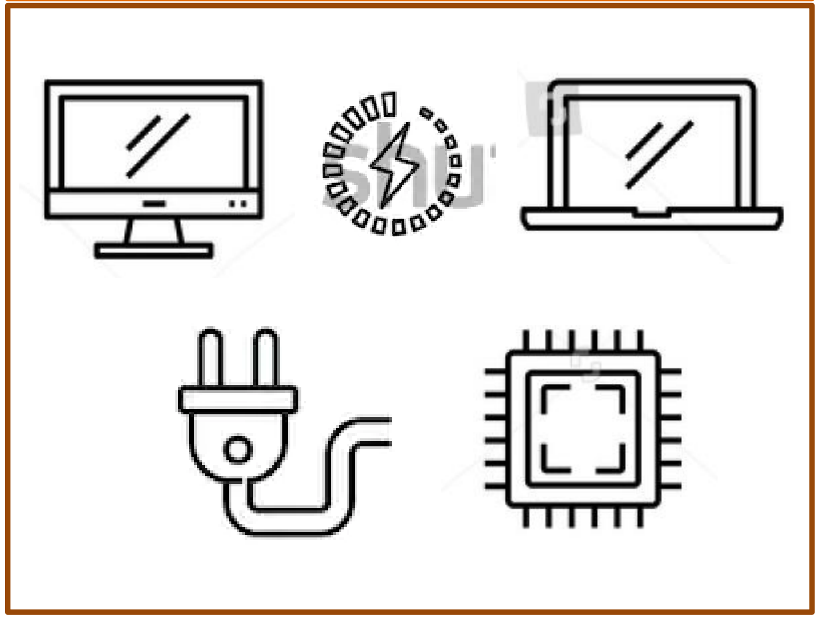
## Cooling



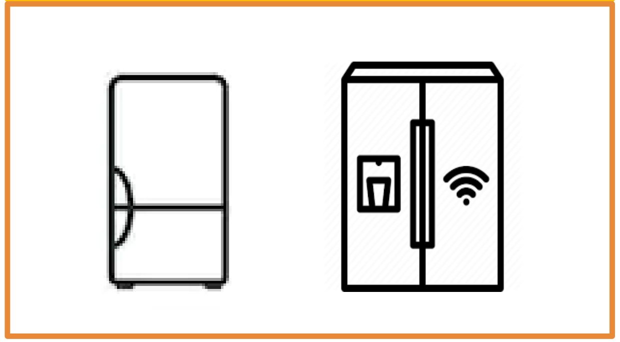
## Equipment



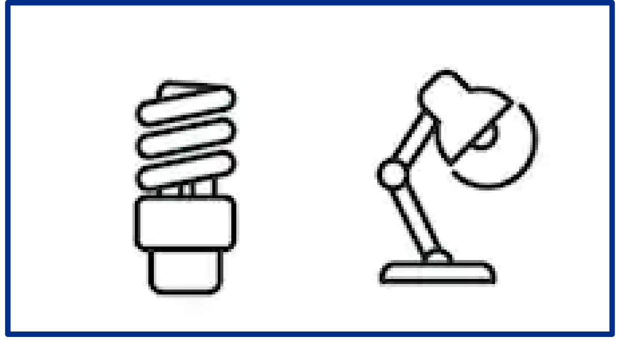
## Electronics



## Refrigeration



## Lighting



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# Proposed activities in the near future

SEAD

- Knowledge exchange portal
- International collaboration events
- Webinar Series
- Master classes
- Tools for policy makers

More information: Emily.McQualter@iea.org



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# IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP)

**4E is one of 38 IEA TCPs**

**All TCPs established under the auspices of the IEA as functionally and legally autonomous bodes**

- 4E TCP platform brings 14 countries and 1 region together to exchange technical and policy information focused on increasing the production and trade in energy efficient end-use equipment.
- 4E collects data, analyses information, shares expertise and pools resources.
- 4E supports & strengthens government policy and regulation.
- 4E disseminates information to Members and others.

## Major technology areas of work

- Electric Motor Systems
- Solid State Lighting
- Electronic Devices and Networks
- Power Electronics and Converter Technology

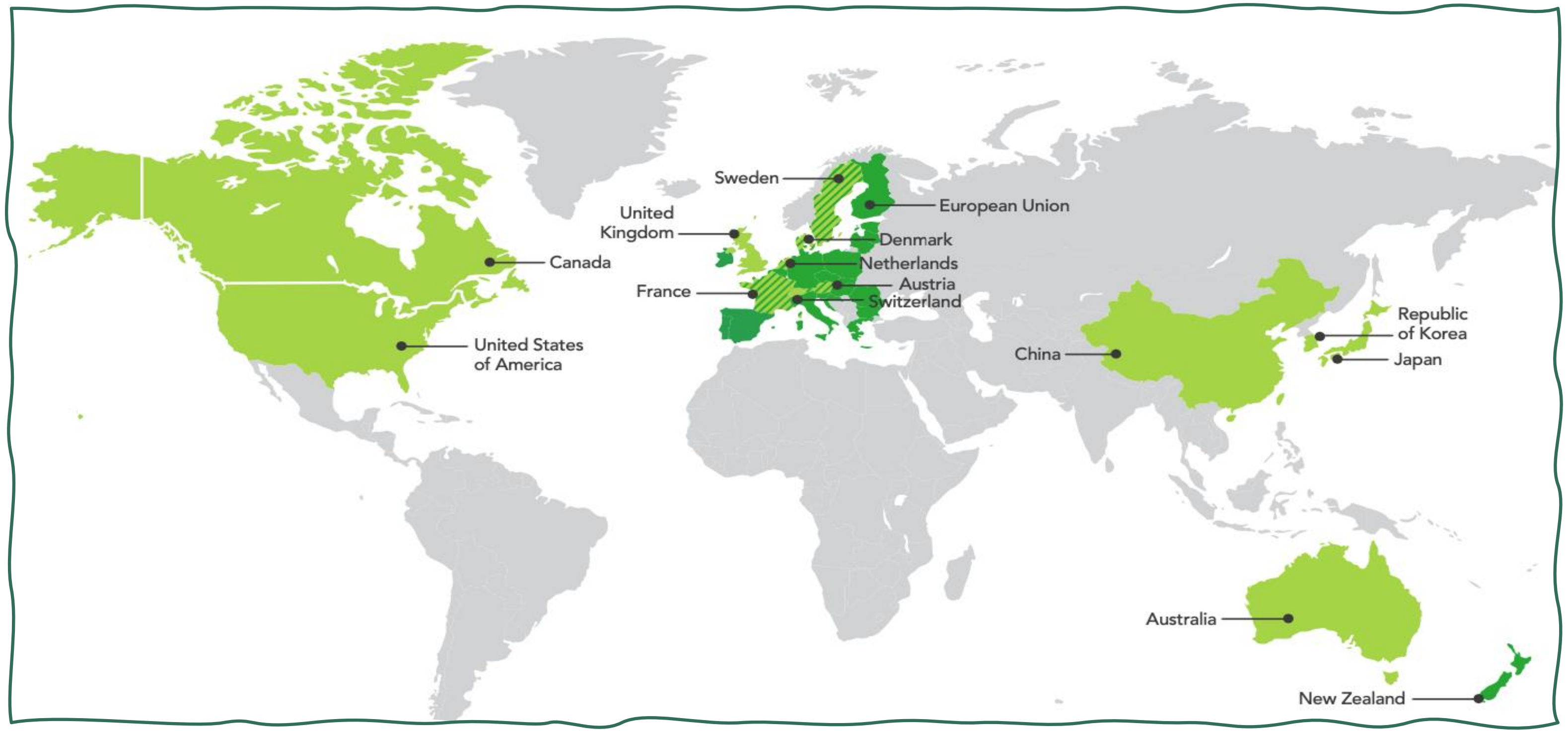
## Cross-cutting themes of work

- Standardisation
- Capacity Building (incl. laboratories)
- Innovation
- Monitoring Verification and Enforcement

# 4E Membership

## 4E Members are government entities involved in product policies

- Australia
- Austria
- Canada
- China
- Denmark
- European Commission
- France
- Japan
- Korea
- Netherlands
- New Zealand
- Sweden
- Switzerland
- United Kingdom
- United States




4E Members tend to be governments with mature energy efficient product policies.

