Skate Key Laboratory of Air-Conditioning Equipment and System Energy Conservation

让世界爱上中国造
Made in China, Loved by the World

Low-carbon Path to Residential Environment in Subtropics



International Workshop on Energy Efficient Cooling, New Delhi, India

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GREE Electric Appliances Inc. of Zhuhai

Trend of Cooling in Subtropics

One of the fastest growing regions for cooling demand

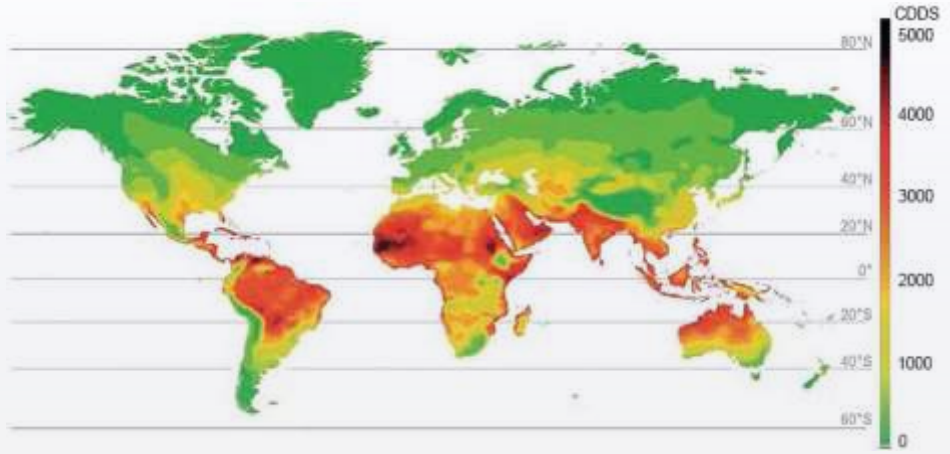
- **High temperature**: Annual average temperature exceeds 22 ℃; Summer lasts for 8-9 months; Temperature in some cities exceeds 40℃;
- **Fast economic growth**: India is one of the fastest growing economics in the world;
- **Large potential for cooling demand**: expected to experience a similar growth with China

Installed Residential Air-conditioning Units (2016)

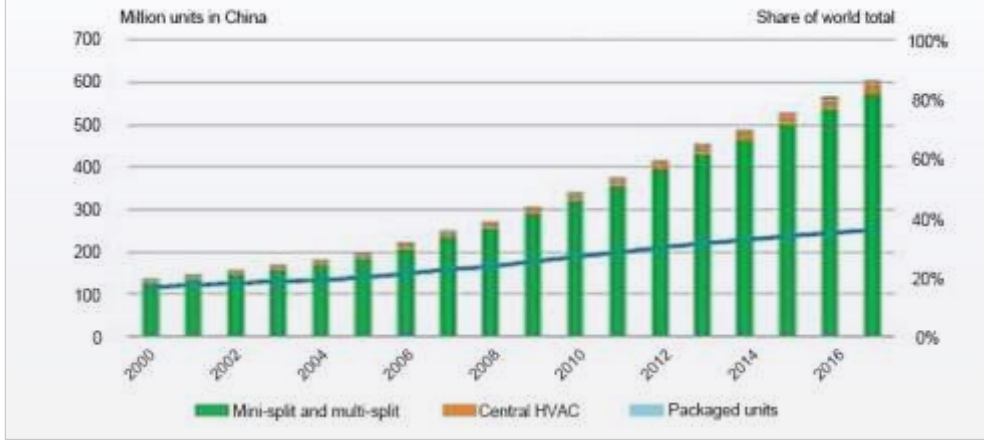
	Million Units [1*]	Per hundred families
United States	241	223
Japan	116	274
China	432	91 [2*]
India	14	3

1* Source：The Future of Cooling, IEA 2018;　2* Source：China Statistical Yearbook 2016

CDDs across the world,mean annual average 2007-17



Stock of air-conditioning systems in China,2017



Trend of Cooling in Subtropics

Suitable for “part time” and “part space” mode

- Different air-conditioning operation modes may cause several times differences of energy consumption. For example, China's energy per capita used for cooling is only 1/7 of that of the United States;
- “Part time” and “part space” operation mode achieves a balance between comfort and energy saving.



USA Residential: Full air system

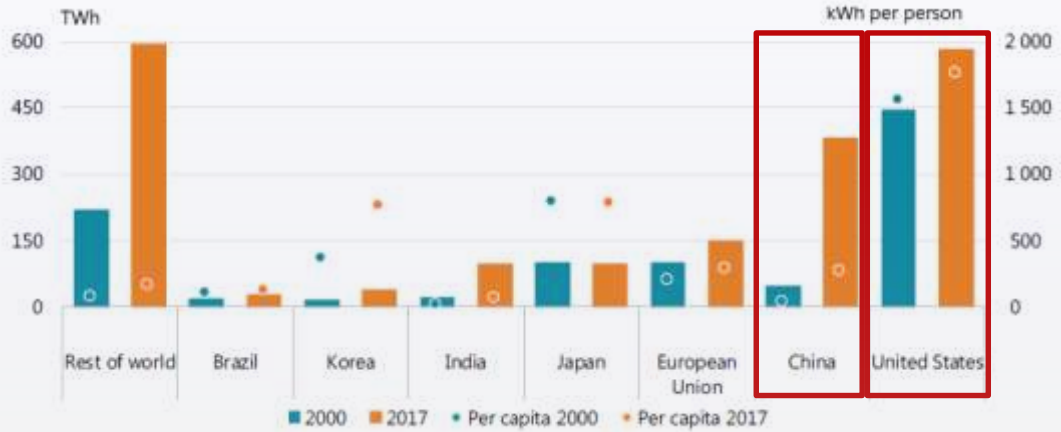
- Centralized air supply; “full time” and “full space” mode;
- Space constant temperature; high comfort;
- 25~40kWh/m^2



CHINA Residential: split unit

- Decentralized; “part time” and “part space” mode;
- Turn on when needed; energy saving;
- 5~10kWh/m^2

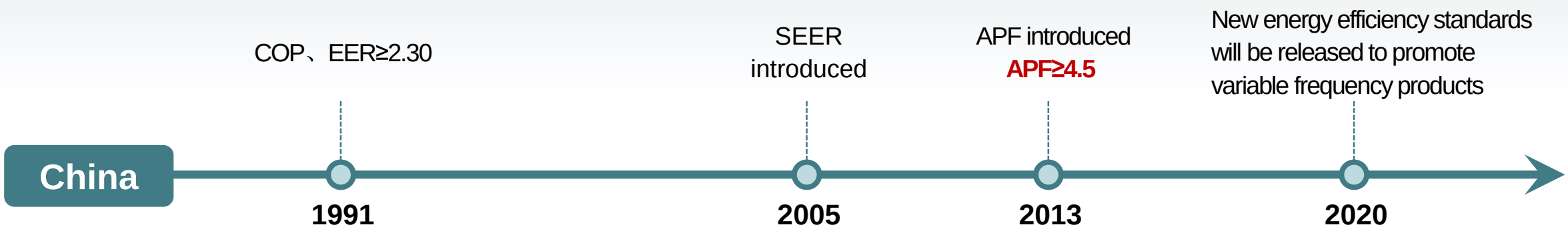
Per capita and total energy used for cooling in selected countries/regions,2000-17

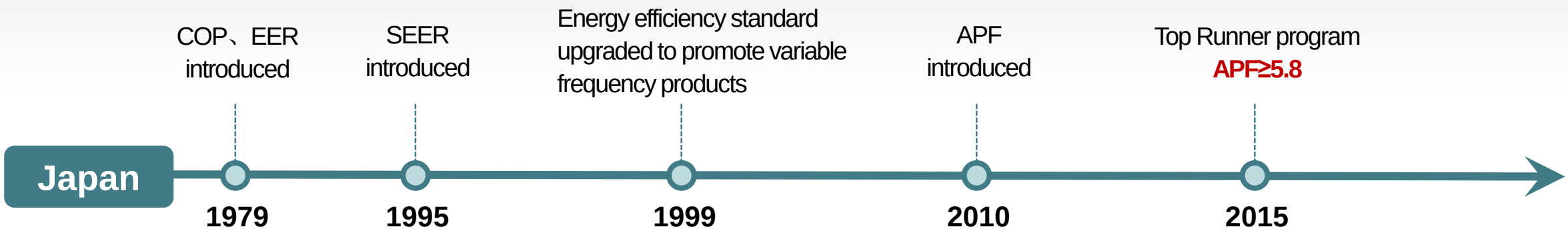


Guidance of Policies and Standards

Development in different countries

- Improve minimum energy efficiency limits to obsolete low energy efficiency products;
- Develop top runner programs to encourage the promotion of high efficiency products





