

# R290 Room Air Conditioners: Challenges and Progress

## Safety, Performance, and Cost

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# Agenda

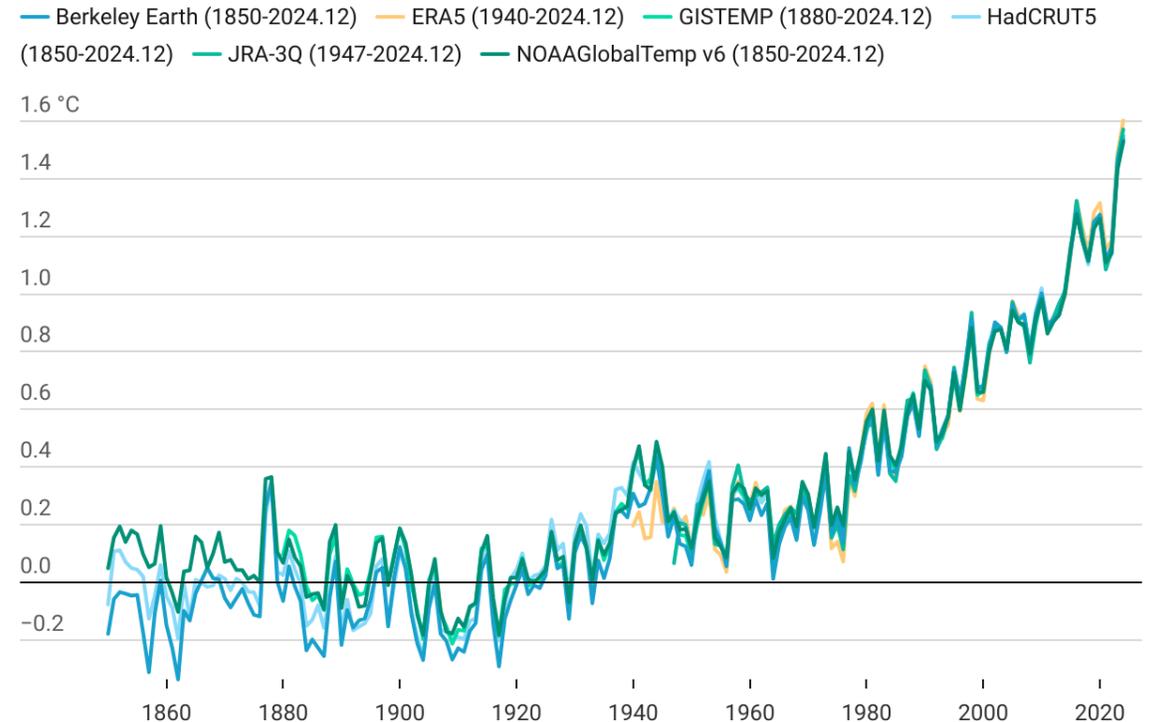
- **Background**
- **Key challenges and recent progress:**
  - » **Safety**
  - » **Thermodynamic performance**
  - » **Cost**
- **Summary**

# Climate Change

- Heatwaves and cooling demand are increasing in frequency, duration, and severity.
- Cooling is both adaptation (health, productivity) and mitigation opportunity (efficiency, refrigerants).
- Decarbonizing cooling is essential to climate goals.