4E works closely with the IEA Secretariat and many other intergovernmental organisations with shared aims, including SEAD.

SEAD tends to focus on emerging economies with developing energy efficient product policies.

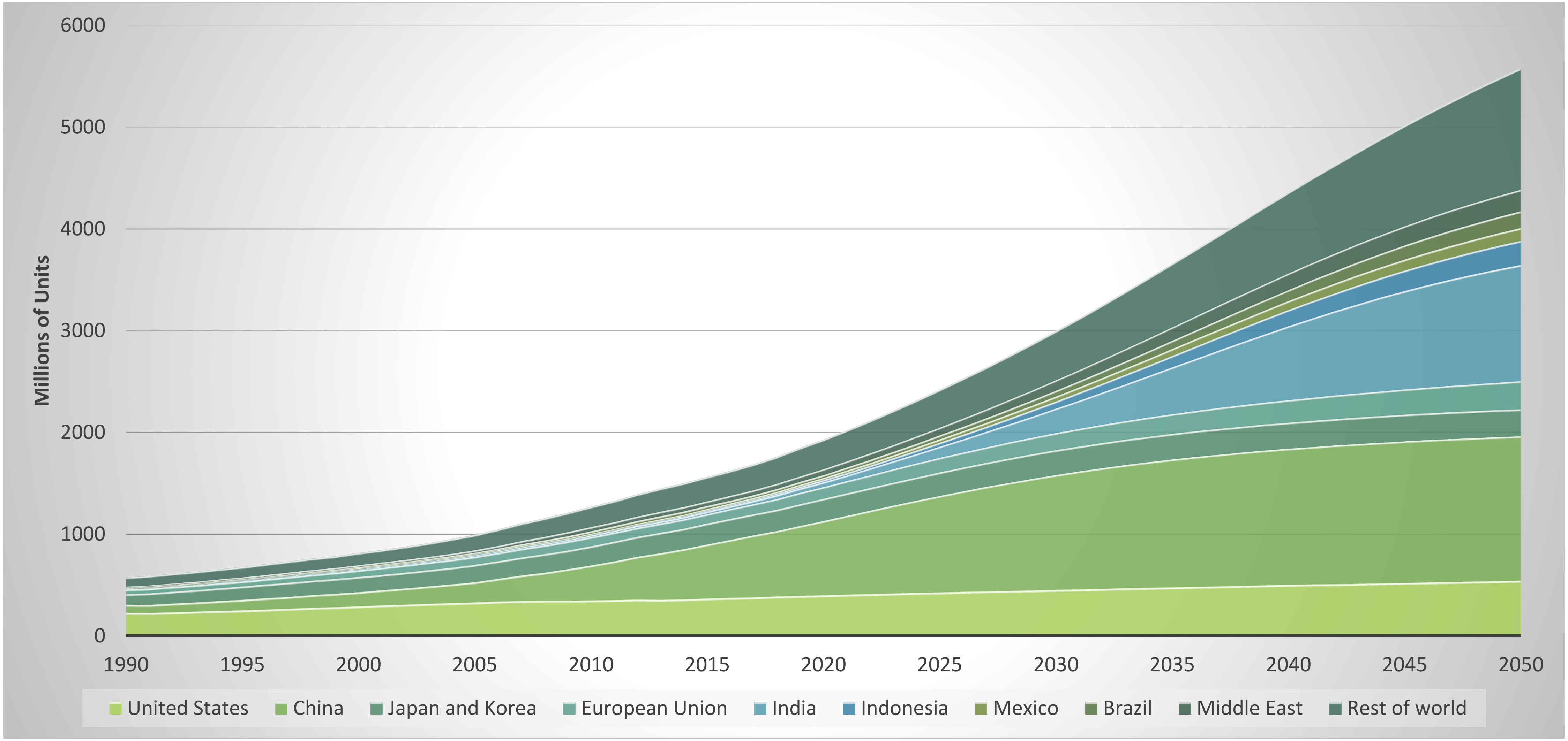
IEA Technology Collaboration Programme
on Energy Efficient End-Use Equipment

# Residential Test Methods for Air Conditioners

## The Importance of Robust Test Methods for Energy Efficiency

John Cymbalsky, US Department of Energy

# The Global Air Conditioner Stock: 1990 - 2050




IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment

Source: IEA Future of Cooling, 2018.