Guidance of Policies and Standards

APF: Depends on 2 basic factors, load and runtime

$$APF = \frac{CSTL + HSTL}{CSTE + HSTE}$$

CSTL: seasonal cooling capacity

HSTL: seasonal heating capacity

CSTE: seasonal power consumption for cooling

HSTE: seasonal power consumption for heating

$$\mathrm{CSTL} = \sum_{j=1}^{m} \mathrm{BL}_c(t_j) \times n_j + \sum_{j=m+1}^{19} \phi_{\mathrm{ful}}(t_j) \times n_j$$

$\mathrm{BL}_c(t_j)$: building load

$\phi_{\mathrm{ful}}(t_j)$: maximum cooling capacity

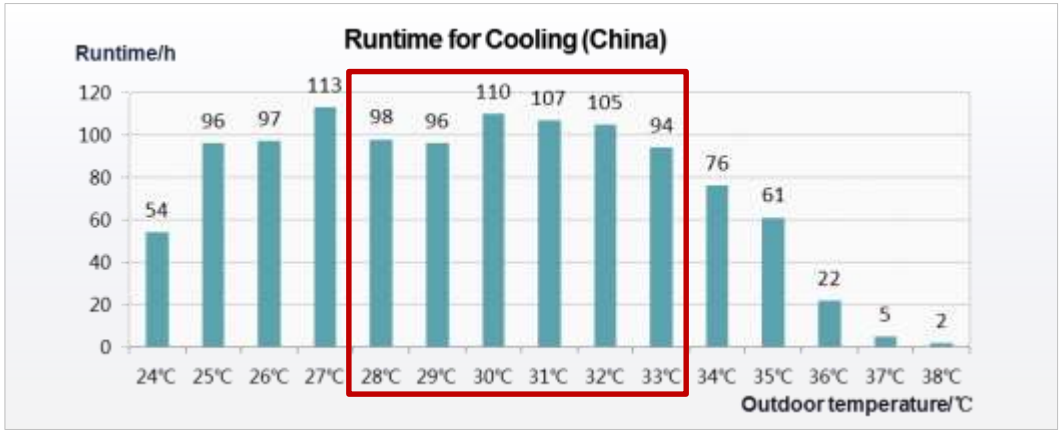
} **Load**

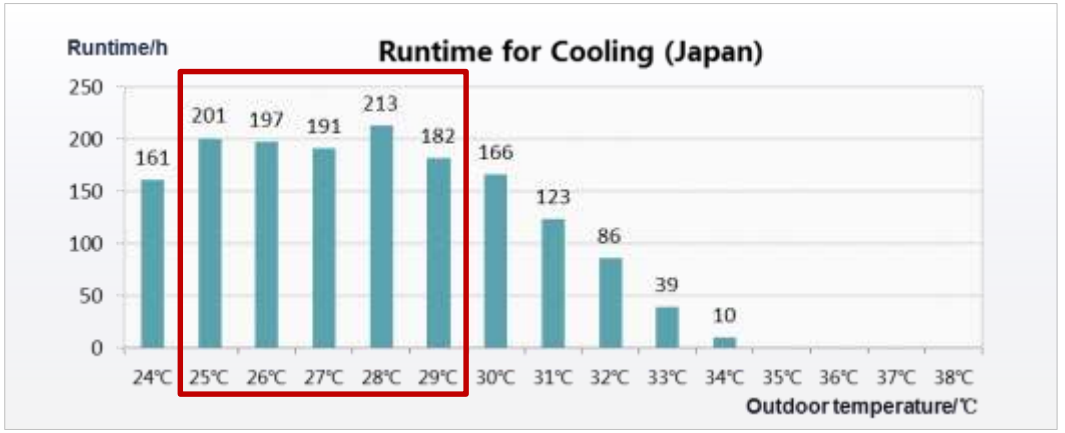
n_j : runtime at each temperature point in cooling season → **Runtime**

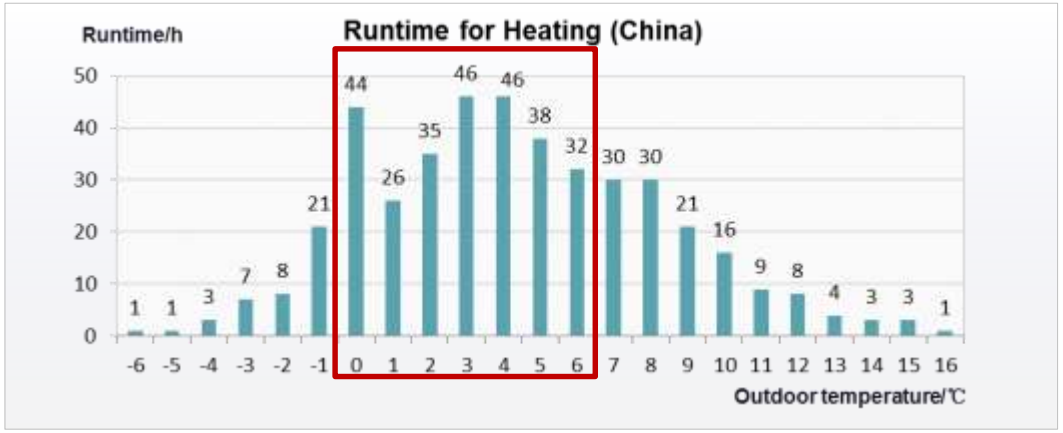
Guidance of Policies and Standards

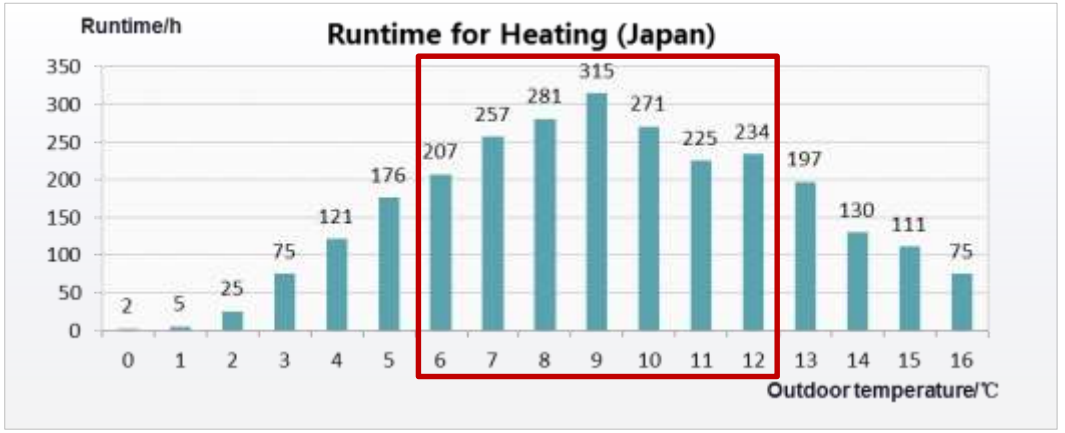
Standards should be adapted to local climate characteristics

- China: APF is mainly affected by refrigeration and rated energy efficiencies;
- Japan: APF is mainly affected by heating and intermediate energy efficiencies;
- The APF calculated by **Japanese standards** for the same air-conditioning product is **about 17%** higher than that calculated by **Chinese standards**.