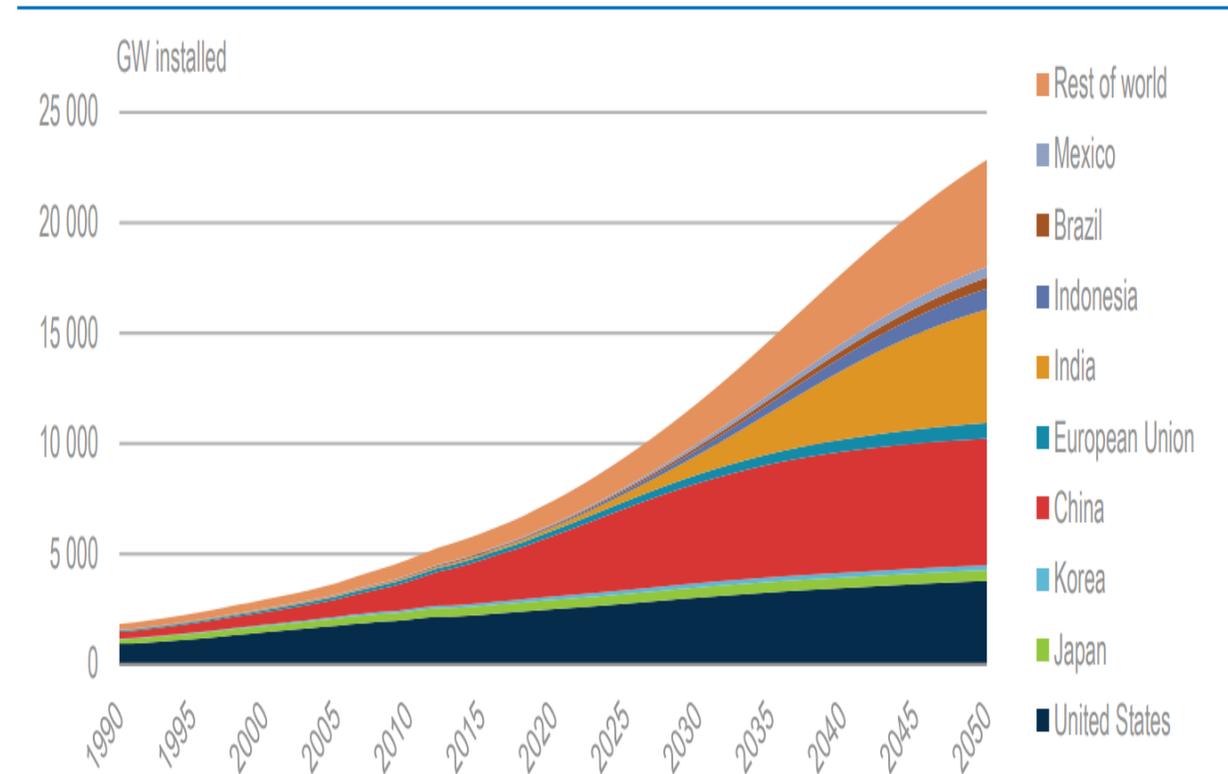
## Global mean temperature 1850-2024

Difference from 1850-1900 average



# Cooling's Scale and Trajectory

- Room ACs are among the most purchased appliances globally
- Global stock is in the billions and growing rapidly, especially in emerging economies.
- Space cooling uses notable electricity share and drives peak demand



IEA: Residential AC cooling capacity

# Why R290?

- Ultra-low GWP and zero ODP
- High potential theoretical energy efficiency

Refrigerant	GWP	Safety Class	Temperature Glide(°C)
<b>R290</b>	3	A3	0
<b>R454C</b>	148	A2L	8.2
<b>R454B</b>	466	A2L	0.9
<b>R32</b>	771	A2L	0.0

# Challenges & Progress: Safety

## □ R290: A3 flammability

LEL/UEL	2.2%/9.5%
Auto Ignition Temperature	468 °C
Vapor Density	1.6 (Air=1)
Molecular Formula	C <sub>3</sub> H <sub>8</sub>
Molecular Weight	44.11 g/mole
Boiling/Condensation Point	-161 °C



# Challenges & Progress: Safety

- Measures for operation period
  - » **Lower the mixture concentration lower than LEL:** minimize charge; expand room space
  - » **Control of ignition sources** (electronics, connectors, relays)
  - » **In-time leak prevention**
  - » **Rapid dispersion after leakage**
- Measures for Installation, servicing, and end-of-life periods
  - » **Personnel training and certifications**

# Lower Refrigerant Charge

- **Direction: Improving the effective utilization ratio of refrigerant**
- **Reducing refrigerant of non-contact heat exchange surfaces:** micro/small-channel heat exchangers, (fully) falling-film evaporators, and reducing circulation ratio in cold storage evaporation systems
- **Reducing refrigerant liquid line length:** adopting indirect refrigeration or secondary loop configurations
- **Reducing refrigerant dissolved in compressor lubricating oil**



# Leakage Sensing and Handling

## □ **Sensor**

- » Measurement range: 0–100 % LFL (10–20 % LEL: early warning)
- » Accuracy: about  $\pm 2.5$  % LFL

