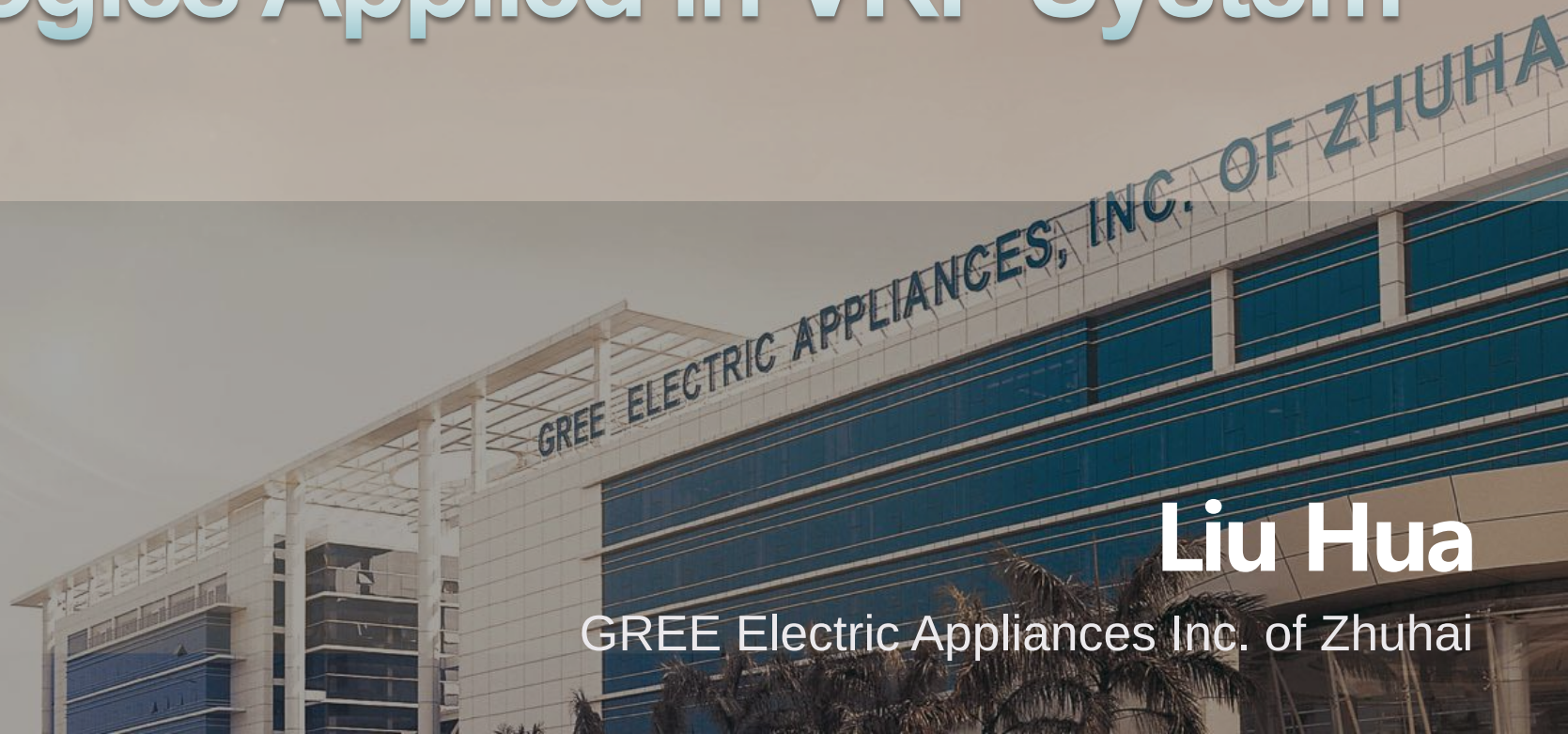
Skate Key Laboratory of Air-Conditioning Equipment and System Energy Conservation

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

New Technologies Applied in VRF System



The 6th IEA-Tsinghua Joint Workshop

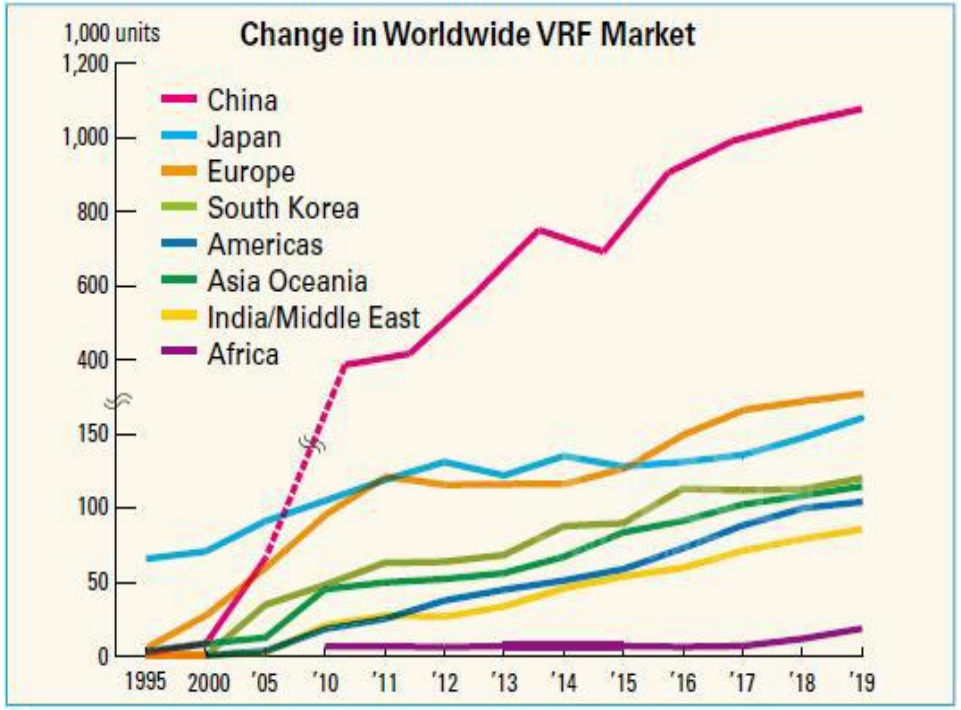
Liu Hua

GREE Electric Appliances Inc. of Zhuhai

Global market trends

More and more popular worldwide

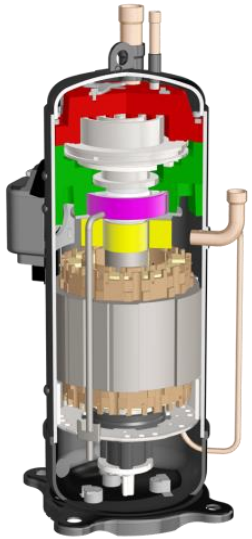
- The global VRF system market has reached **1.86 million** units
- China, Japan, and South Korea are the world's three major VRF markets, which account for about **70%** of global market
- Areas such as the Americas, Southeast Asia, and India have yet to be developed
- Residential VRF has become fashionable among Chinese consumers



New technology development

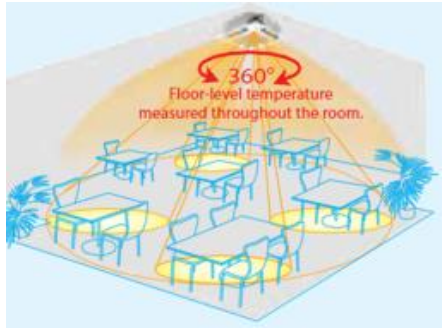
Fast development with the information technology revolution

- New VRF systems are developing towards **intelligence, comfort, and health**
- Combined with artificial intelligence (AI), the Internet of Things (IoT) and 5G, new products with remote control, intelligent operation, voice intelligent control, and other functions have been developed, so as to provide users with a better and smoother experience

