Use of Solar Energy in Buildings and Kitchens

Professor DAI Yanjun

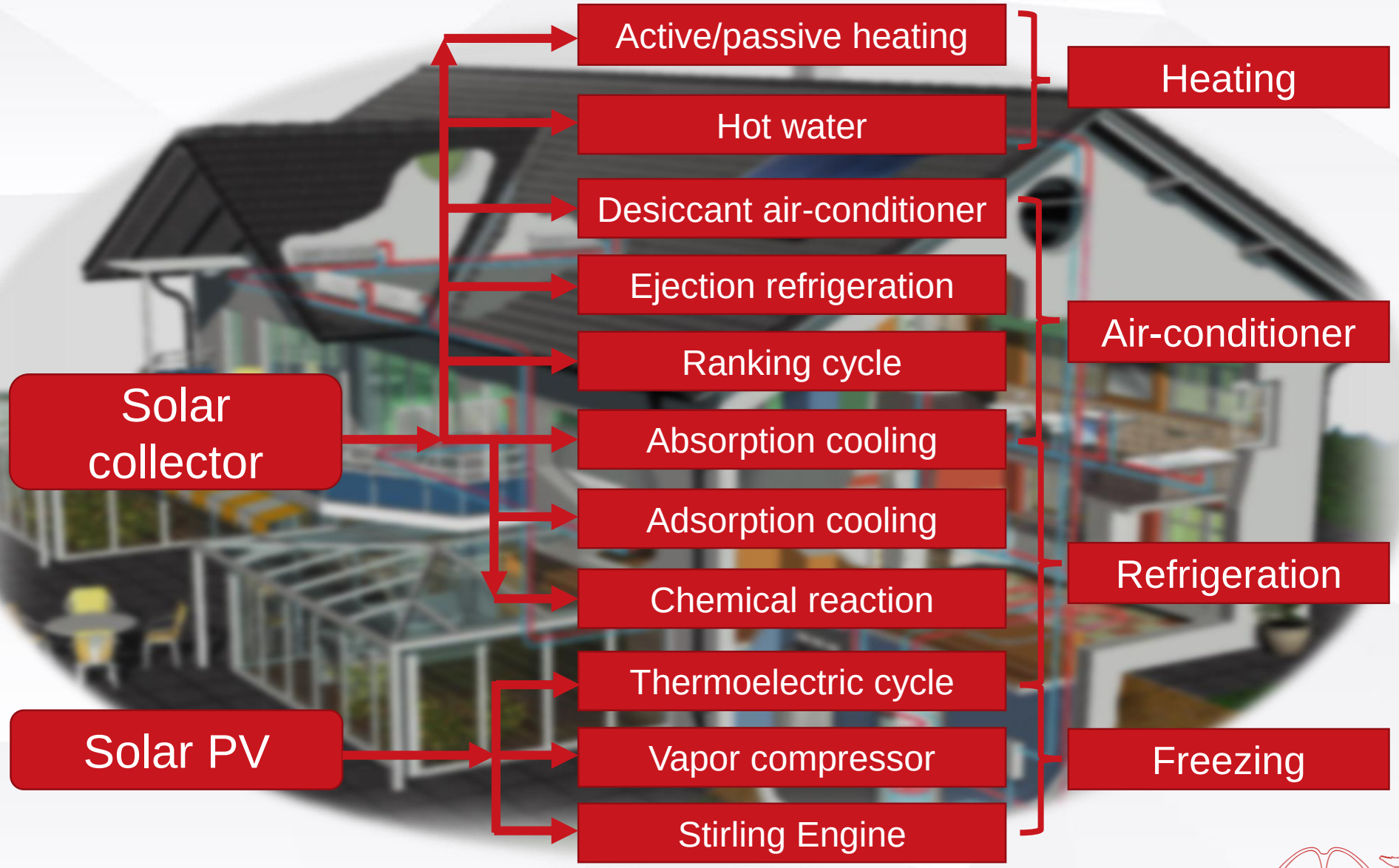
Department of Power and Energy Engineering

Shanghai Jiao Tong University

饮 水 思 源 • 爱 国 荣 校

2021.6.15.

Solar energy technical Pathways in building

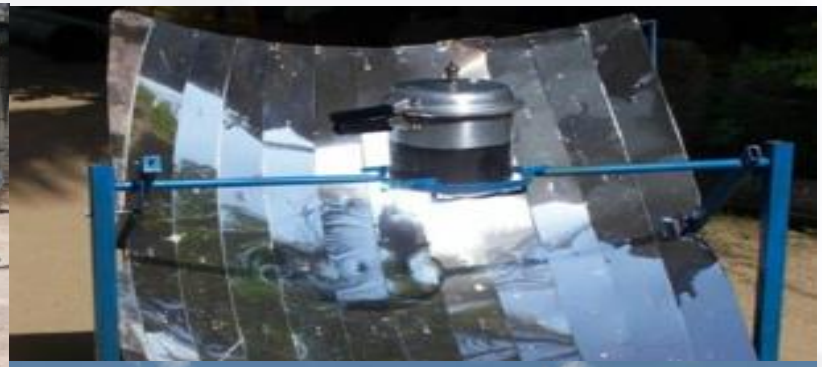


Solar cooker

“Pucca cooker” —Kiln type solar funnel cooker

“Solar restaurant”