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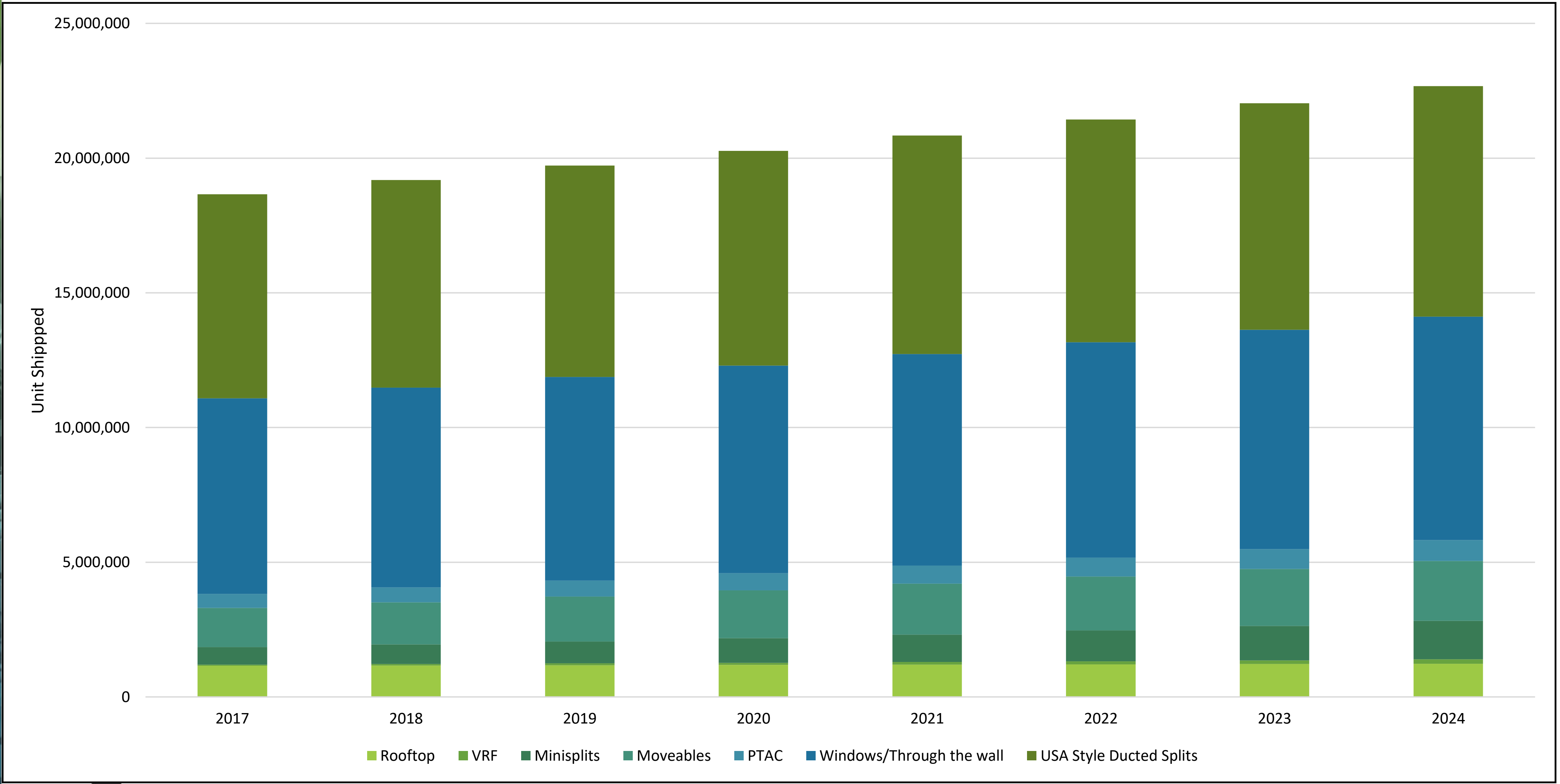
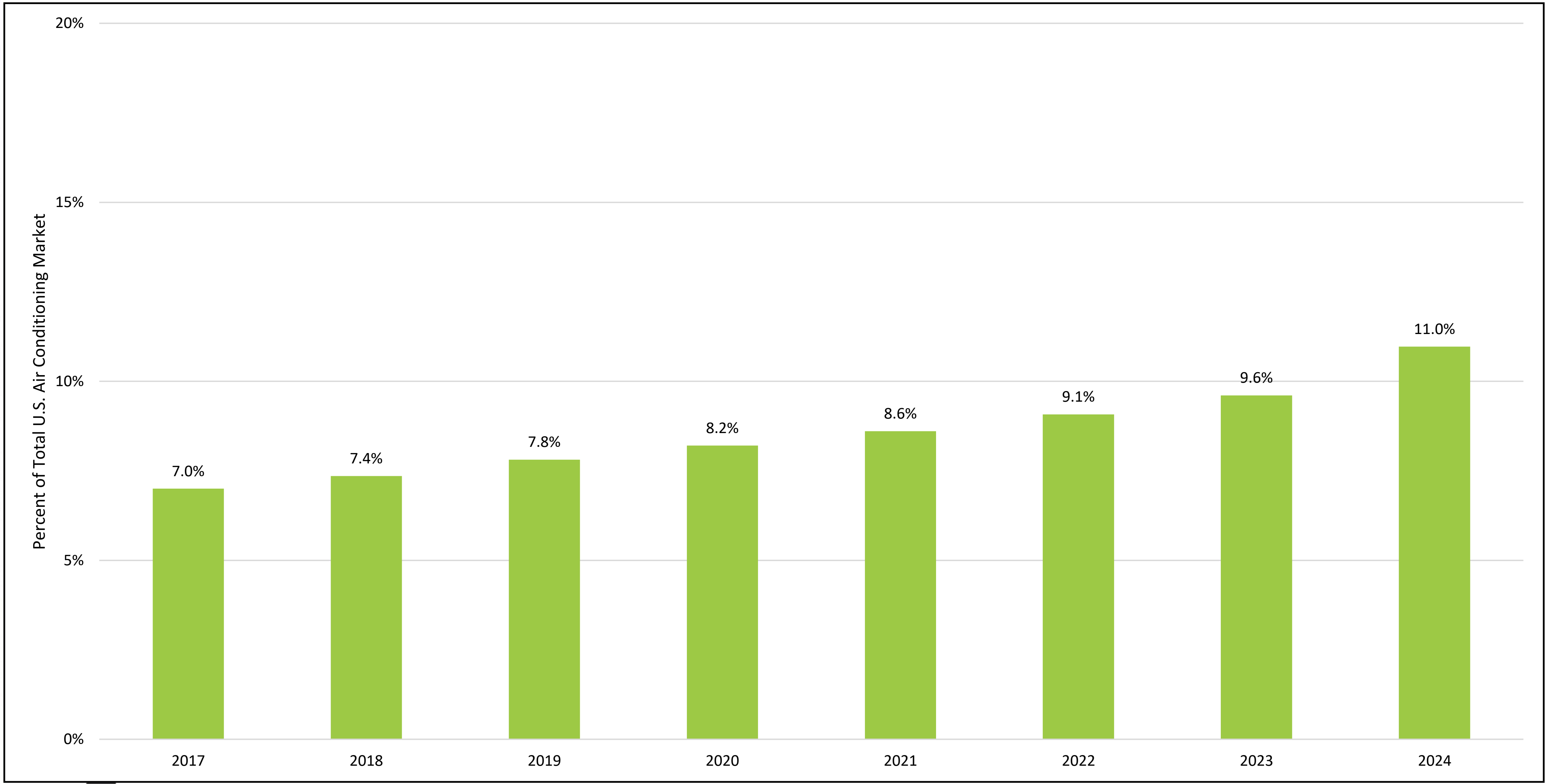
# U.S. Air Conditioner Shipments by Product




IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment

Source: BSRIA: Minisplits and VRF in the USA. 2018, U.S. Department of Energy, Energy Conservations 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.

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




IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment

iea-4e.org

Source: BSRIA: Minisplits and VRF in the USA. 2018, U.S. Department of Energy, Energy Conservations 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.

# 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<br>AU/NZS 3823.4.1:2014<br>AU/NZS 3823.4.2:2014 |
| China | GB/T 7725-2004 |
| EU | BS EN 14511:2018 |
| Japan | JIS B 8615-1:2013<br>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

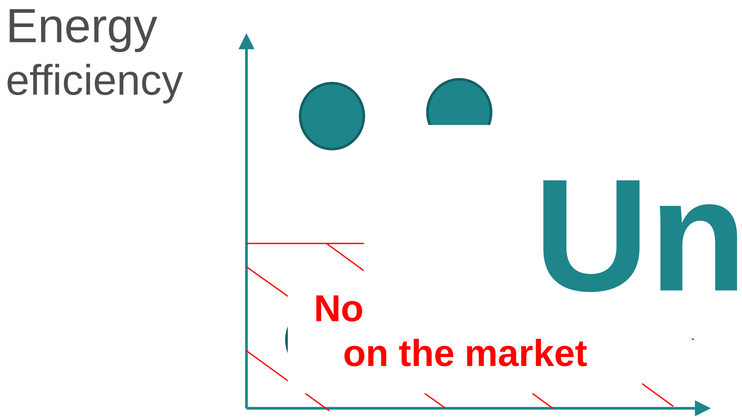
European Commission, DG Energy, Veerle Beelaerts