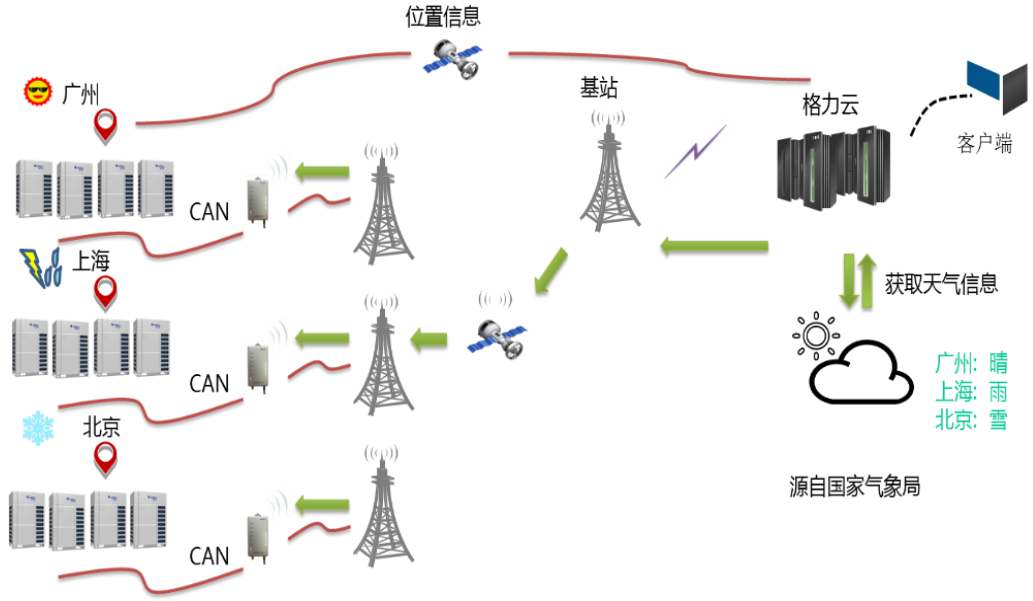


Good heating performance at –20ºC

Fresh air cleaning technology



Intelligent control with AI



Big data platform for VRF

Technical paths

Technical paths to improve efficiency of residential VRFs

High performance compressor

Improve the compressor efficiency at low load condition

Distributed air supply

Improve air distribution of heating supply, and avoid aggregation of hot air

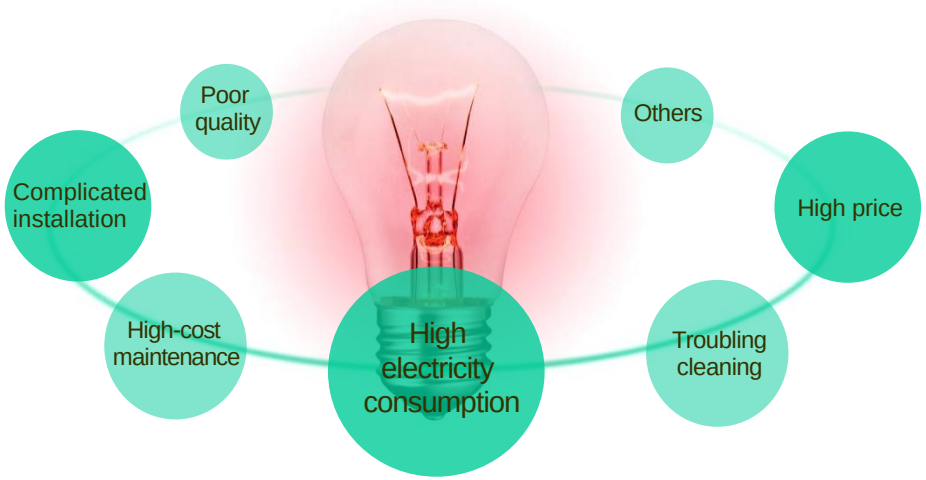
Renewable energy

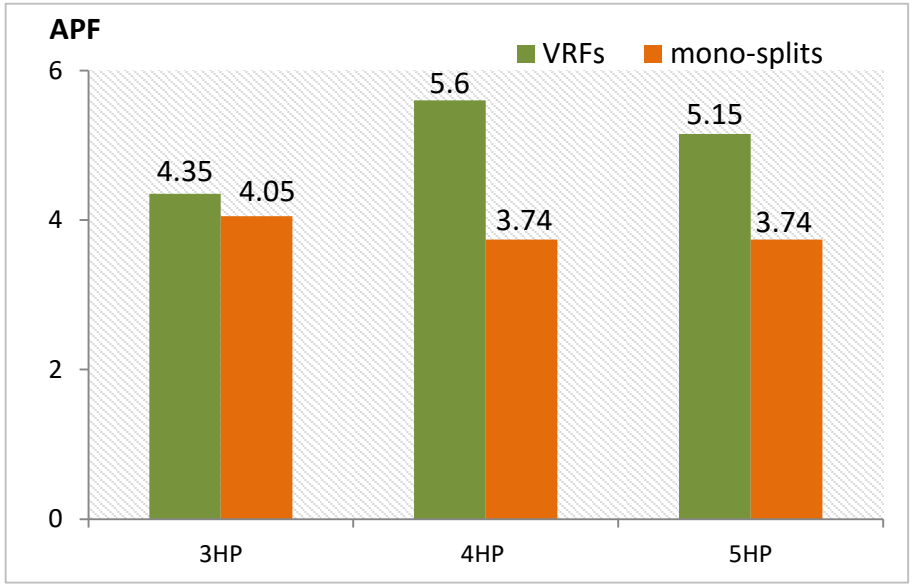
Photovoltaic air conditioner, make full use of solar energy

Newly developed compressor

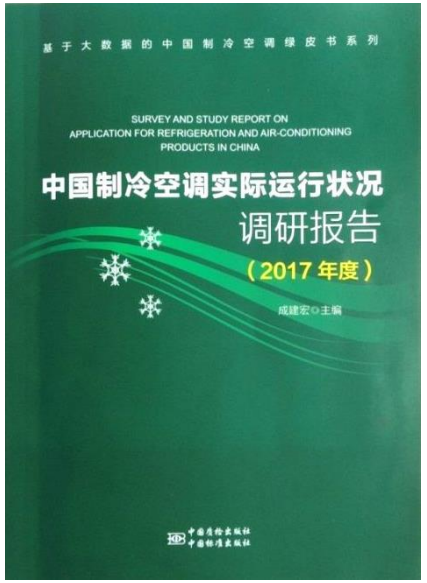
Disadvantage for residential VRFs: high electricity consumption

- General impression: mono-splits are more energy saving than VRFs
- **Isn't it true that the energy efficiency of VRF is higher than the mono-split? Why?**
- Green book "Survey and Study Report on Application for Refrigeration and Air-Conditioning Products in China" being published by GREE and China National Institute of Standardization, based on operation data of 200,000 VRF samples





Energy Efficiency Comparison Between VRFs and mono-splits

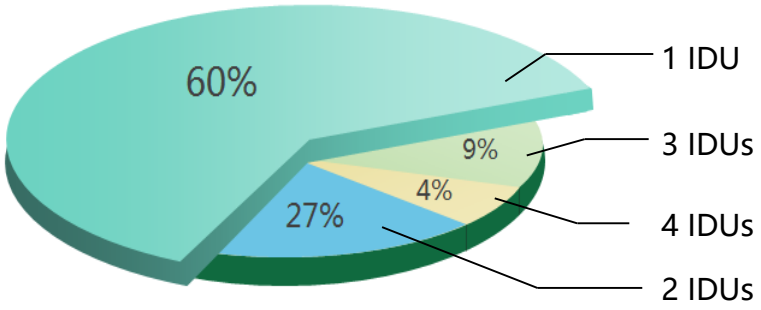


Newly developed compressor

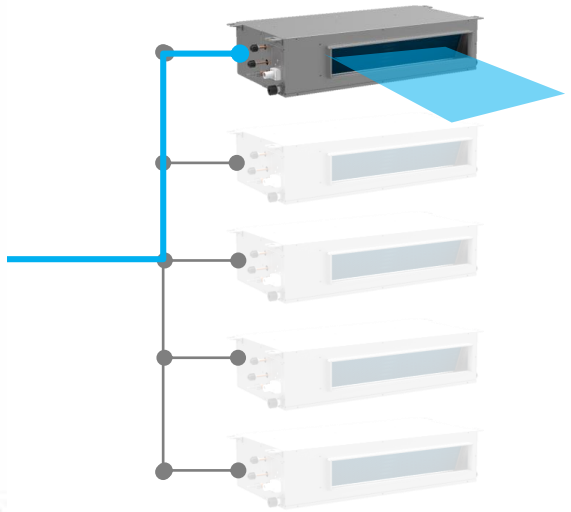
Realities for residential VRFs in China:

- **Running quantity:** only one indoor unit running during 60% of the time
- **Operating Load:** load lower than 30% during 60% of time
- Common habit for most Chinese users: minimize family living expense

Indoor Unit Quantity Operating at the Same Time (Nationwide)



6HP compressor → 1HP indoor unit



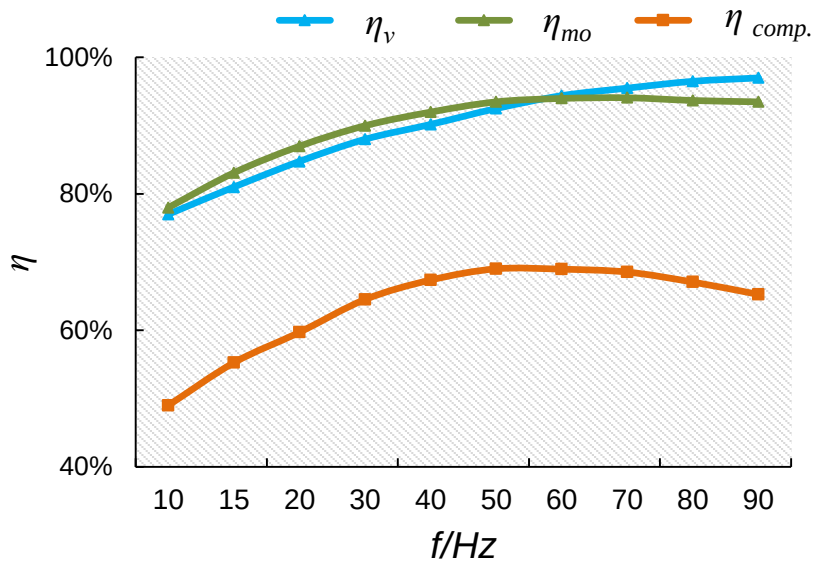
*Source: Survey And Study Report On Application For Refrigeration And Air-conditioning Products In China.

Newly developed compressor

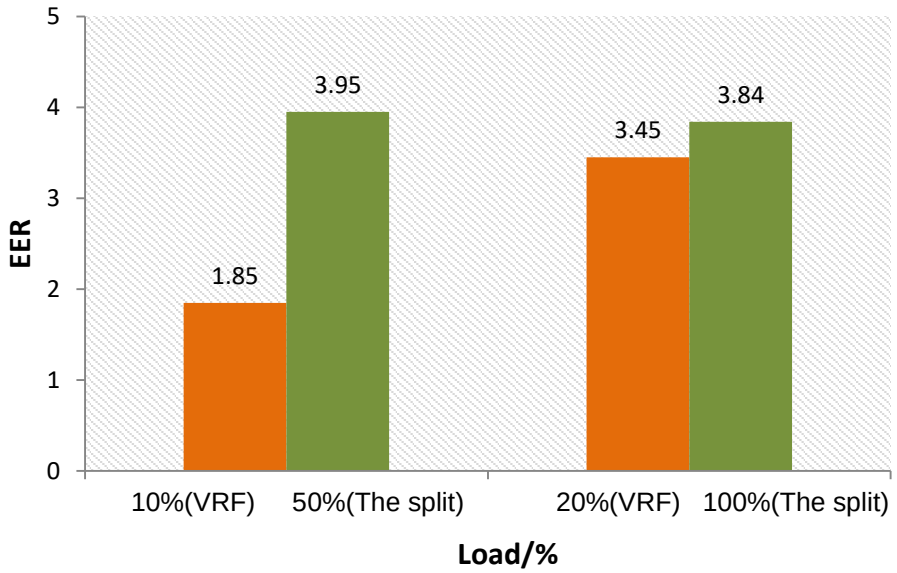
Key to decrease the consumption of residential VRFs: improve the energy efficiency at low load

- With motor speed decreasing at low load, motor efficiency and the volumetric efficiency go down as well
- When only one indoor unit is operating at 50% load, 1HP mono-split: load 50%, **EER 3.95**, 5HP VRF: load 10%, **EER 1.85**. It is why the consumption for VRF is higher than split
- Minimum load of the traditional VRFs is 10% only, compressors frequently start and stop

Efficiency Curves of the Compressor at Difference Frequencies



Energy Efficiency Comparison Between VRFs and the Splits

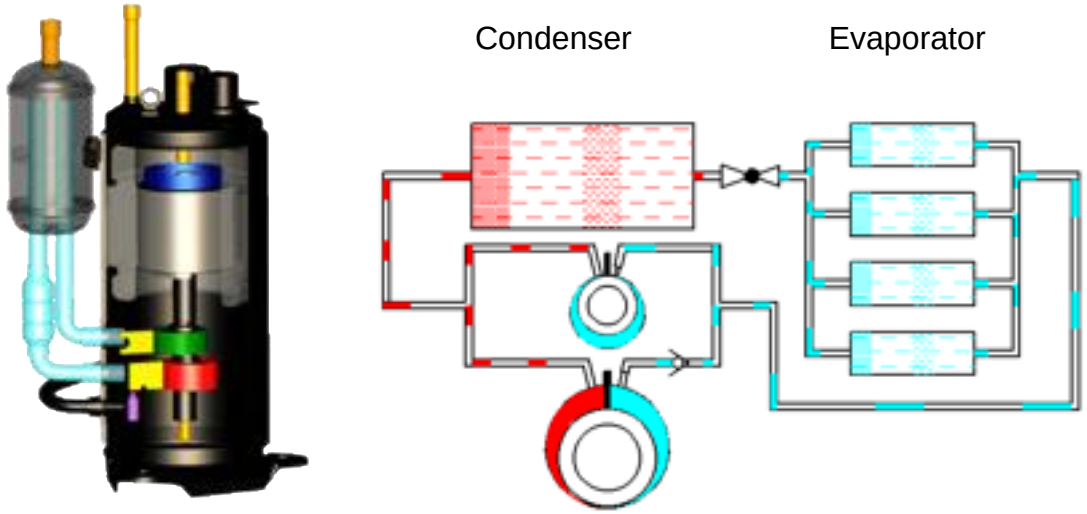


Newly developed compressor

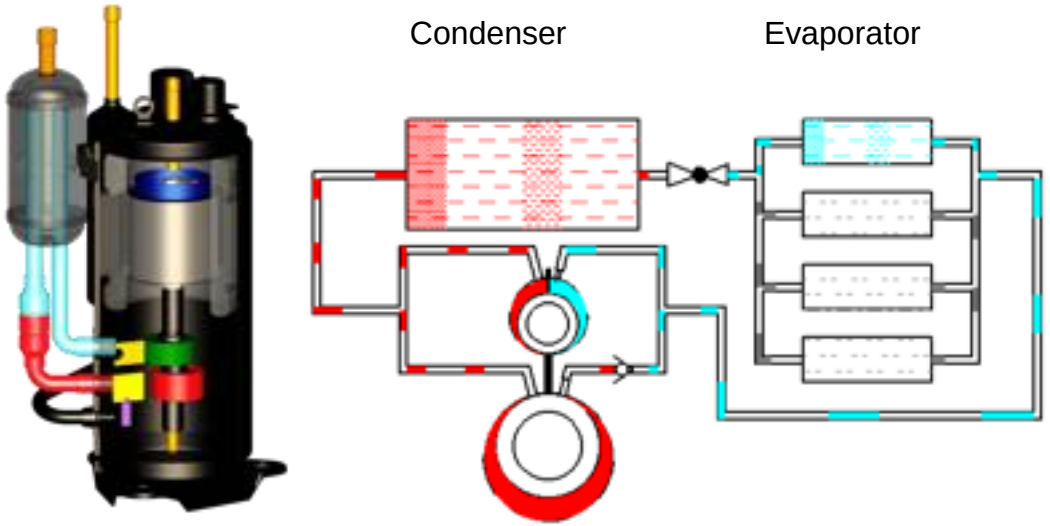
Newly developed compressor: large and small volume cylinders in parallel