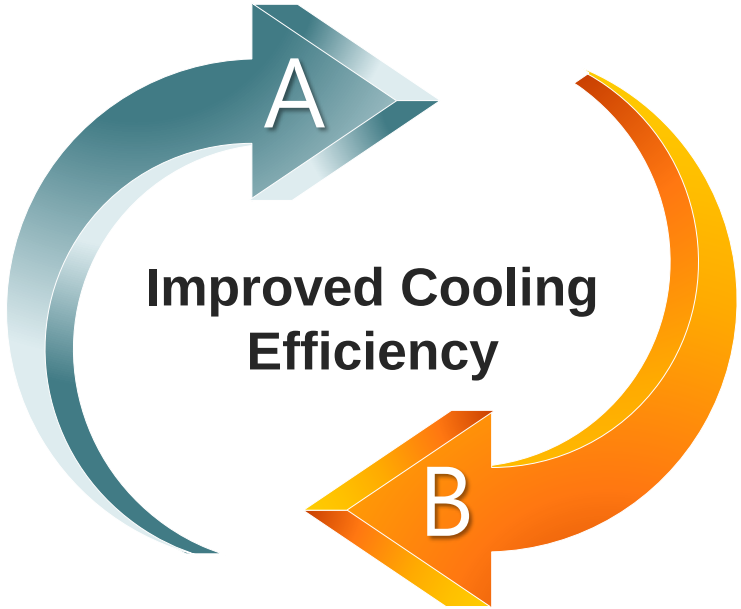




Technical paths

A Equipment improvement technology

- Variable Frequency;
- Multi-stage compression;
- High efficiency heat exchanger;
- Environmentally friendly refrigerant
- Improvement of residential VRF system



B Renewable energy technology

- Photovoltaic air conditioner;
- DC Micro-grid system

Technical paths

Global Cooling Prize, New Delhi

- Goal: develop cost-effective refrigeration solutions with only one-fifth of climate influence of the current market standard products;
- The GREE and Tsinghua University team proposes an “advanced vapor compression refrigeration integrated with evaporative cooling and solar photovoltaic”; suitable for Indian climate; annual energy consumption reduced by **80%**





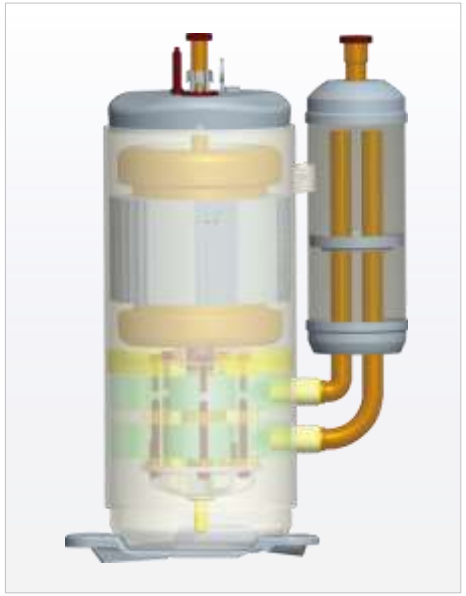
Technical paths

Popularization of variable frequency AC

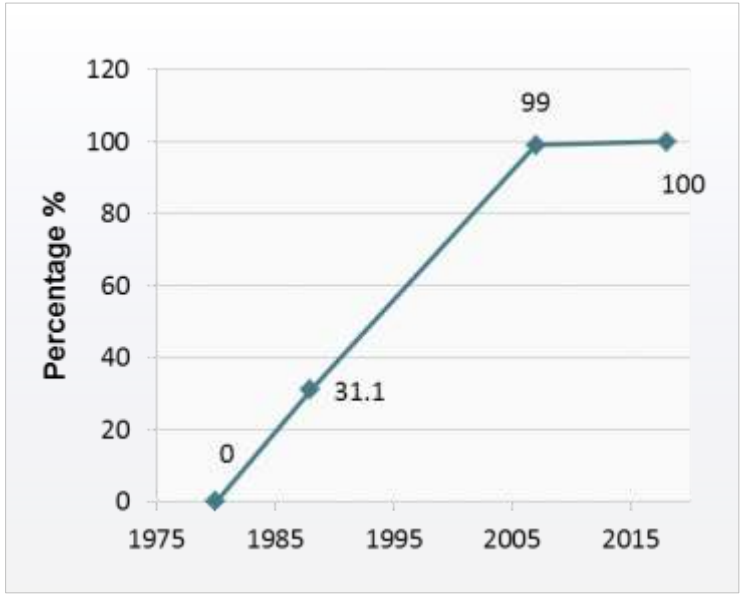
- **DC inverter motors**: used in compressors and fans, 30% efficiency improvement compared to AC motors;
- **Japan**: first variable frequency AC appears in 1980, 100% market share since 2007;
- **China**: market share about 57% now; May grow to 100% due to the release of new energy efficiency standard in future;
- **India**: popularization of variable frequency AC is expected.



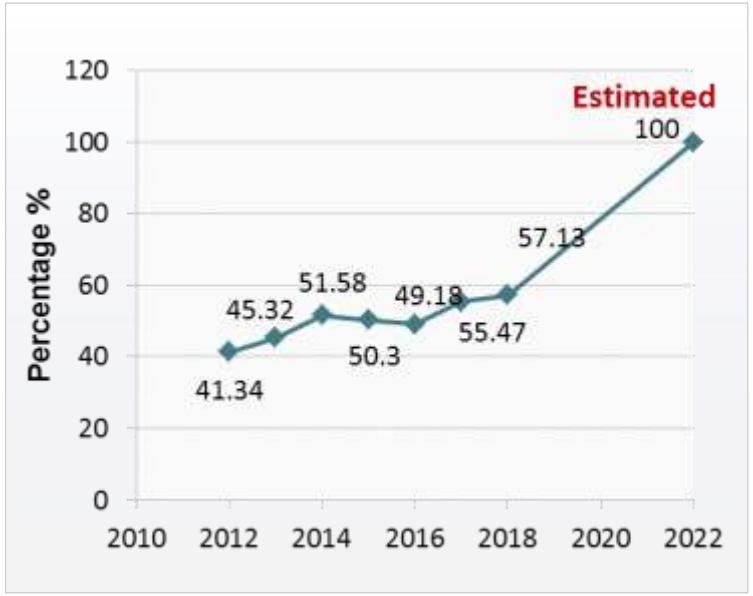
DC inverter motor



DC inverter compressor



Growth of variable frequency AC in Japan

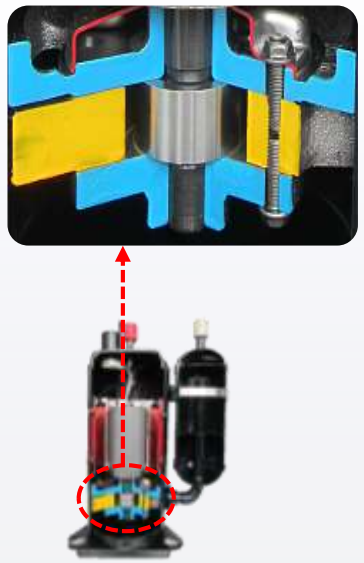


Growth of variable frequency AC in China

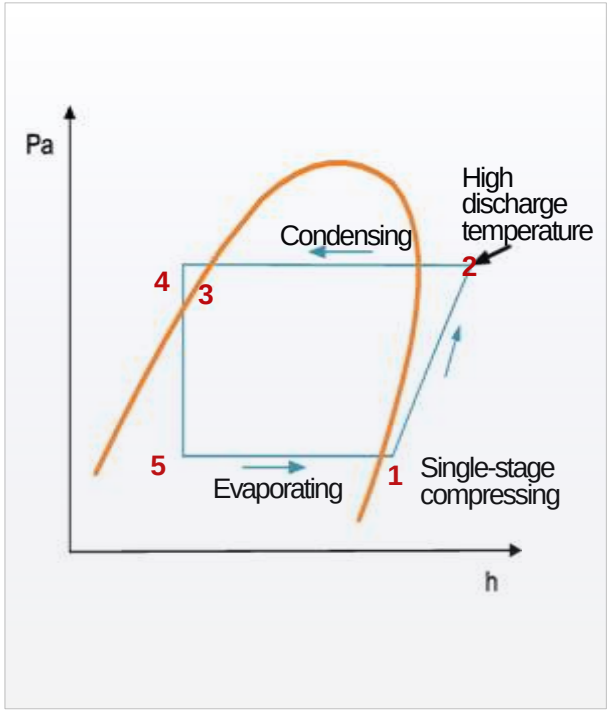
Technical paths

Multi-stage compression

- Improvement of components has been close to upper limits. Future trend is the expansion of operation range;
- **Double stage** compression combined with intermediate vapor injection, EER increased by about 6%;
- Decrease compressor discharge temperature to expand the operation range.