# Energy efficiency requirements for residential air conditioners

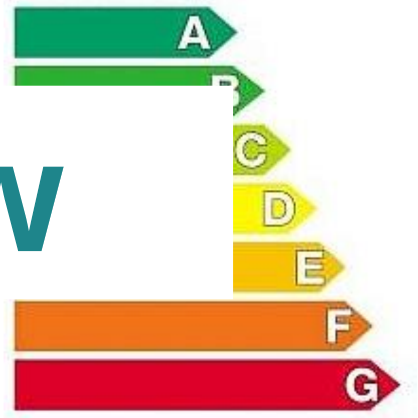
Residential air conditioners
and heat pumps (≤12 kW)

Ecodesign*

Energy labelling**




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)

European Commission

# 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)

European Commission

# Thank you

# Variable Refrigerant Flow Test Procedure Developments: Connecting Dynamic and Steady-State Tests

Catherine Rivest, US Department of Energy

# United States Variable Refrigerant Flow Test Procedure Developments

- Current Federal Test Procedure:
  - Cooling mode metric is in terms of Energy Efficiency Ratio (EER)
    - Full-Load steady state test with manufacturer involvement.
    - Metric doesn't capture benefit of variable capacity.
- Working group was formed with the goal of negotiating test procedure recommendations to DOE which would result in a test procedure that:
  - Reflects energy efficiency and energy use during a representative average use cycle.
  - Isn't unduly burdensome to conduct.
  - Is reproducible.
- Initial stakeholder positions generally split between two approaches:
  - Dynamic Test
  - AHRI 1230 Steady-State Tests
    - IEER metric composed of 4 load points: 100%, 75%, 50%, 25%

# Controls Verification Procedure (CVP)

- AHRI 1230 allows for certain parameters to be overridden in order for the steady state test to be performed.

- “Critical Parameters” are key variables that have been deemed to have a measurable impact on efficiency.
  - Operational state or position of a component.
    - i.e. compressor speed(s), fan speed(s), and valve position(s)

- During the control verification procedure (CVP) at a given test condition:
  - The unit’s operation is directed by it’s own “native controls”. No parameters are “overridden”.
  - Indoor room temperature is gradually decreased in a “ramping” procedure, passing through the VRF system setpoint.
  - “Critical Parameters” are observed throughout the duration of the test. Average values for critical parameters are calculated during a shorter period (defined in the test procedure)
  - The number of thermally active indoor units (connected capacity) decreases at part load test conditions.

# Critical Parameters - Connecting Dynamic and Steady-State Tests

**The CVP identifies VRF system controls behaviour and establishes system operation boundaries for AHRI 1230 steady-state test conditions. The CVP is not intended to quantify the performance or efficiency at any condition.**

## Controls Verification Procedure

- Operate under Native Control settings
- Respond to dynamic conditions
- Observe controls behavior

**Critical Parameters** →

## Steady-State Test

- Override critical parameters within tolerances of values obtained from CVP
- Develop performance ratings

# The Canadian Perspective: Test Methods for Residential Air Conditioners (and Heat Pumps)

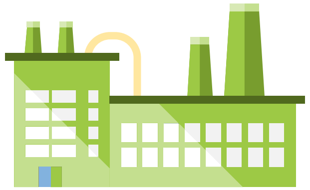
Kim Curran, Natural Resources Canada

# Outline

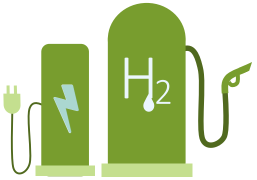
- Canada's Pan Canadian Framework
  - Energy Use and GHG emissions
- Regional Considerations
  - Climate
  - Electricity emission intensity
  - Energy costs
- Finding near term opportunities
- Work underway
  - Canadian Standards Association EXP-07
  - Heat Pump Coalition
  - Laboratory and Field testing