## □ **Placement**

- » Near floor level
- » Close to potential leak sources (compressor, joints, evaporator)
- » Avoid airflow dead zones

## □ **Handling**

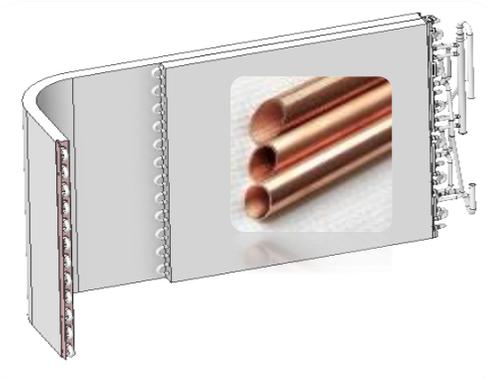
- » Forced ventilation
- » Shutoff valves / compressor stop
- » Fail-safe mode

# Standards and Regulations

Lifecycle of Flammable Refrigerant Air Conditioner					
Design	Production	Transportation	Installation	After-sales	Recycling
IEC 60335-2-40:2022 GB 4706.32-2024 GB/T 24986.4-2017 T/CPQS E0010-2020			QB/T 4976-2016 QMK-J090.0003-2017 T/CRAAS 1014-2022 QMK-J037.1029-2017		GB/T 4706.92-2024
	QB/T 4975-2016	QB/T 4825-2015			