- 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

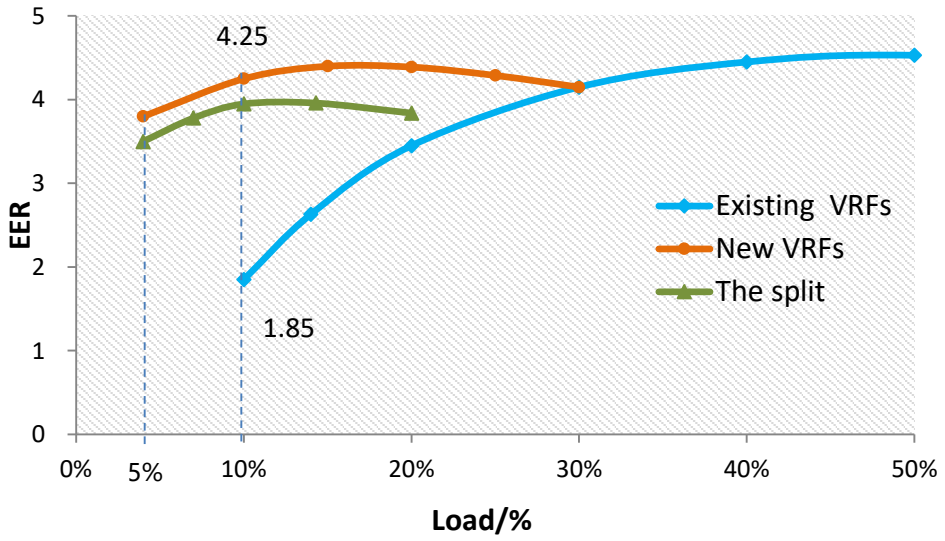


Newly developed compressor

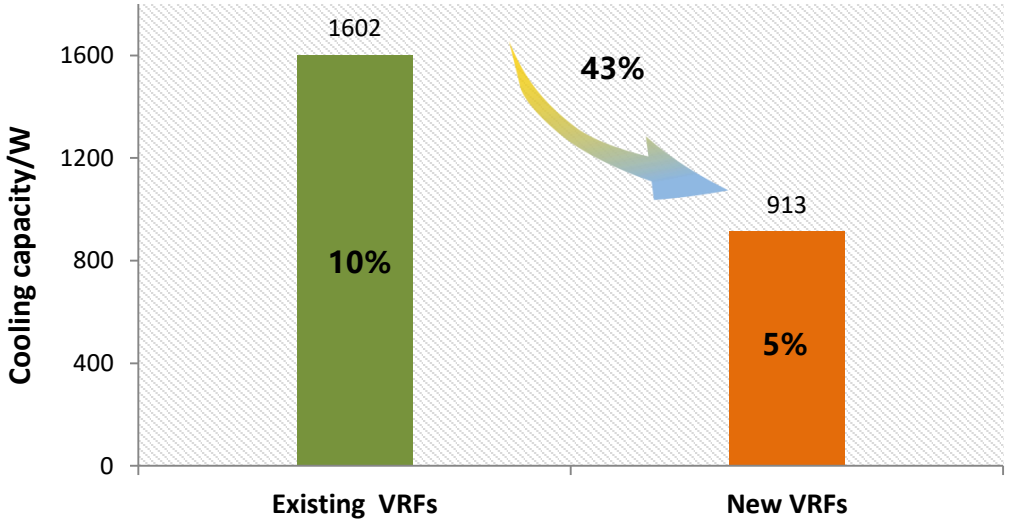
Greater comfort, more energy-saving

- EER of new VRFs has been greatly improved at load below 30%, now **higher than the mono-split**
- **At 10% load:** EER increases from 1.85 to 4.25, improved by 130%
- The minimum operation load down **to 5%**, indoor temperature fluctuation and frequent start-stop problems are solved

Energy Efficiency Curves



Minimum Cooling Capacity of the Residential VRFs

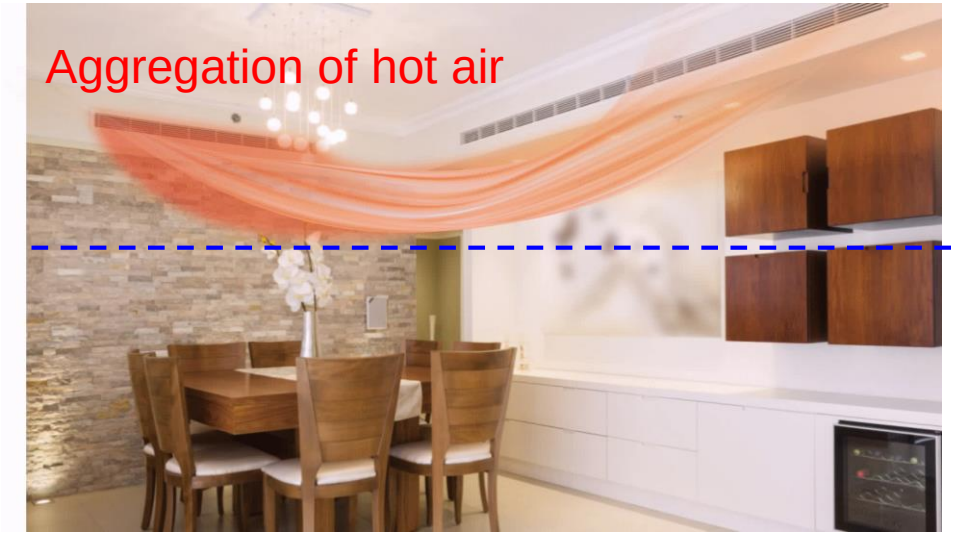


*Note: tested by National Quality Supervision and Inspection Centre of Compressor and Refrigerator Products.

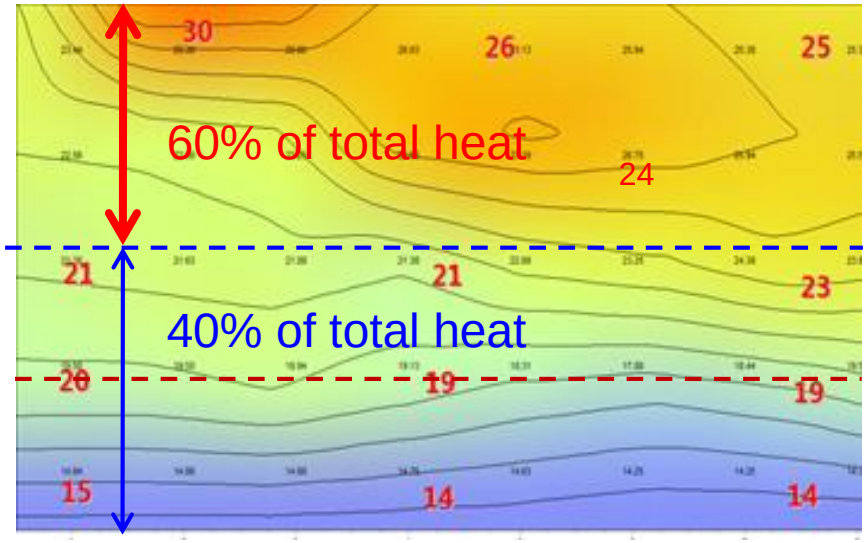
Distributed air supply

Discomfort caused by indoor air aggregation

- For traditional VRF, fixed air duct is installed at higher position
- Hot air aggregates at upper space when heat supply, vertical temperature difference reaches **9.7℃**, and room temperature rises slowly, causing discomfort