# Canada's Pan-Canadian Framework – Energy Efficiency

BUILD SMART: CANADA'S BUILDINGS STRATEGY



INDUSTRIAL EFFICIENCY & ENERGY MANAGEMENT



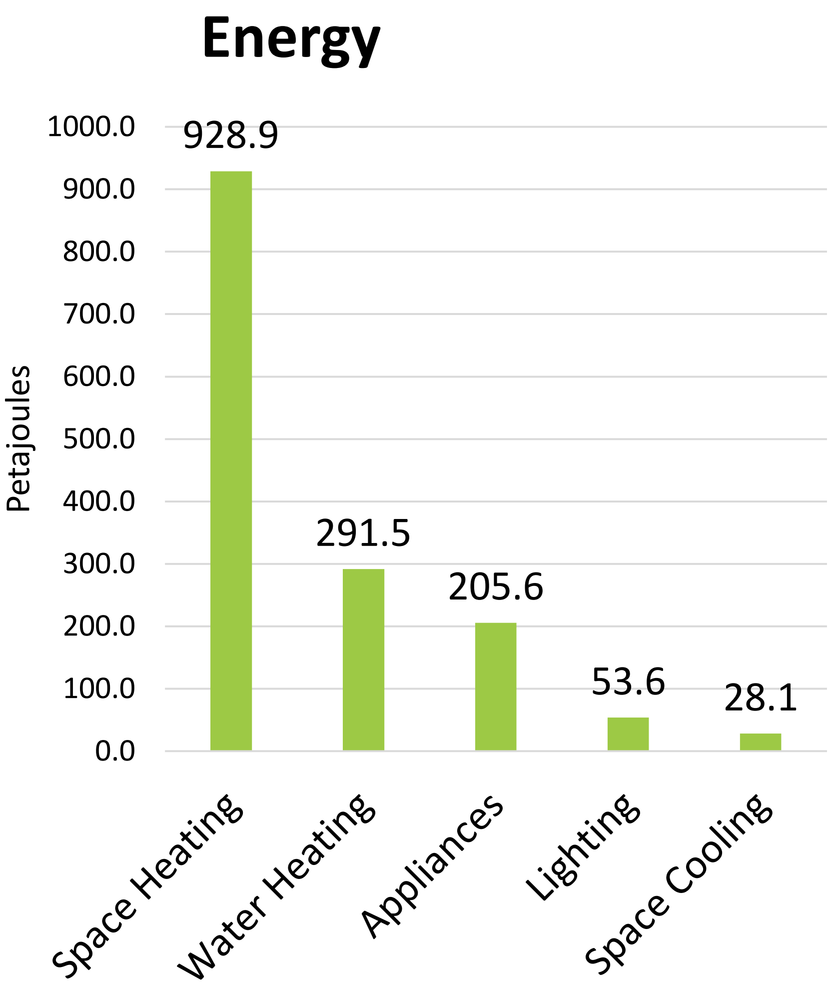

LOW-CARBON TRANSPORTATION & ALTERNATIVE FUEL

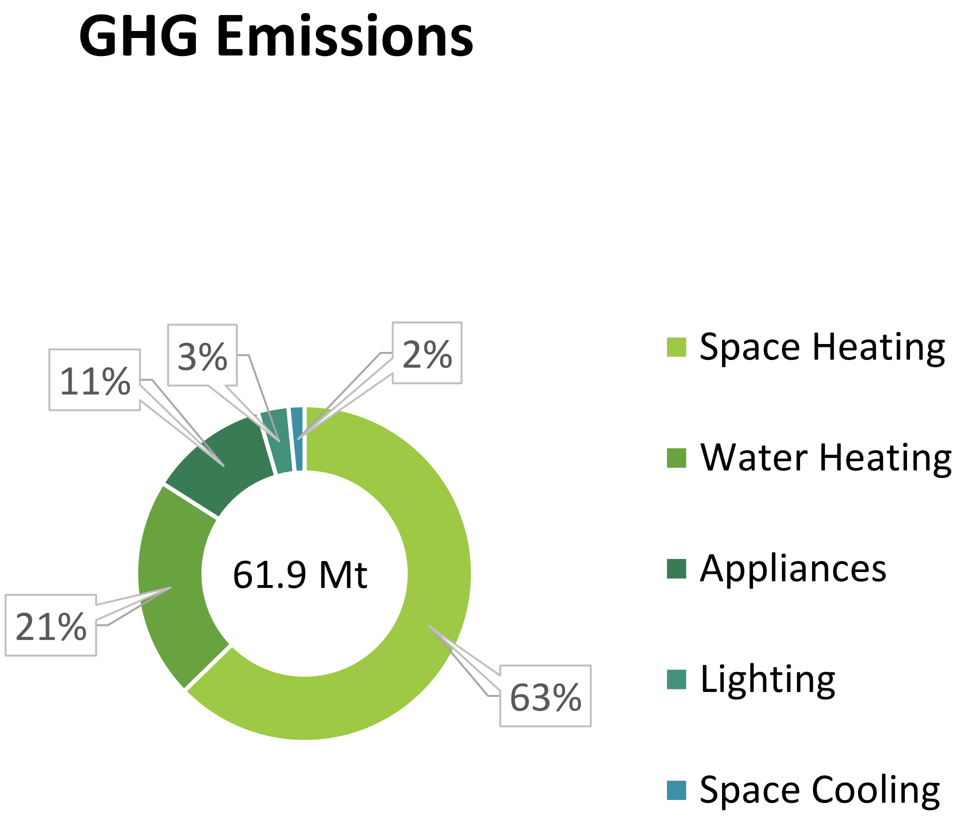
GREENING GOVERNMENT

SOCIAL INNOVATION & DIGITALIZATION

Investments through the PCF drive advancement in all sectors

# Energy use and GHG emissions - Residential End-Use

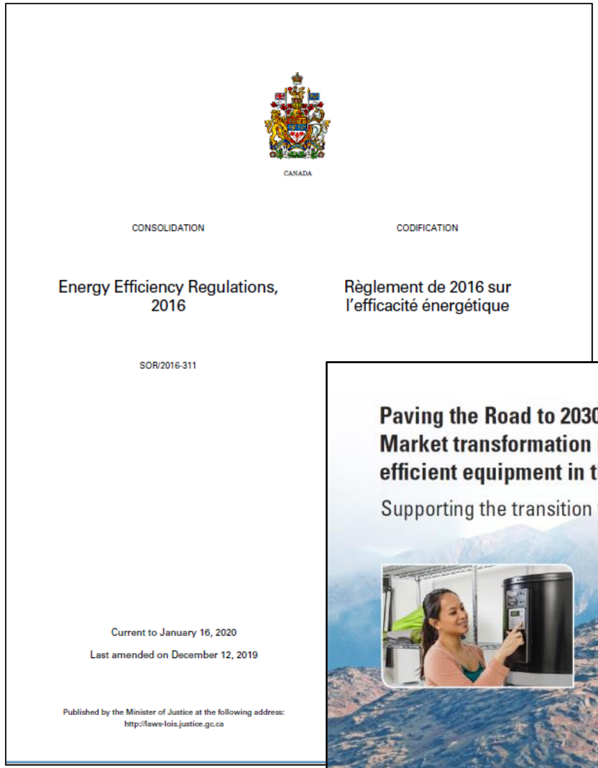



Source: Natural Resources Canada – National Energy Use Database (2017 data), GHG Emissions include Primary Energy Use

# Natural Resources Canada – Office of Energy Efficiency

- Transforming the Equipment Market through:
- Energy Efficiency Regulations:
  - eliminate worst performers through regulated minimum energy efficiency requirements
- ENERGY STAR program:
  - promote high efficiency products through voluntary certification and labelling
- Market transformation roadmap implementation:
  - space heating, water heating and windows