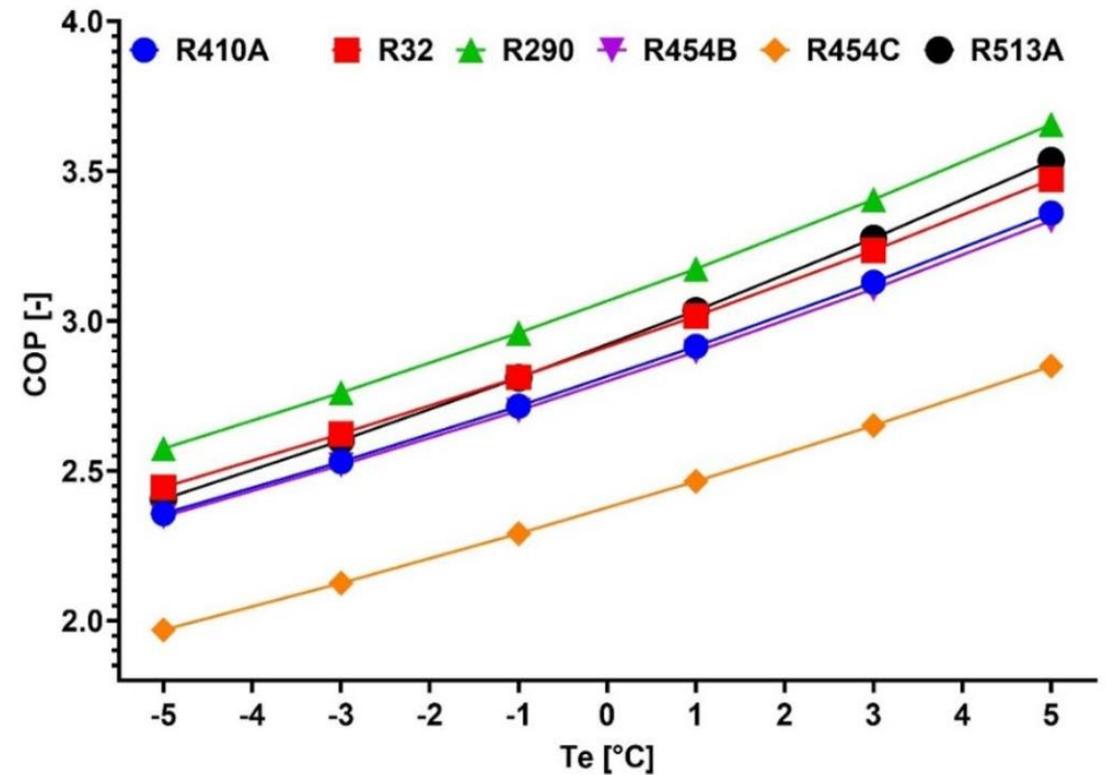
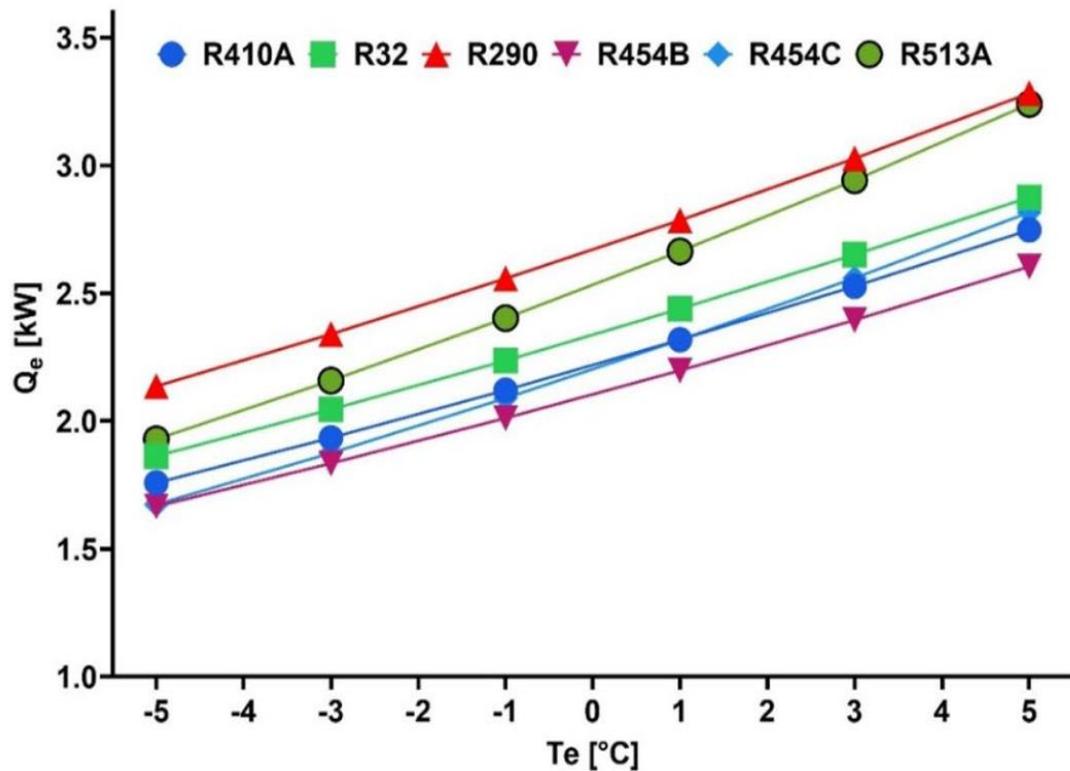
# Challenges & Progress: Thermodynamic Performance

- R290 has a high theoretical coefficient of refrigeration performance
- The unique physical properties, entirely different from traditional refrigerants, necessitate a complete system redesign
- Key breakthroughs required for high-efficiency R290 air conditioners:
  - » High-speed rotary compressor
  - » High-performance micro-channel heat exchanger
  - » Oil-blocking-free expansion valve



# Challenges & Progress: Thermodynamic Performance

- Through reasonable design and optimization, energy efficiency and cooling capacity of R290 air conditioners can both reach their optimal levels



# Challenges & Progress: Cost

## □ Challenges:

- » Factory retrofits: charging stations, ventilation, detection, zoning
- » Safety-related costs have increased significantly
- » Compliance, testing, and certification costs
- » Service tool kits and training investments

## □ Progress:

- » BOM can be competitive as designs mature; propane is inexpensive
- » Energy savings reduce total cost of ownership
- » Economies of scale lower per-unit compliance costs
- » Financing and incentive programs emerging

# Summary

- R290 offers ultra-low GWP and strong efficiency potential
- Dominant barriers: A3 safety, code harmonization, implementation capacity
- Rapid progress: evolving standards, charge-reduction designs, better components, training
- With coordinated policy, investment, and workforce development, safe large-scale deployment is achievable



# Thanks

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