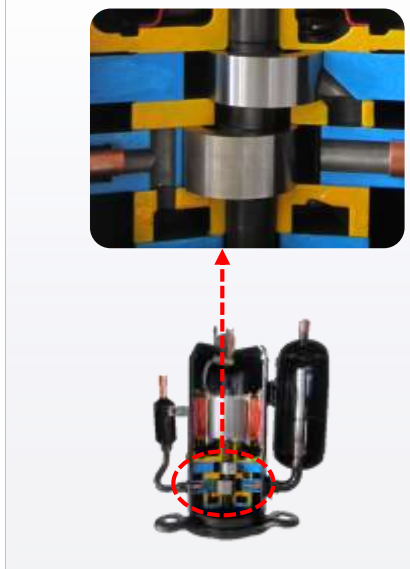


Generation I: Single-cylinder single-stage compression

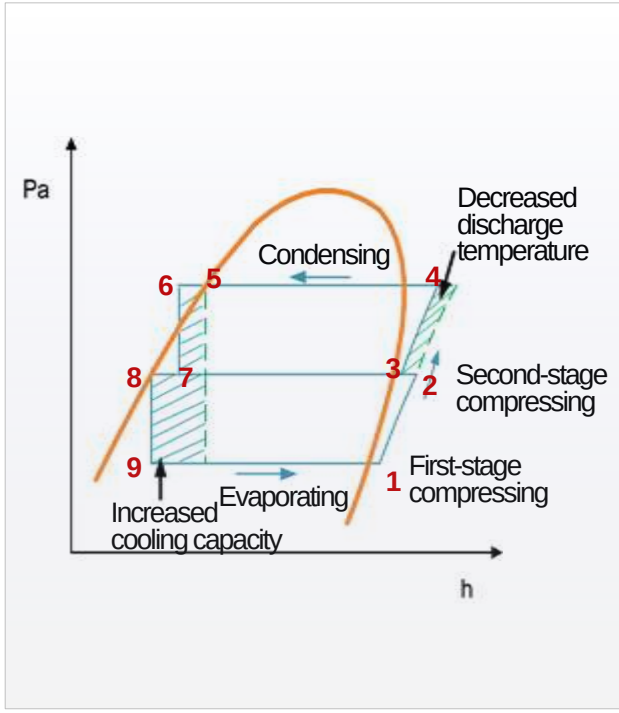


Applicable to regions -15~45℃

Single-stage Compression Circulation System



Generation II: Dual-cylinder double-stage compression



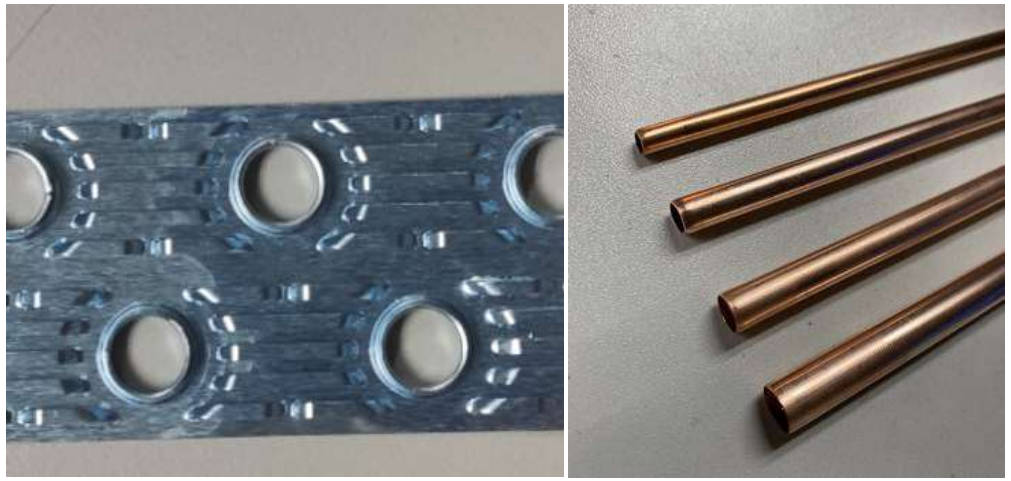
Applicable to regions -30~54℃

Double-stage Compression Circulation System

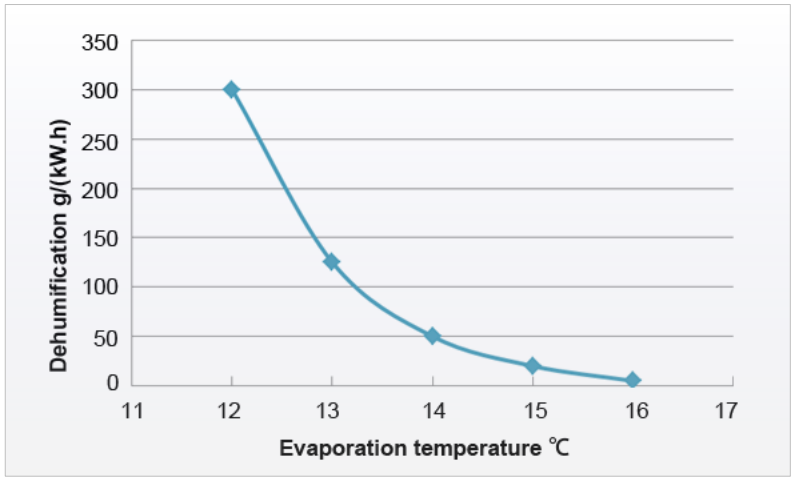
Technical paths

High efficiency heat exchanger

- **Traditional heat exchanger :** increase of heat transfer area in condenser or evaporator improves efficiency. However, increase of heat transfer area in evaporator leads to higher evaporation temperature and **lower dehumidification ability**;
- **Micro-channel heat exchanger:** improve the EER by 15~20%. However, may cause the problems of dust accumulation and maintenance difficulty when leakage. Not widely used.



Traditional heat exchanger (improvement of fins and tubes)