CANADA

CONSOLIDATION

Energy Efficiency Regulations, 2016

SOR/2016-311

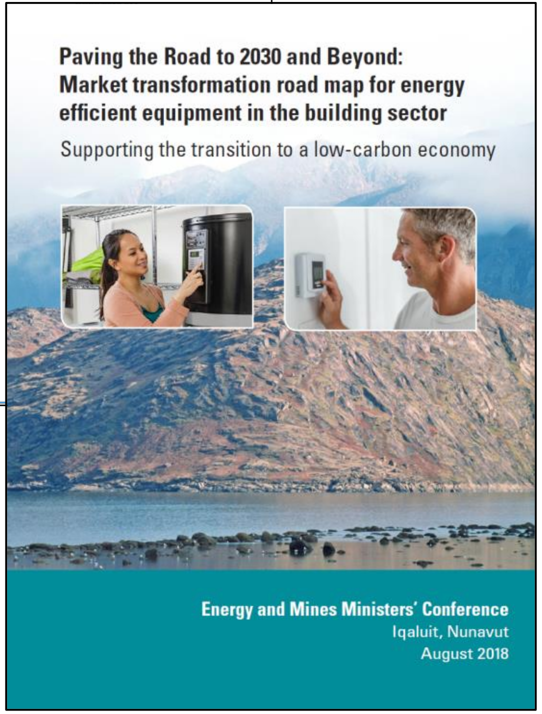
CODIFICATION

Règlement de 2016 sur l'efficacité énergétique

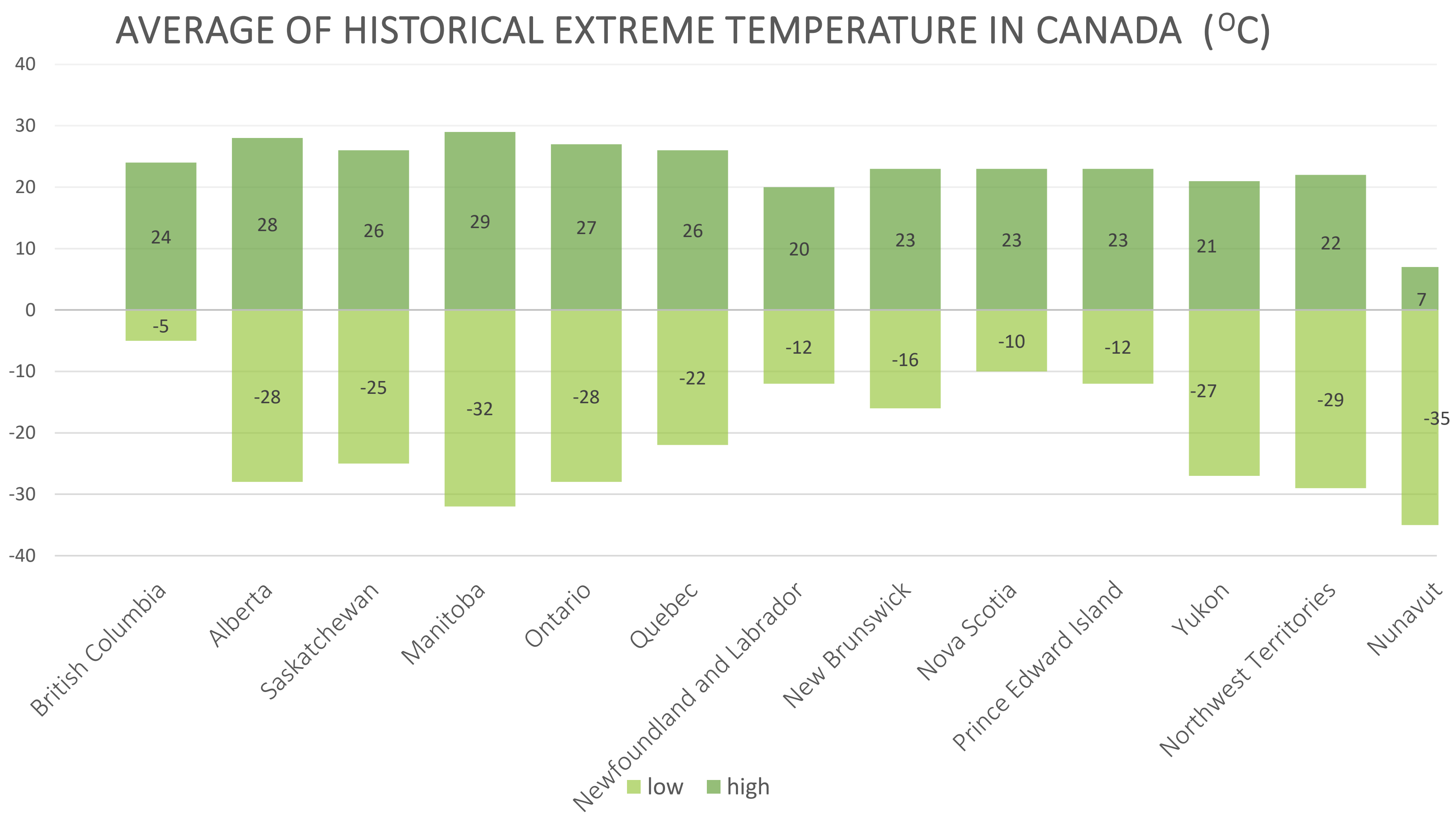
Current to January 16, 2020

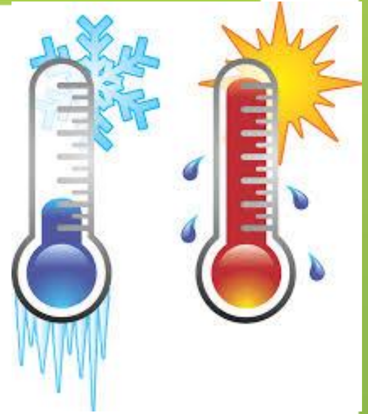
Last amended on December 12, 2019

Published by the Minister of Justice at the following address: http://laws-lois.justice.gc.ca