Uneven air distribution for the traditional air duct

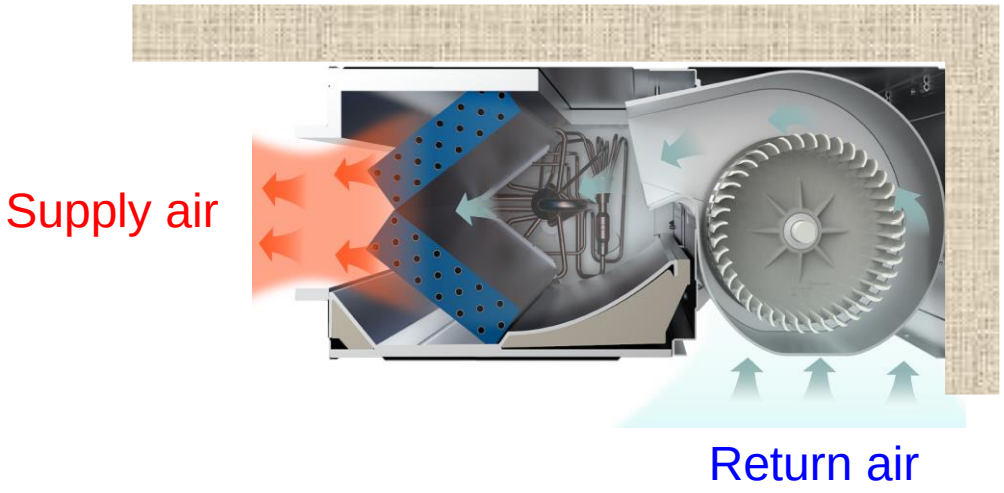


Vertical temperature difference is still large after heating for 3 hours

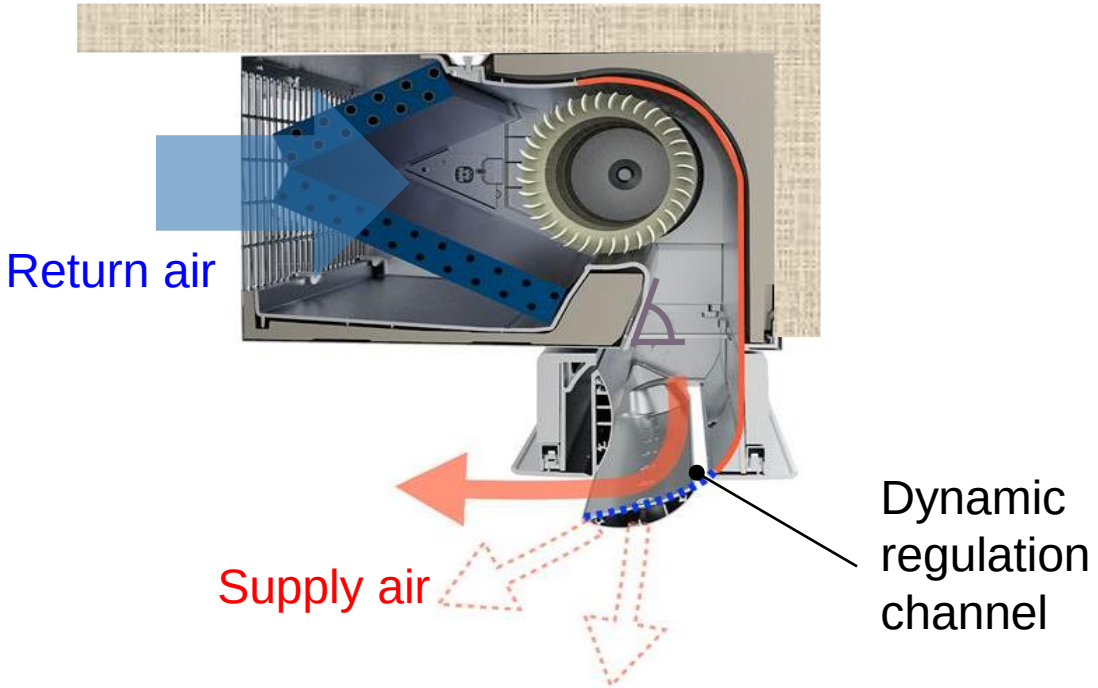
Distributed air supply

New technology: distributed air supply

- Supply downwards and return from side, 0~90° sweeping, ensuring the sinking of hot air
- Improve indoor air distribution of heating supply, and avoid aggregation of hot air