Dehumidification varies with evaporation temperature



Micro-channel heat exchanger

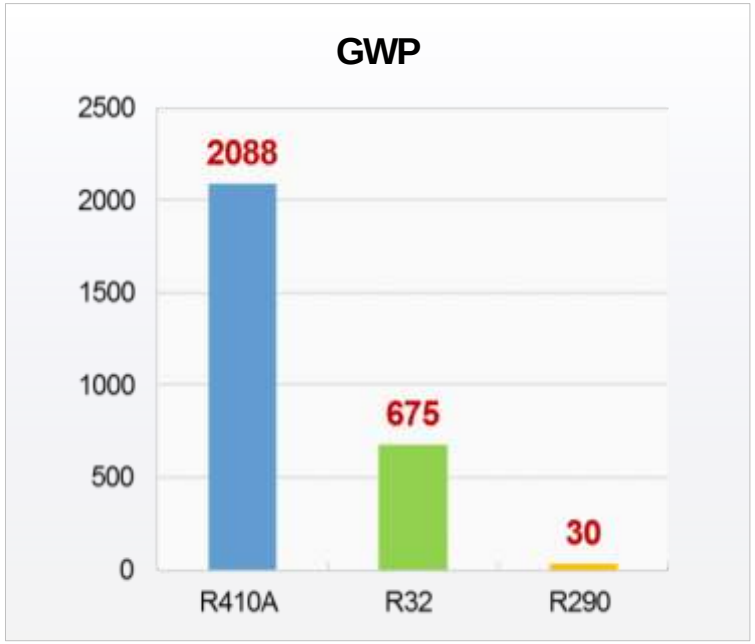
Technical paths

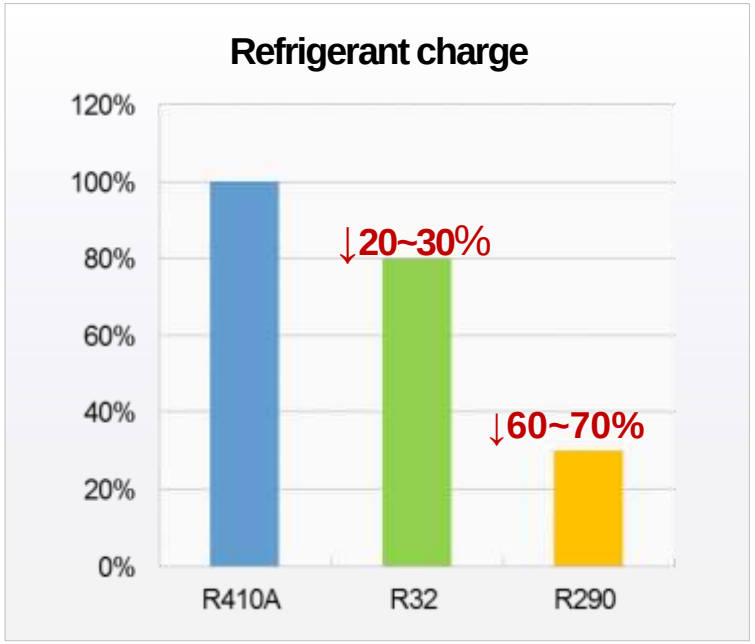
Environmental friendly refrigerant

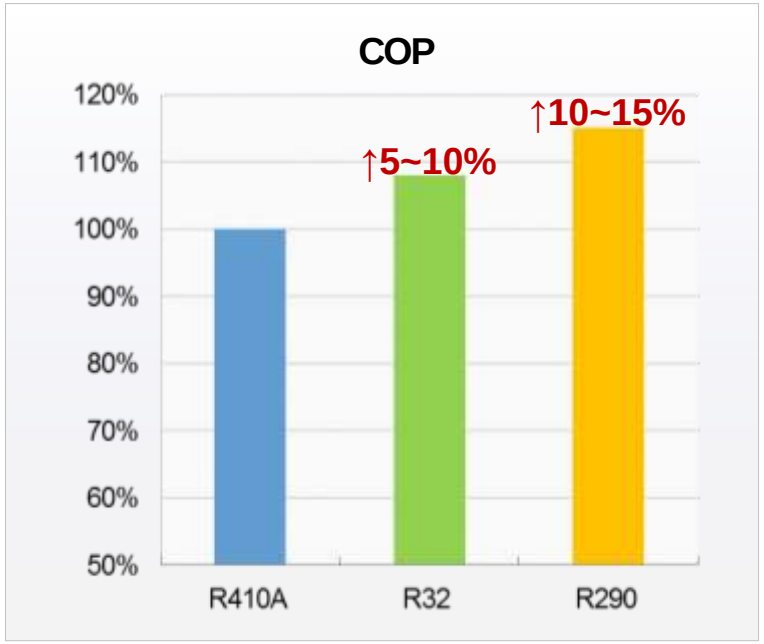
- **R32:** GWP reduced by 75%, EER improved by 5~10%;
- **R290:** GWP reduced by 99%, EER improved by 10~15%

Application in GREE products

Chiller	Unitary air conditioner	Room air conditioner
		
HFO	R32	R32





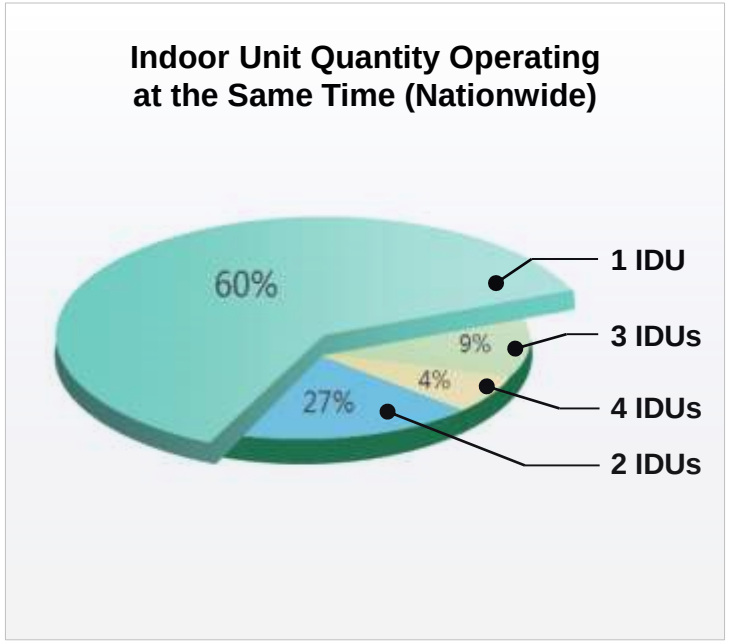


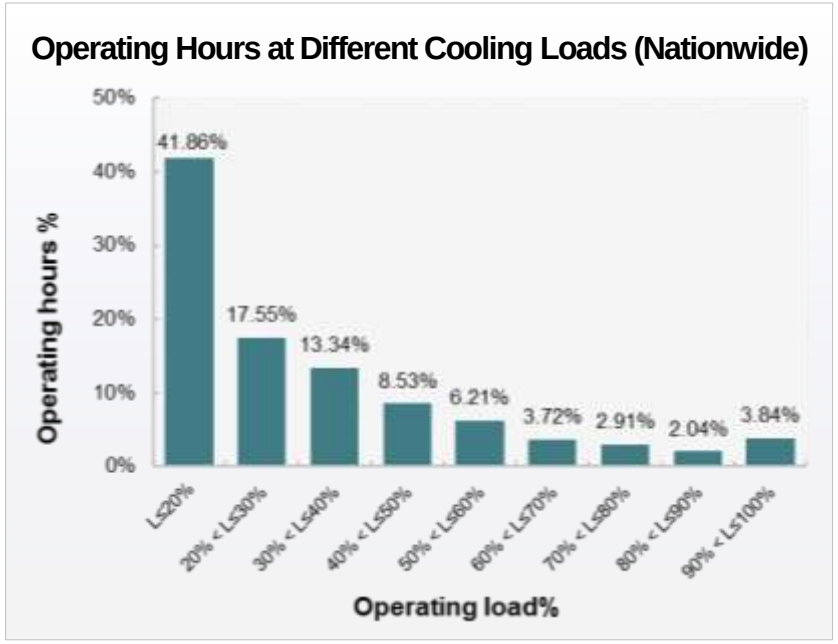
Technical paths

Key technologies to improve efficiency of residential VRFs

- 50% of VRF market, 30% of average annual growth rate in China.
- Only one indoor unit running, load lower than 30% during 60% of the time.
- Common habit for most Chinese users: minimize family living expense.







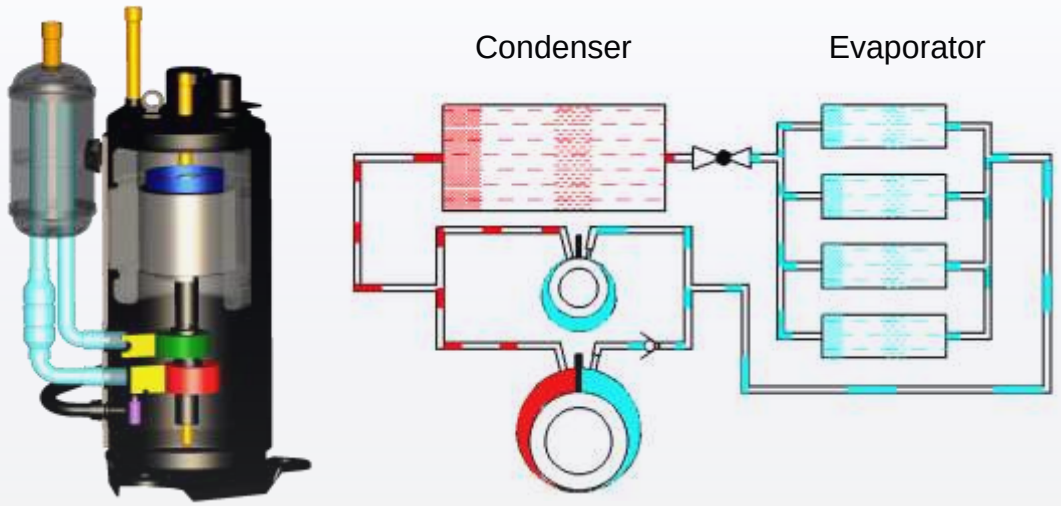
*Source: Survey And Study Report On Application For Refrigeration And Air-conditioning Products In China.