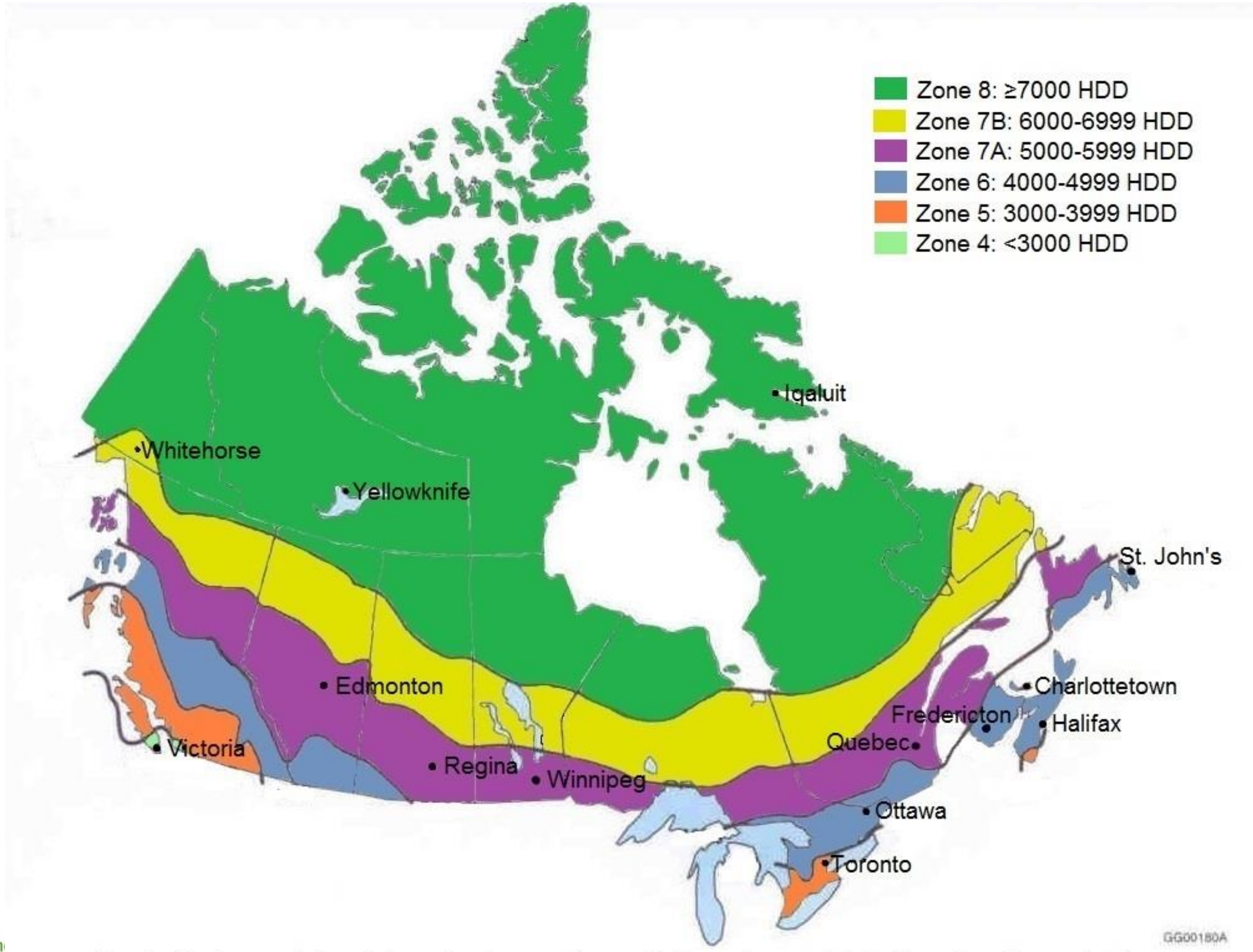
# Regional considerations



Source: climate.weather.gc.ca

# Climate – multiple climate zones

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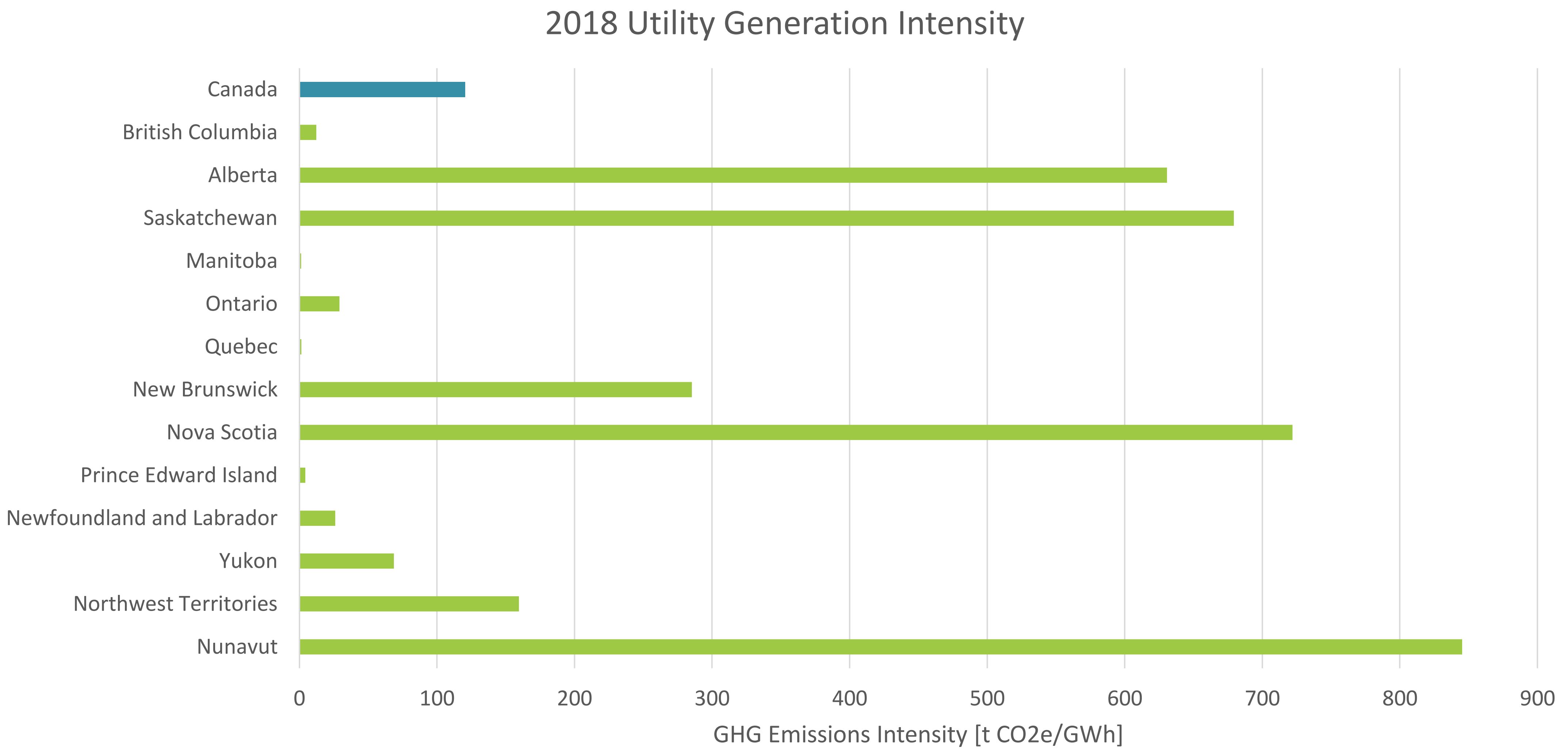
# Electricity emission intensity – by region




Source: Environment and Climate Change Canada - National Inventory Report 1990–2018

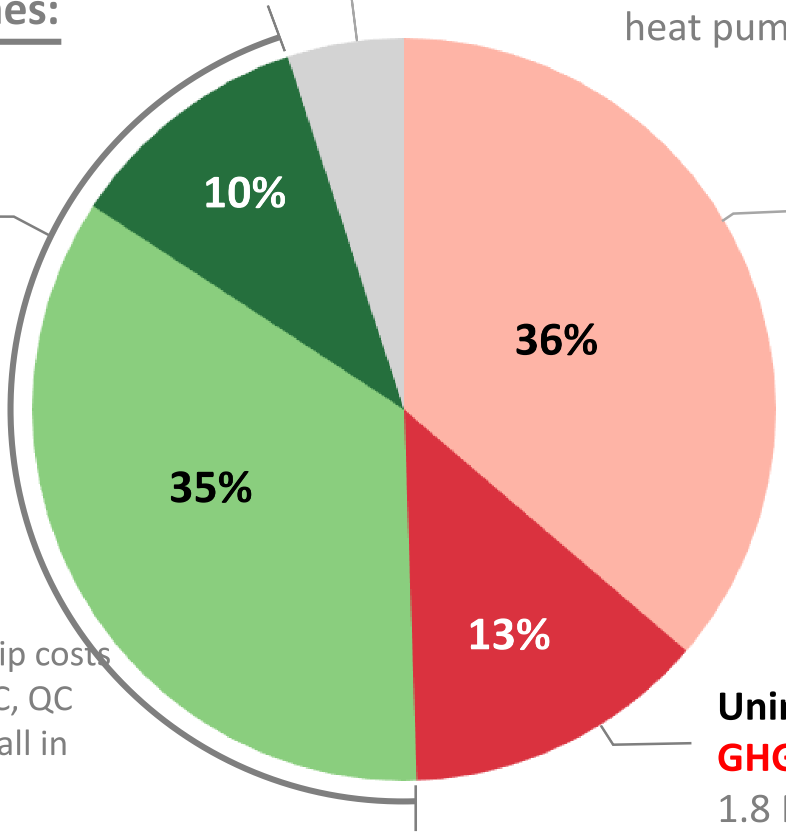
# Energy costs play a role

Today, cold-climate electric heat pumps can be cost effective, save energy in 45% of Canada's homes. To a lesser extent there are also opportunities now to reduce GHG emissions.

**Electric heat pump opportunities for Canada's 14 million homes:**

0.7 M homes already use heat pumps

**Low-hanging fruit + the cost-effective alternative:**
Costs ↓ in 6.4 M homes;
GHGs ↓ in 2.8 M of those homes*




**The toughest nut to crack:**
GHGs ↓, Costs ($) ↑
5.1M gas-heated homes

**Unintended consequences**
GHGs ↑, Costs ($) ↑
1.8 M gas-heated homes

* Electric heat pumps will lower ownership costs in 3.6 M electrically heated homes in BC, QC and MB, but the GHG impacts will be small in these clean electricity markets.

# Where heat pumps make sense

- Heat pumps are a very efficient alternative to oil, gas and electric resistance heating.
- When deployed in regions with non-emitting power generation ("clean" grid power), they can also cut carbon emissions.
- New, cold-climate heat pump technology works better in cold temperatures, making the technology more suitable in northern climates.
- In Canada, heat pump potential depends on regional context.