Traditional air duct: return from bottom and supply from the side

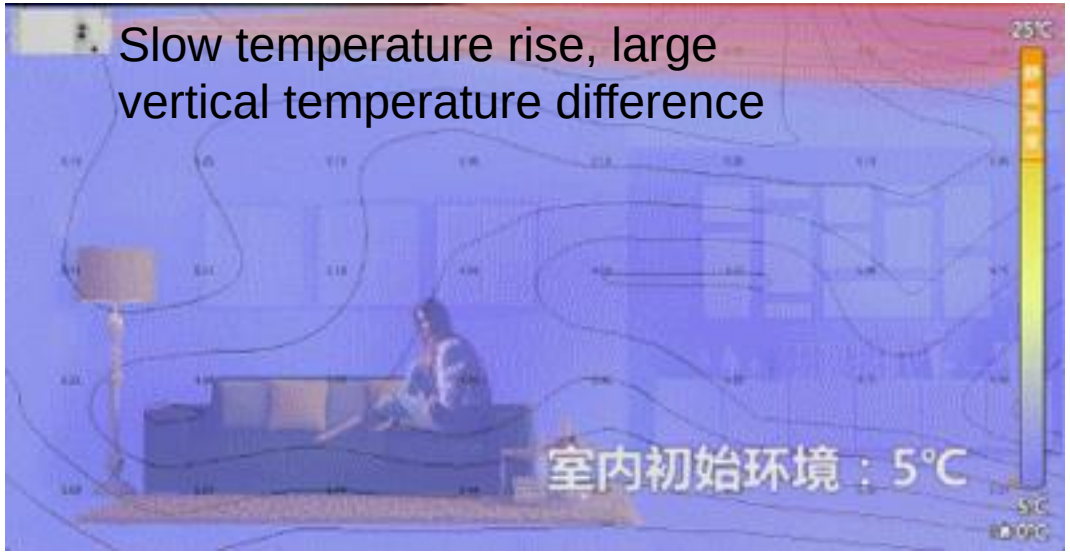


New technology: return from side and supply downwards with 0~90° sweeping

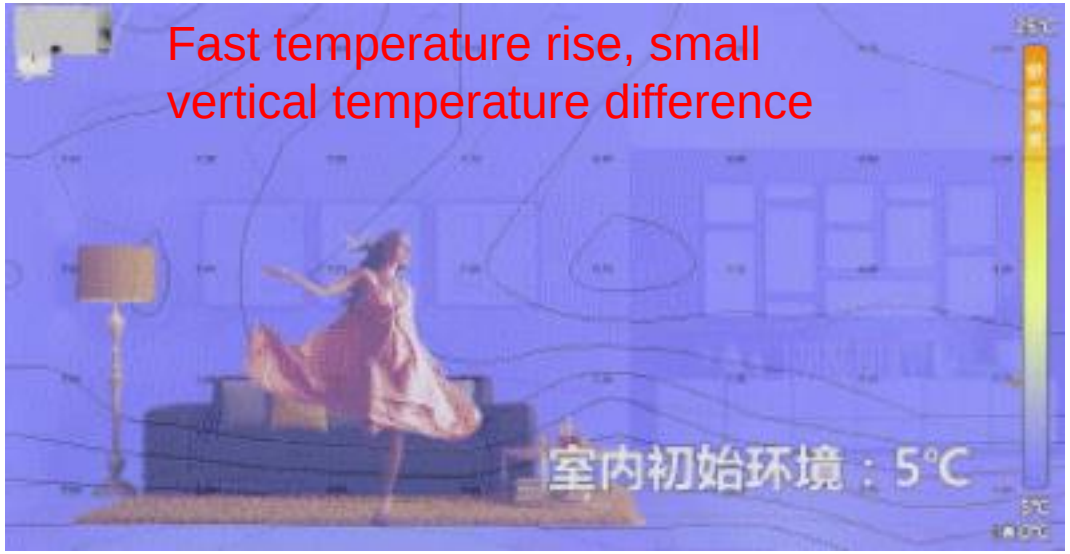
Distributed air supply

Effect comparison

- **Uniform temperature field:** Vertical temperature difference drops from 9.7℃ to **2℃**
- **Fast temperature rise:** effective heat increased by **45%**, time interval of temperature rise decreased by **64.4%**



Traditional air supply

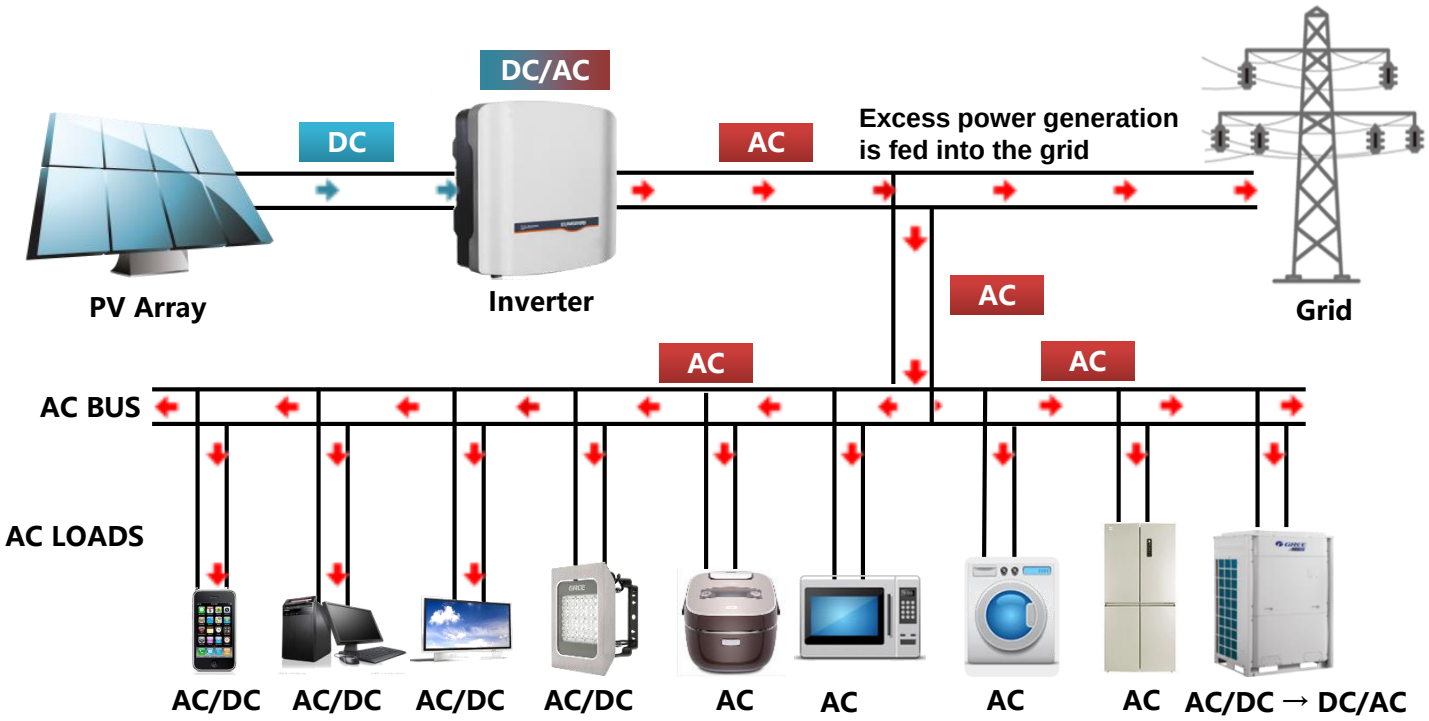


New technology of distributed air supply

Photovoltaic air conditioner

Typical Micro-grid PV System

- PV power converted to AC current and supplied to home appliances, extra power fed into the public grid
- Air conditioner power consumption accounts for 50% of household electricity
- Air conditioner, PV power converted **3 times**, power loss up to **6-8%**

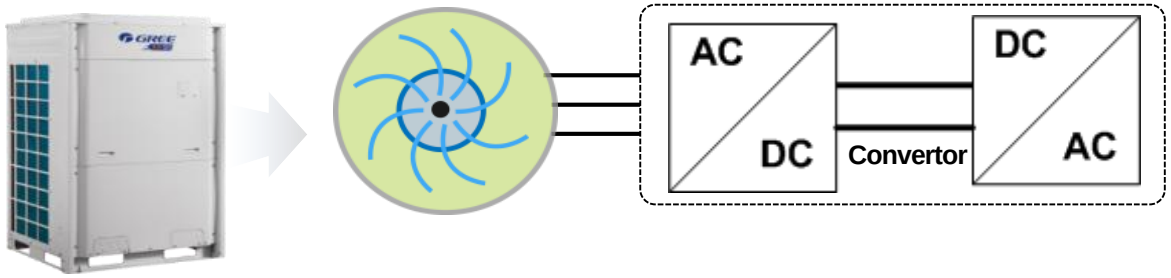


Traditional Micro-grid PV System

Photovoltaic air conditioner

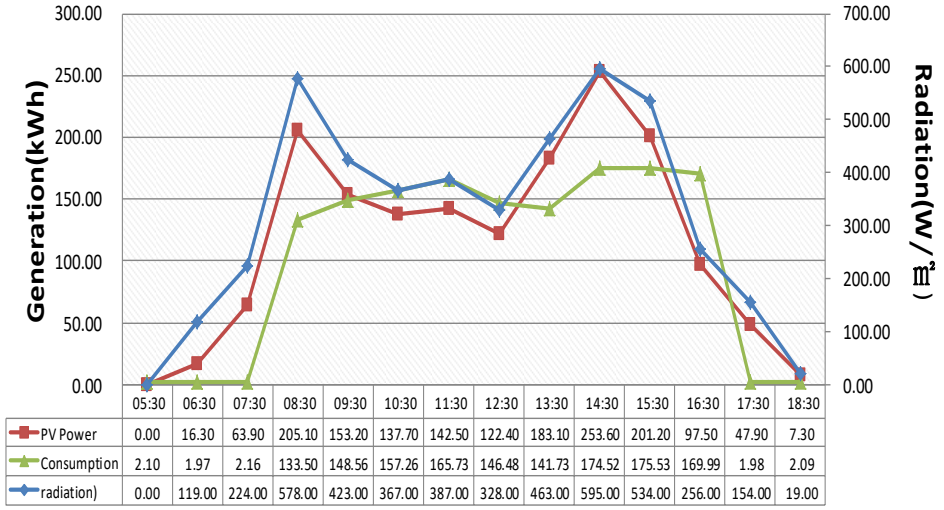
PVAC is the best link to the home micro-grid system

- **Lower investment**: built-in DC/AC module inside air conditioner ; replace PV inverter
- **Higher efficiency**: PV directly driven, **2 power conversion less**, efficiency increased by 4~6%
- **Perfect match**: Solar radiation intensity, PV power generation and air conditioning power consumption are in direct proportion. The self consumption of PV power is maximized