Technical paths

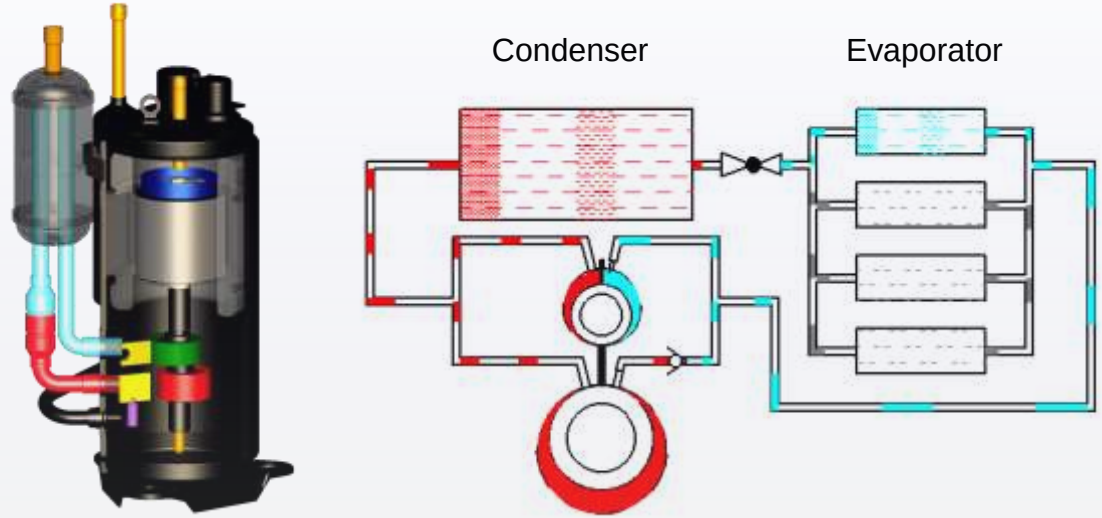
Newly developed compressor: large and small volume cylinders in parallel.

- High load: both cylinders working at the same time.
- Low load: large cylinder stops and only small cylinder works.
- Motor working always at high speed, energy efficiency at low load is improved.

System with Both Cylinders in Operation



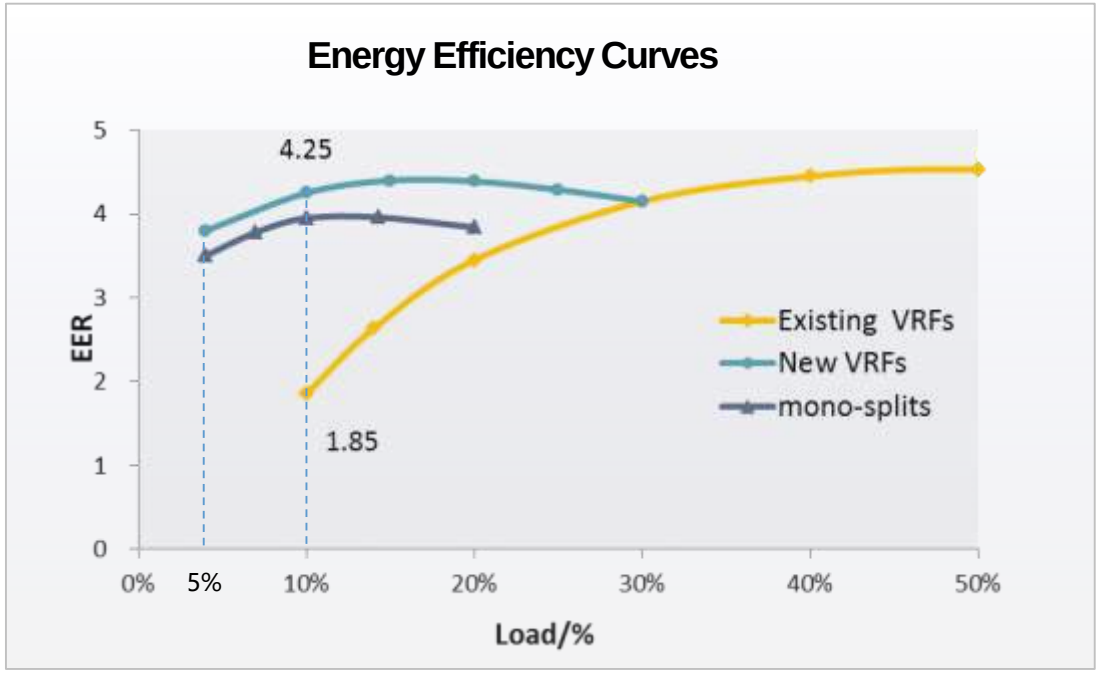
System with Only Small cylinder in Operation

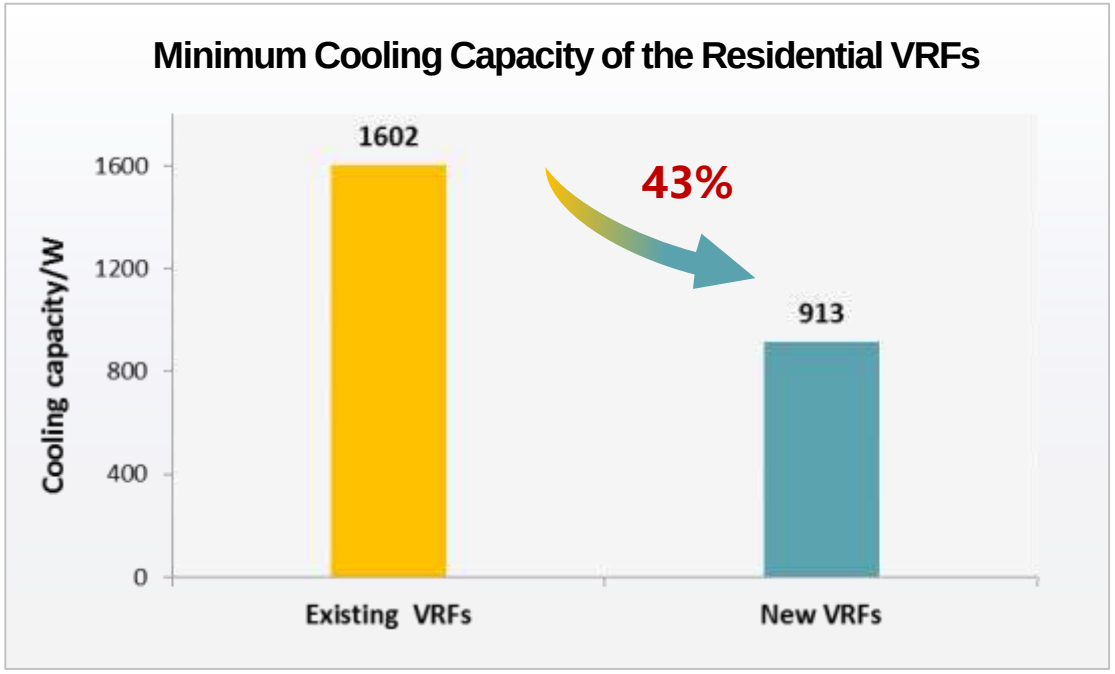


Technical paths

Greater comfort, more energy-saving

- EER of new VRFs has been greatly improved at load below 30%.
- EER increases from 1.85 to 4.25 at load 10%:
- The minimum operation load down to 5%, indoor temperature fluctuation and frequent start-stop problems are solved.