# Heat pump performance testing – traditional units

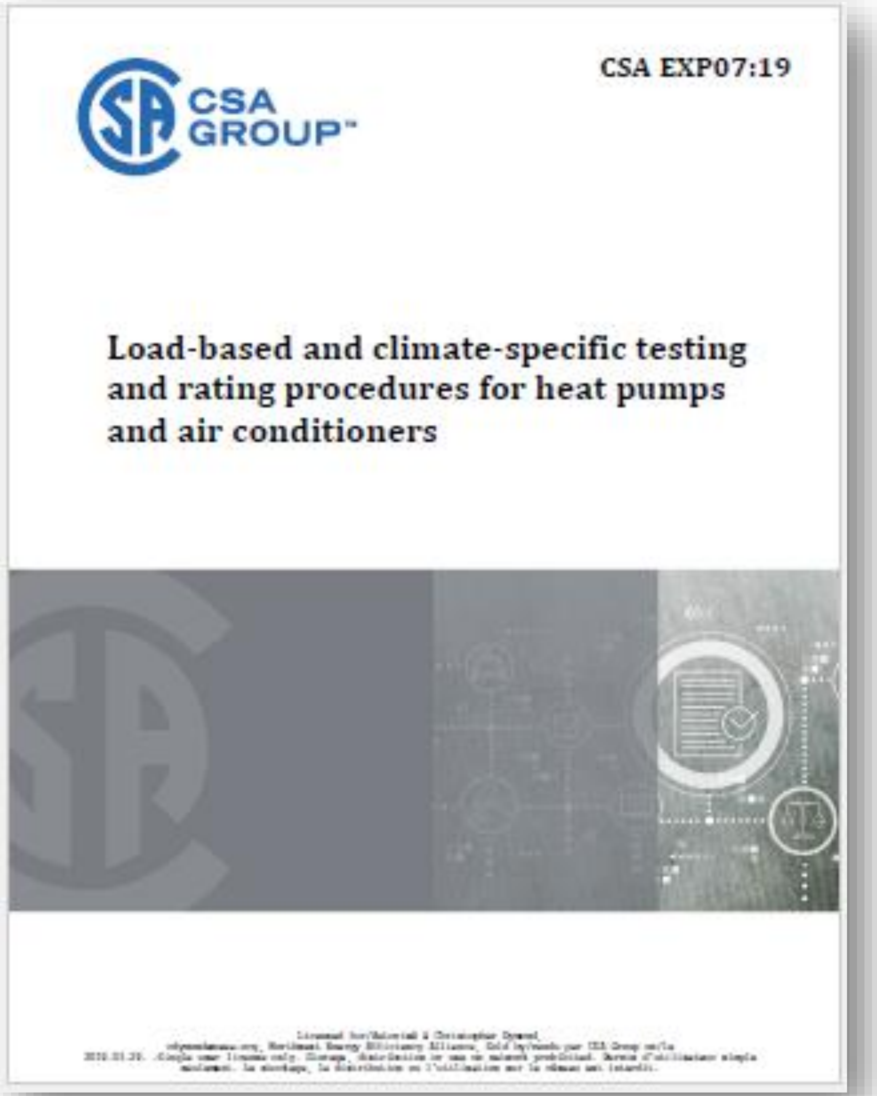
- Traditional testing procedures for heat pumps focus on single capacity unit types.
- Single capacity units are not ideal in low-temperature cold climates.
- Current traditional testing procedures are inadequate for cold climate variable heat pumps.

# Heat pump performance testing – variable capacity units

- To ensure energy savings, dependable information regarding unit performance is required.
- Variable capacity heat pumps respond to extremes of low and high temperatures.
- Work is underway to develop a test procedure for a variable capacity heat pump.
- Enhanced procedure evaluates units under actual cold and hot operating conditions, load based test.
- Advantage – allows for dependable comparison of actual performance for units in the market

# Standards Development

- Voluntary test procedure
- Variable capacity load based test
- Cold and hot climate specific
- Testing temperature range: -23 $^{o}$C to 40 $^{o}$C


CSA GROUP™

CSA EXP07:19

Load-based and climate-specific testing and rating procedures for heat pumps and air conditioners

# The need to validate the new procedure - the three R's

- In the lab
  - **Repeatability** –ability to achieve consistent test results when tests are repeated on the same unit at the same laboratory
  - **Reproducibility** – ensuring test results can be replicated in different laboratories
- In the field
  - **Representativeness** – how laboratory results represent the performance from field tested units operating under real world conditions

# Recent work

## Repeatability and reproducibility

- Extensive support for laboratory testing – participated in testing of 19 units, with 10 units funded by Canada

## Representativeness

- Collect field data for residential cold climate heat pumps in different climate regions of Canada
- Field testing projects across the country
- Collaborative efforts with provinces, utilities, industry

## Resources

- NRCan’s Air Source Heat Pump Sizing and Selection Guide – September 2020

# Collaboration with Heat Pump Coalition

**Federal Governments**

- Natural Resources Canada
- US Environment Protection Agency

**Regional organizations**

- Northwest Energy Efficiency Alliance,
- Northeast Energy Efficiency Partnerships,
- Midwest Energy Efficiency Alliance,

**California Energy Commission**

**Utilities, non-profits, cities, and research organizations**

## Closing Remarks

- Collaboration is the key to finding solutions to complex problems.
- The increasing shift of heat pump technologies to variable capacity and use in cold climate conditions requires a test procedure that represents the true performance of the unit.
- Canada is working on a number of fronts to better understand the expected energy performance from these units.

# Thank you


Kimberly Curran, MASc, P. Eng.

Chief Standards Development
Office of Energy Efficiency – Natural Resources Canada

# Residential Test Methods for Air Conditioners: Benefits and Challenges of International Alignment

Rusty Tharp, Goodman Manufacturing Company, a member of **Daikin group**

# Benefits of International Alignment

- Test Burden
  - Performance (capacity and efficiency), reliability and safety testing consume significant manufacturer resources during new product development. Steps to reduce the amount of testing required is beneficial to bringing newer, more efficient products to market in less time.
- Marketability
  - Utilizing the same test procedure for multiple countries will allow manufacturers, distributors and retailers of subject products to be able to market and sell the newer, more efficient products into broader markets.
- Performance Representation
  - Recent changes in test procedures provide performance representations that are more typical of actual applications. An aligned international test procedure will help to provide equipment rating values that are more consistent with product applications. This will help with determining relative performance of products.
- Equipment Capabilities
  - Technology has changed significantly in recent decades. New HVAC equipment has many control options for improved comfort and efficiency, such as humidity control, peak load reduction, etc. A harmonized test procedure could account for the energy consumption reduction of such products.

# Challenges of International Alignment

| | |
|---|---|
| • Ambient Condition Variation | • Indoor and outdoor ambient conditions vary greatly across the globe. One test procedure that covers the extremes of cold, mild and hot outdoor temperatures, dry, moist and marine outdoor conditions, as well as differing indoor conditions, all while reducing test burden would be difficult. |
| • Controls / IoT | • The range of control schemes and IoT applications that could affect energy consumption is virtually limitless. Options may include control changes based upon consumer behaviour or ambient conditions. Ideally, the test procedure would be able to provide a method of reasonably estimating energy savings for various functions. |
| • Building Load | • Most equipment performance representations are based upon an assumed building load. Actual building load, however, varies significantly based upon many factors. Preferably an aligned test procedure would provide information necessary to be able to estimate performance for diverse building applications. |
| • Reproducibility / Repeatability | • A test procedure should be defined such that very similar results will be produced regardless of which test facility or location is used for testing. Further, test procedure requirements should be such that if the same product is removed then reinstalled in the same facility, very similar measured findings occur. |

IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment

# Residential Test Methods for Air Conditioners

## Q & A Discussion

# Some questions……..

- *Do national and regional test methods for non-ducted split system air conditioners differ much?*
- *What are the benefits of more consistent terminology and how can we improve the situation?*
- *What can be done to improve the part-load testing of inverter ACs?*
- *What is the likely impact of not improving the part-load testing of inverter ACs?*

# Closing

# Follow-up

- We will be producing a FAQ, including where people can find further information on this subject
- Presentations and FAQ available here:
  - https://www.iea.org/events/residential-test-methods-for-air-conditioners
  - https://www.iea-4e.org
- Interest in organising a follow-up webinar in 6 months?

# Tender for consultants/labs to assist with new 4E project

https://www.iea-4e.org/projects/air-conditioners

Many thanks for joining us
and keep safe!

# 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)