PVAC internal structure

Solar radiation , PV power generation and air conditioning power consumption curve

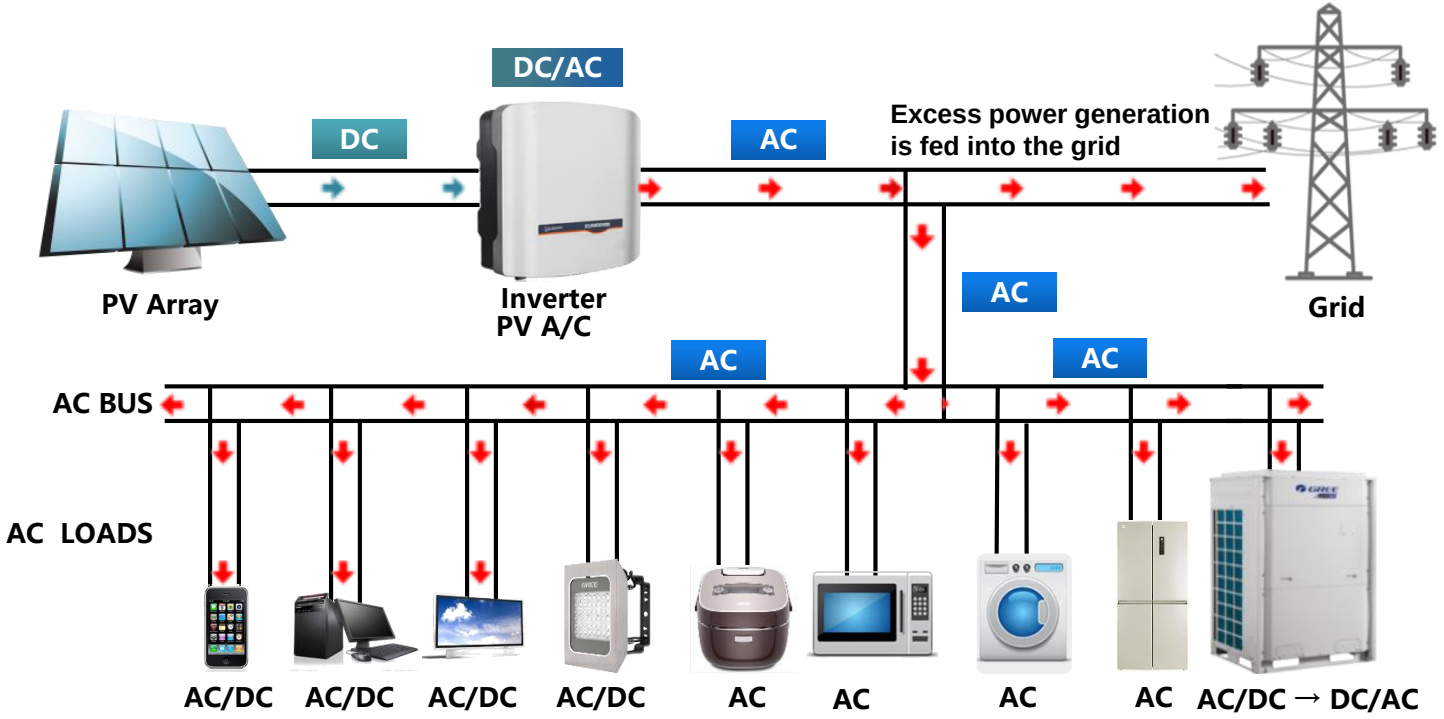


	05:30	06:30	07:30	08:30	09:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30
PV Power	0.00	16.30	63.90	205.10	153.20	137.70	142.50	122.40	183.10	253.60	201.20	97.50	47.90	7.30
Consumption	2.10	1.97	2.16	133.50	148.56	157.26	165.73	146.48	141.73	174.52	175.53	169.99	1.98	2.09
radiation)	0.00	119.00	224.00	578.00	423.00	367.00	387.00	328.00	463.00	595.00	534.00	256.00	154.00	19.00

Photovoltaic air conditioner

PVAC Micro-grid System

- PV inverter replaced by air conditioner
- Air conditioner directly driven by PV power
- Excess power supplied to other appliances, or fed into to the public grid