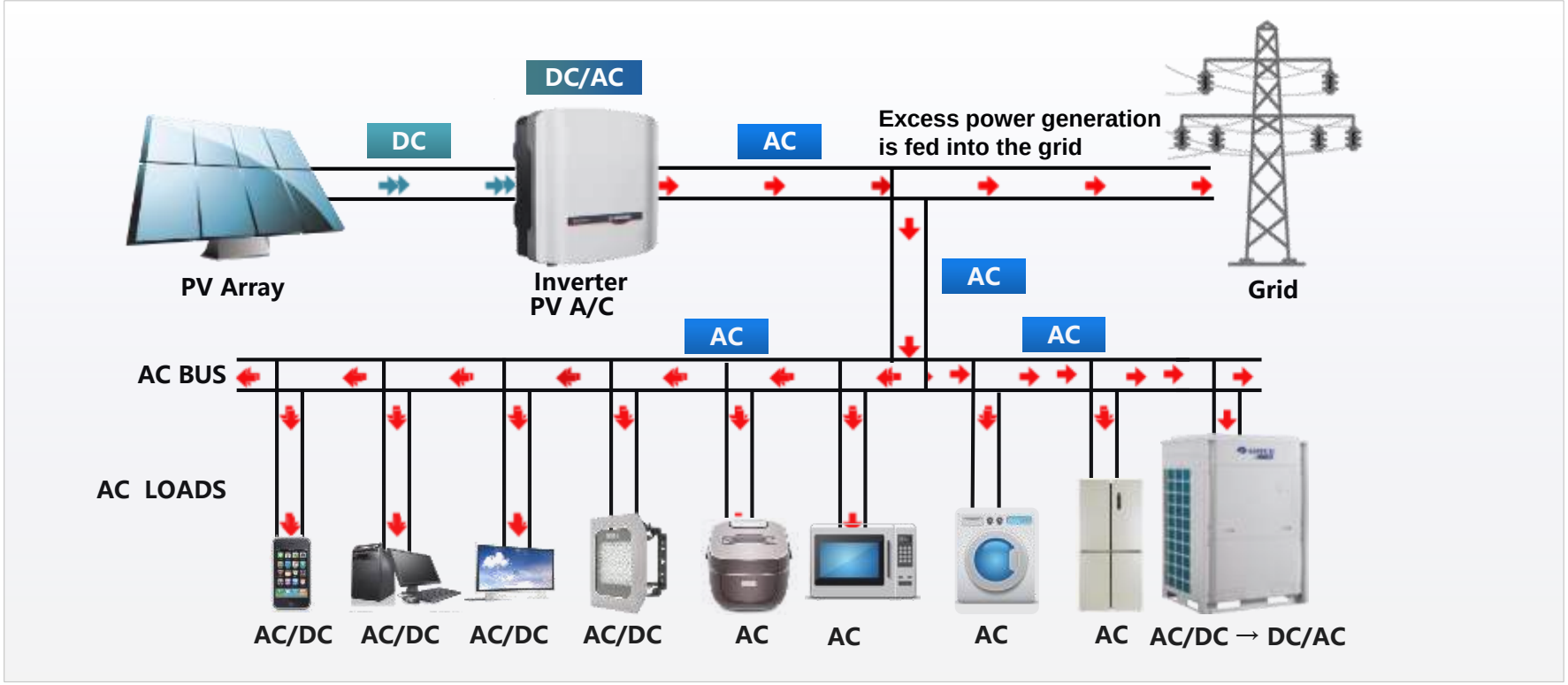


*Note: tested by National Quality Supervision and Inspection Centre of Compressor and Refrigerator Products.

Technical paths

PVAC is the best link to the home micro-grid system

- PV inverter replaced by air conditioner, and air conditioner directly driven by PV power;
- Directly driven, **2 power conversion less**, efficiency increased by 4~6%;
- Excess power supplied to other appliances, or fed into to the public grid.

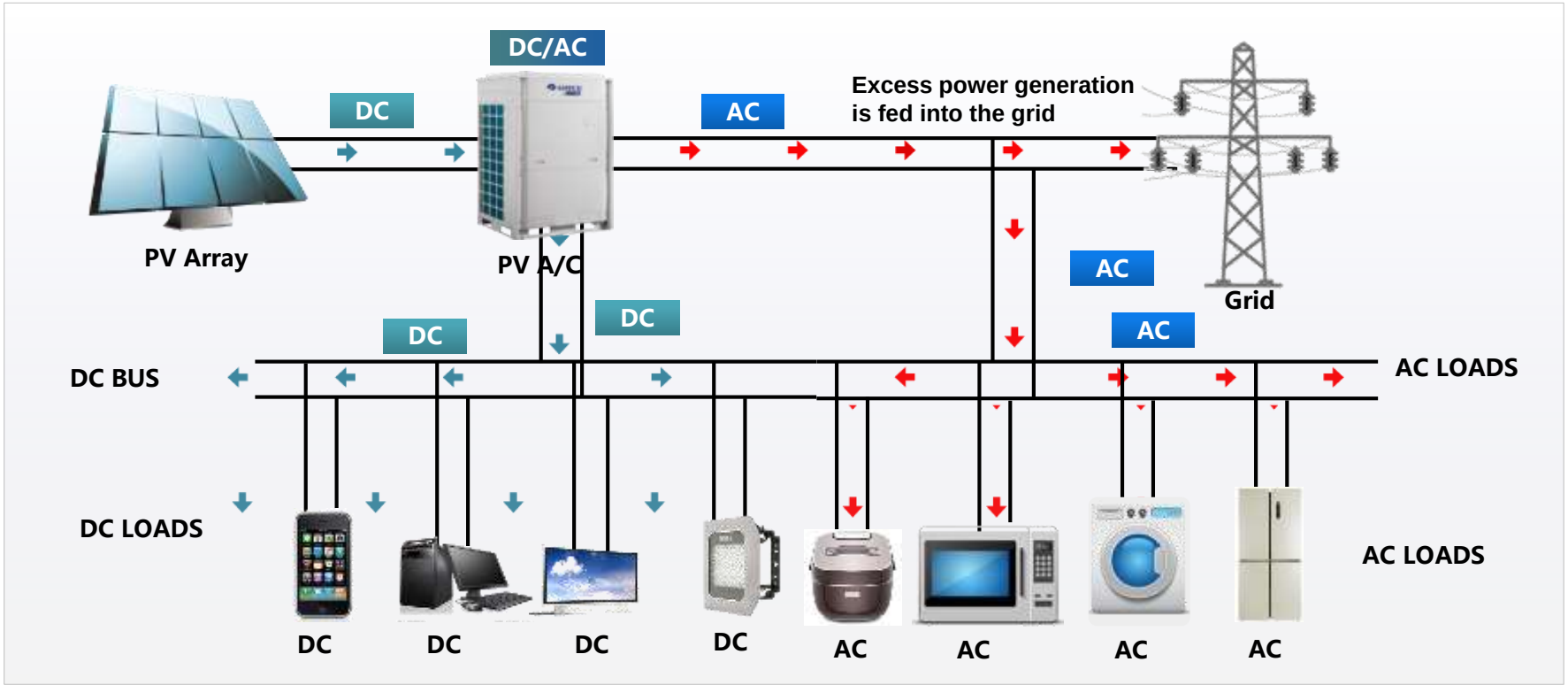


PVAC Micro-grid System

Technical paths

PVAC Micro-grid System

- More and more DC powered household appliances.
- The DC bus of the PVAC directly supply DC power to DC loads, seamless connection between PV power and appliances.



The DC bus of the PVAC supply DC power to DC loads directly

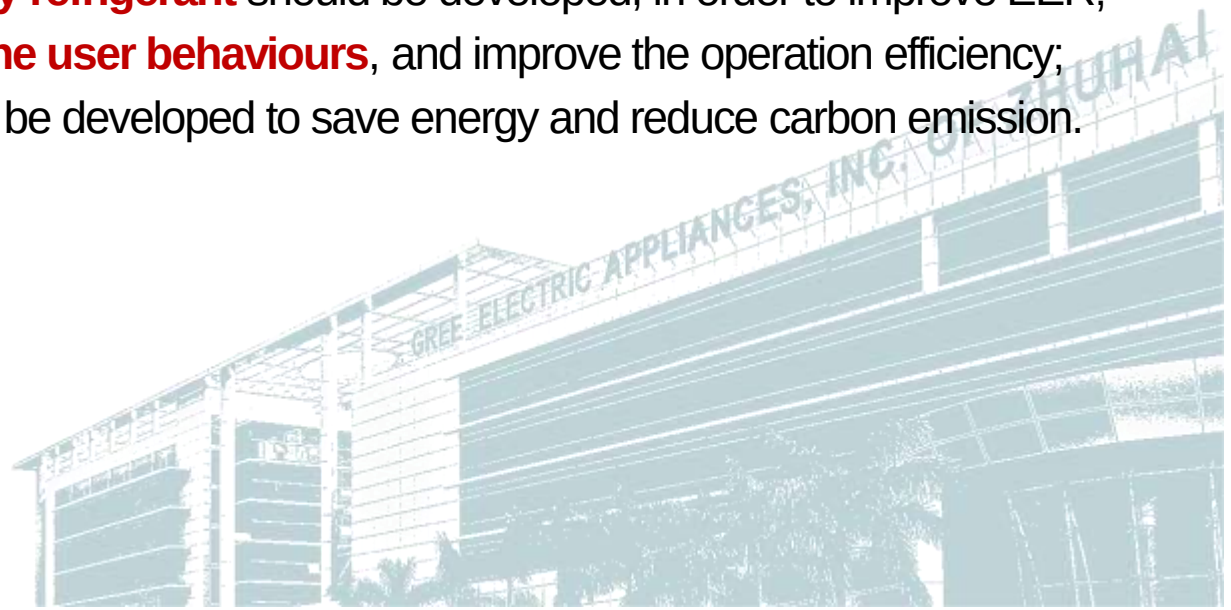
Summary

1. It is suggested that countries in subtropics should improve the policies and standards based on its own climate characteristics

- Minimum energy efficiency limits should be improved to eliminate the low efficiency products;
- Top runner program should be introduced to encourage the promotion of high efficiency products.

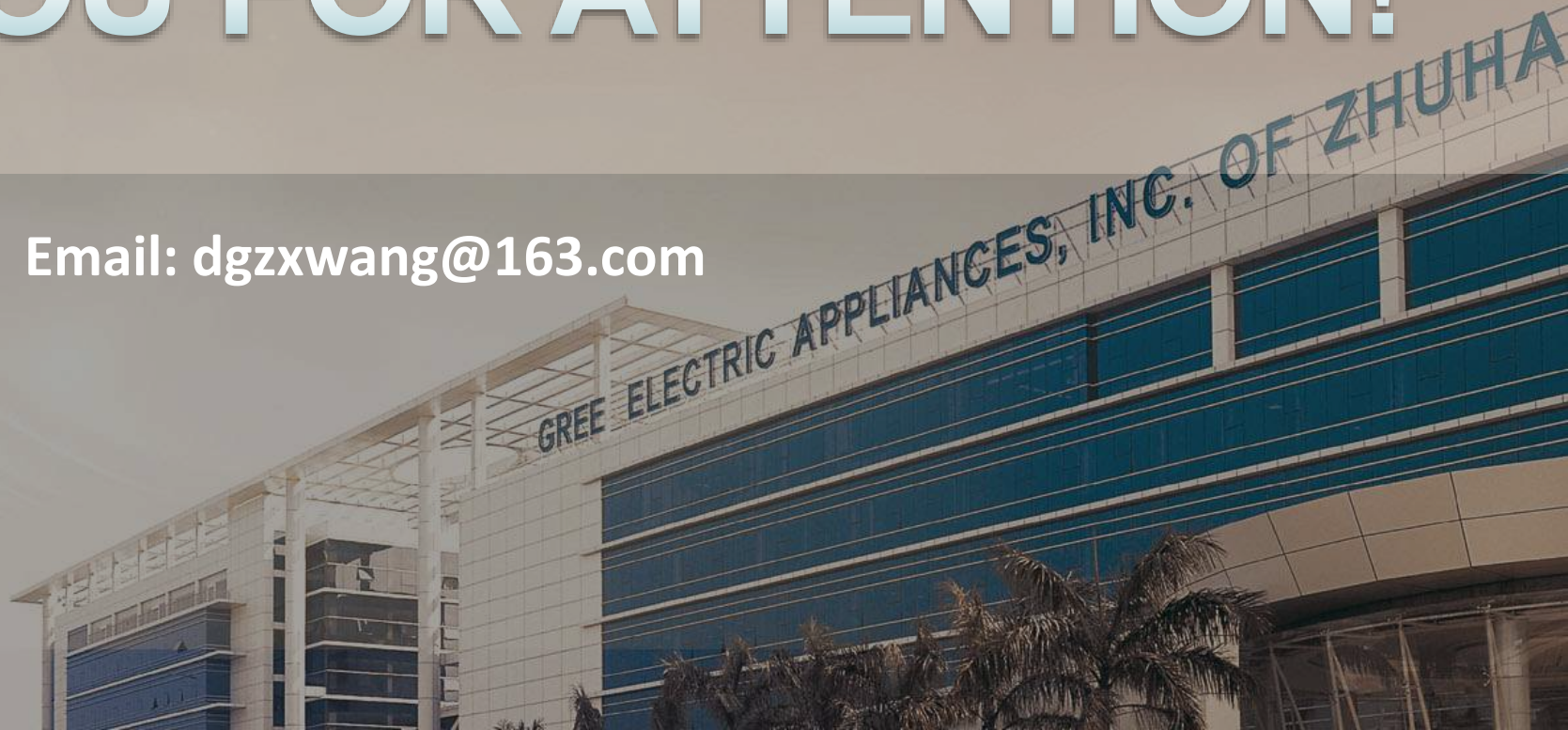
2. New refrigeration equipment needs to be developed, in order to adapt the “part time” and “part space” cooling behaviour

- **High efficiency compressors** and **environmental friendly refrigerant** should be developed, in order to improve EER;
- New technologies should be developed, in order to **adapt the user behaviours**, and improve the operation efficiency;
- AC products and micro-grid driven by **solar energy** should be developed to save energy and reduce carbon emission.



THANK YOU FOR ATTENTION!

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GREE Profile

- Founded in **1991**;
- A diversified international industrial group;
- Main products: Residential air conditioners, Commercial air conditioners home appliances, intelligent equipments, etc.
- Business in more than **160** countries and regions, over **400 million** users worldwide.
- In 2018, sales revenue achieved **200 billion RMB** (22.4 billion USD) ;

Wall-mounted units
Window units
Floor Standing units
Portable units
Dehumidifiers
…



Residential air conditioning

Chillers
VRF
Unitary units
ATW
AHUs
…



Commercial air conditioning

Refrigerators
Washing Machines
Water purifiers
Air purifiers
…



Home appliances

Industrial robots
High-end digit control machine tools
Industrial integration applications
…



Smart equipment

GREE Profile

- Headquarters in Zhuhai, China.
- About 90,000 employees and 11 production bases all over the world.
- 6 subsidiary companies for compressor, motor, electronics, intelligent equipment and precision mould.



Zhuhai


Chongqing


Shijiazhuang


Wuhan


Changsha


Wuhu


Hefei


Hangzhou


Zhengzhou

China Bases

Overseas Bases


Brazil



Pakistan

GREE Profile

- Above **12,000** R&D personnel, **25,000** authorized patents;
- **929** advanced labs for performance, safety, EMC, and sound test etc., 173 of which have obtained CNAS, CQC, UL, AHRI, CSA, or SGS certificate.



EMC Lab



Acoustic Lab



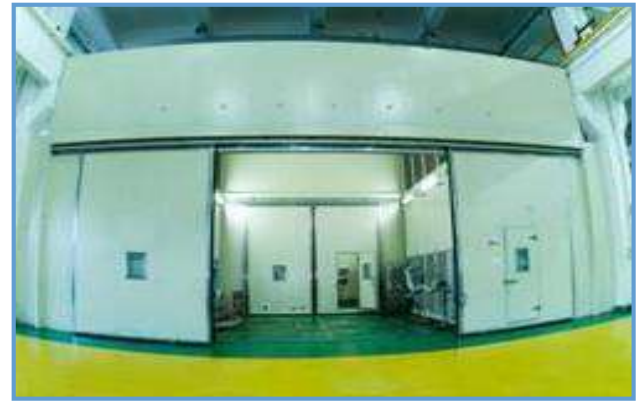
Water-cooled chiller Lab



Environmental Simulation Lab



PV Lab



Air-cooled chiller Lab