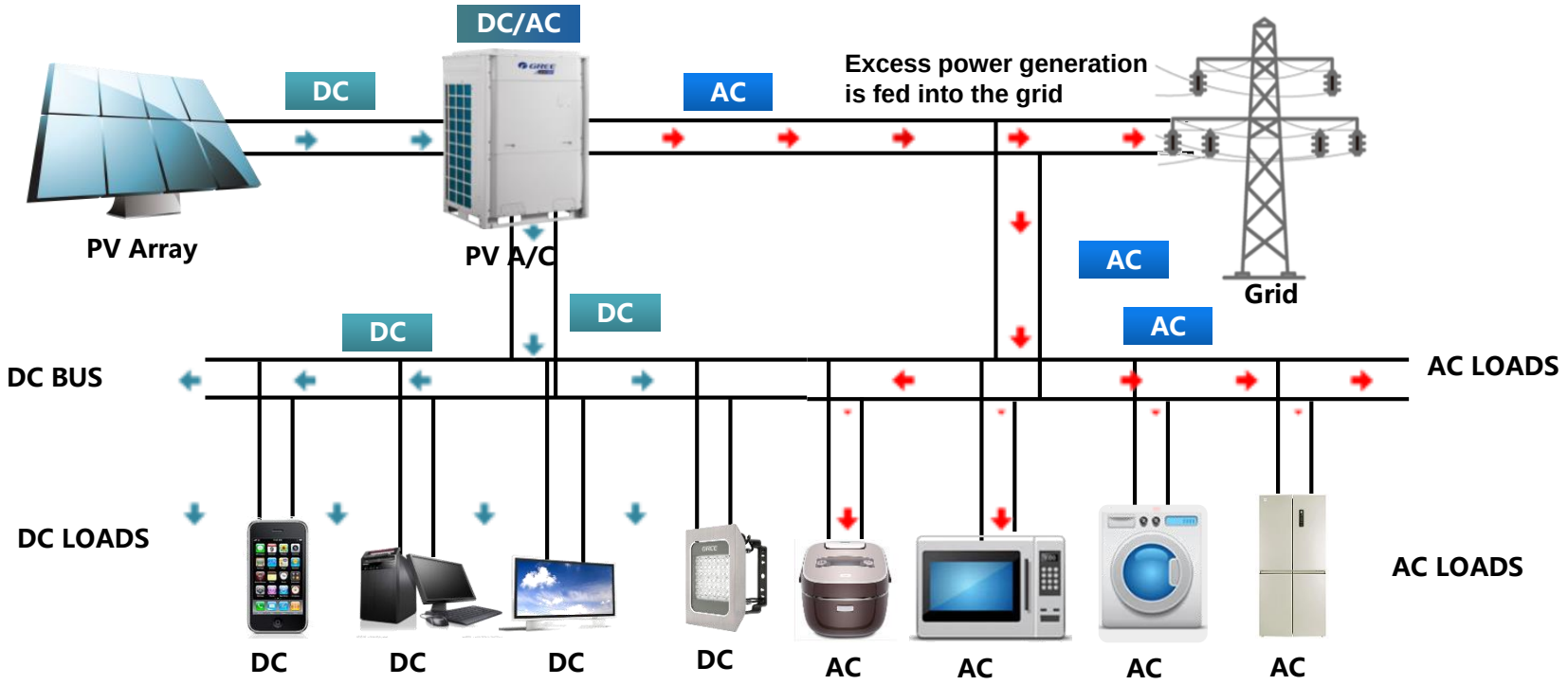


PVAC Micro-grid System

Photovoltaic air conditioner

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

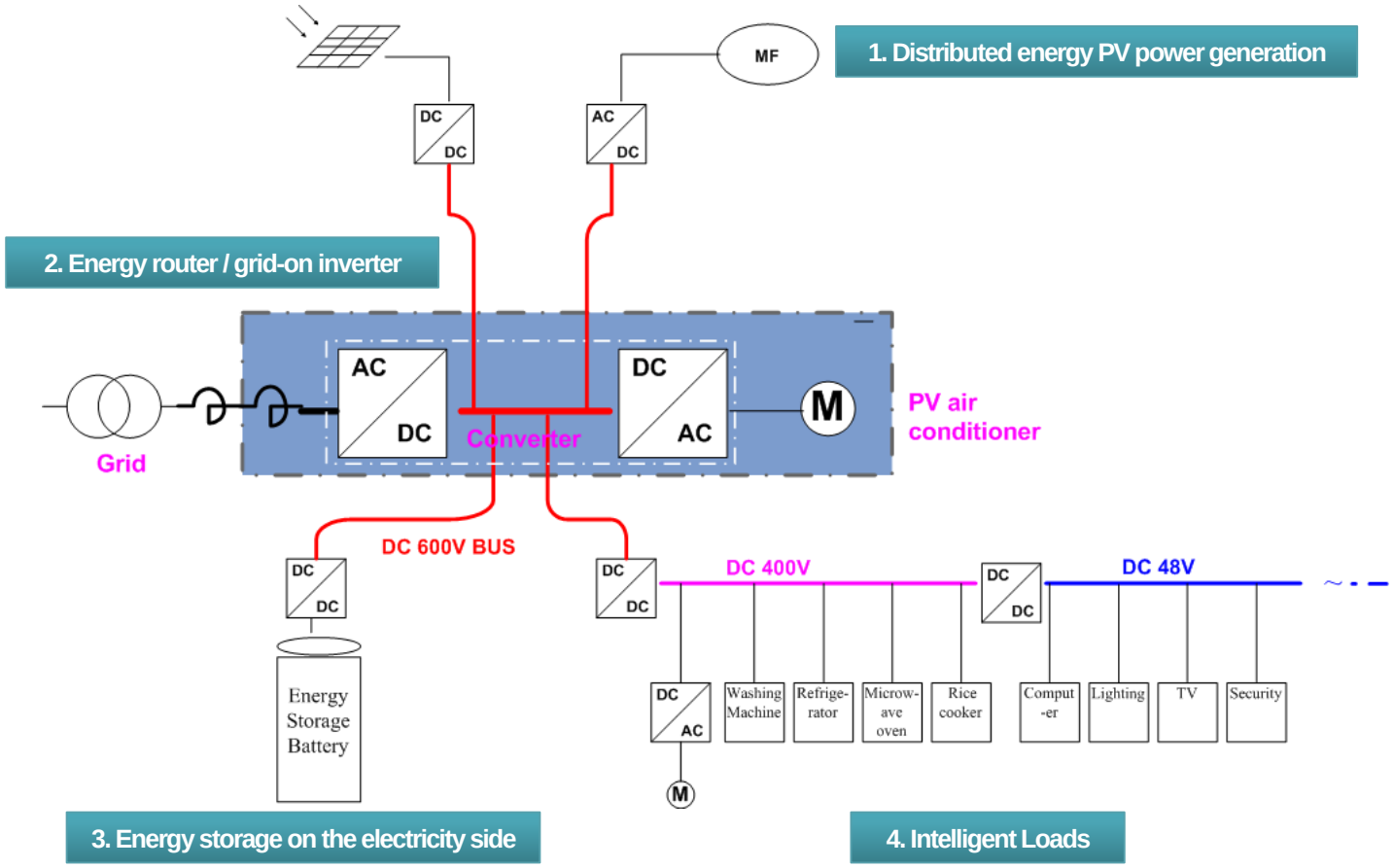


The DC bus of the PVAC supply DC power to DC loads directly

Photovoltaic air conditioner

PVAC Micro-grid System

- Wind power and other renewable energies can be fed into the system
- Energy storage can be integrated to the system to realize off-grid operation
- DC bus can supply DC power to different appliances with different Voltages

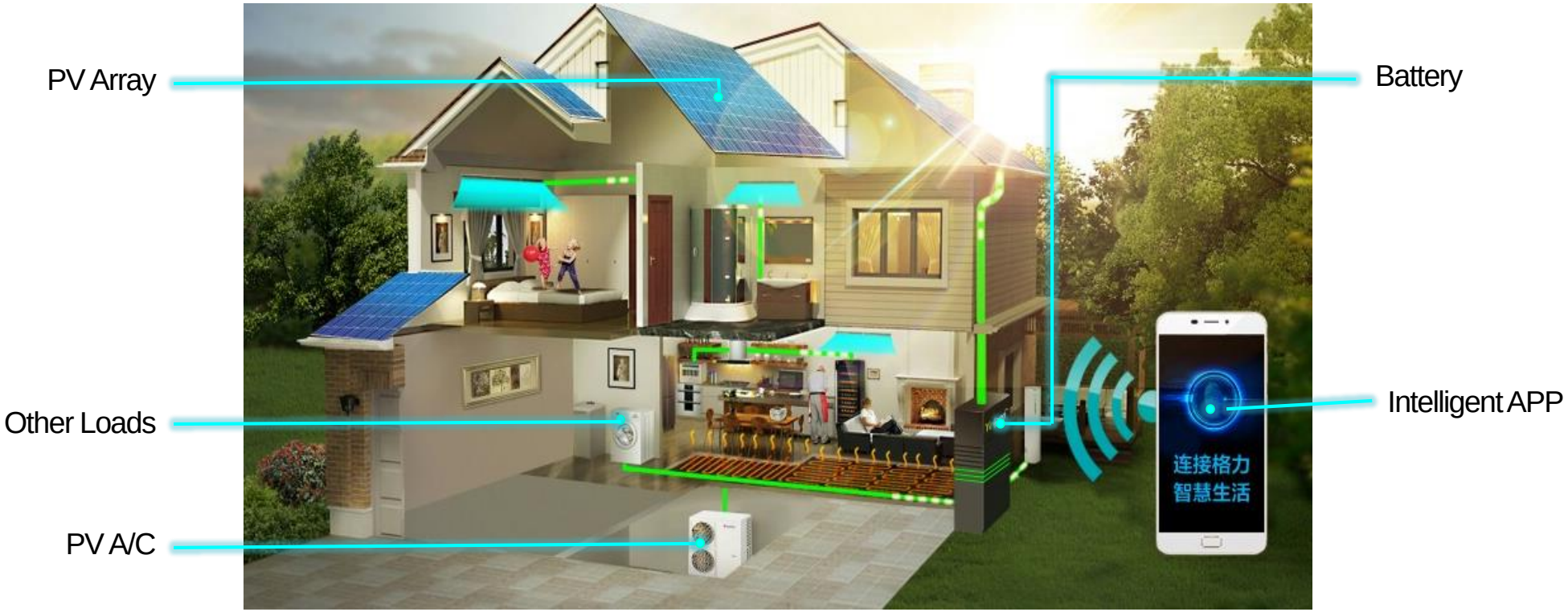


Topology Diagram of PVAC Micro-grid System

Photovoltaic air conditioner

Future PV House

- PVAC works as energy dispatch center, other renewable energies can be combined into the system
- The system can achieve power generation, storage and consumption at both on-grid and off-grid statuses



Future PV Family

Photovoltaic air conditioner

More than **10,000** Gree PV air conditioning systems;

23 countries, including middle east, north America, Southeast Asia;

Sales countries of product applied with the new technology

Summary

New VRF products need to be developed, in order to adapt the “part time” and “part space” cooling behavior

- New compressor technologies should be developed, in order to **adapt the user behavior**, and improve the operation efficiency
- Indoor air distribution should be improved to realize comfort and energy saving
- AC products and micro-grid driven by **solar energy** should be developed to save energy and reduce carbon emission

THANK YOU FOR ATTENTION!