Solar cooker in China

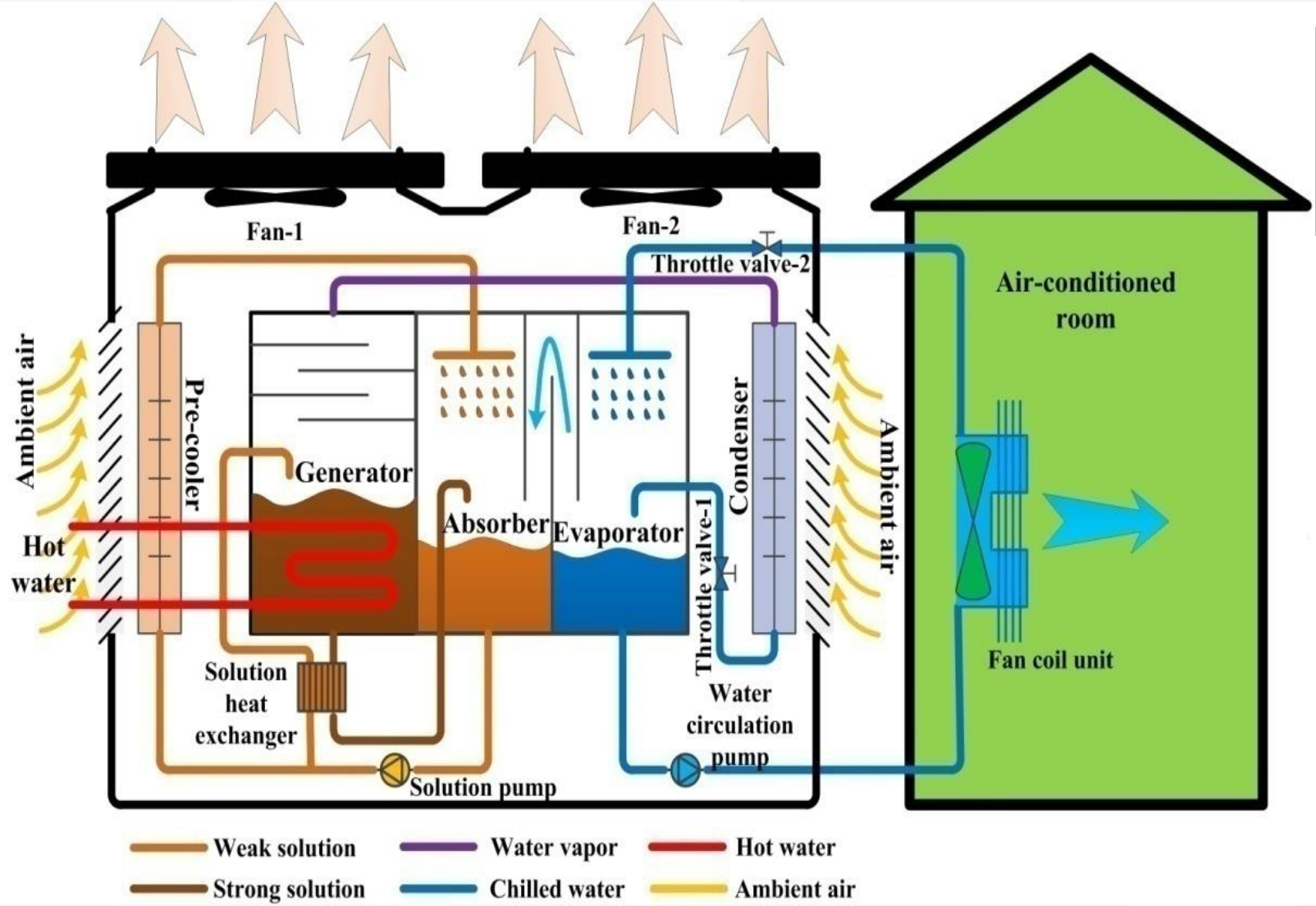


Solar cooker

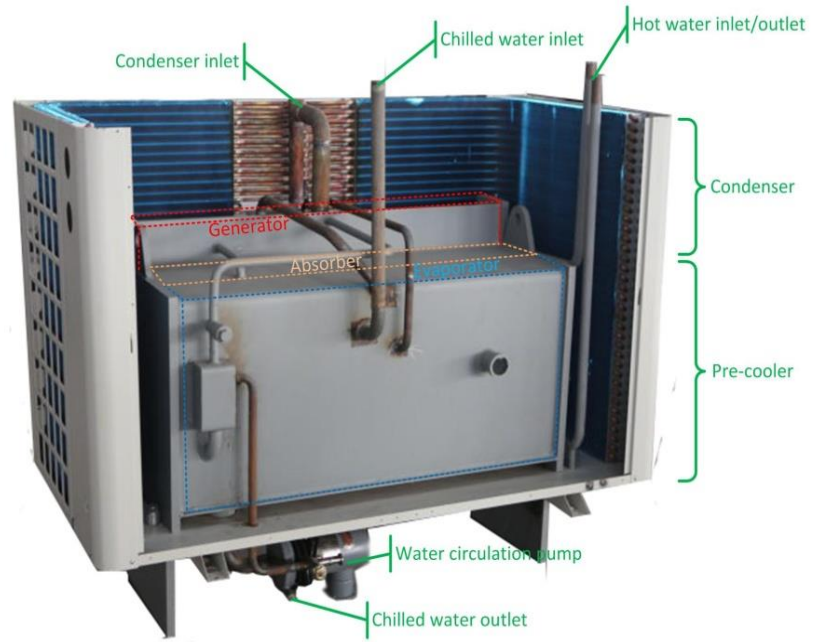
Himin “Solar Kitchen” Product

Solar cooker using stirling engine

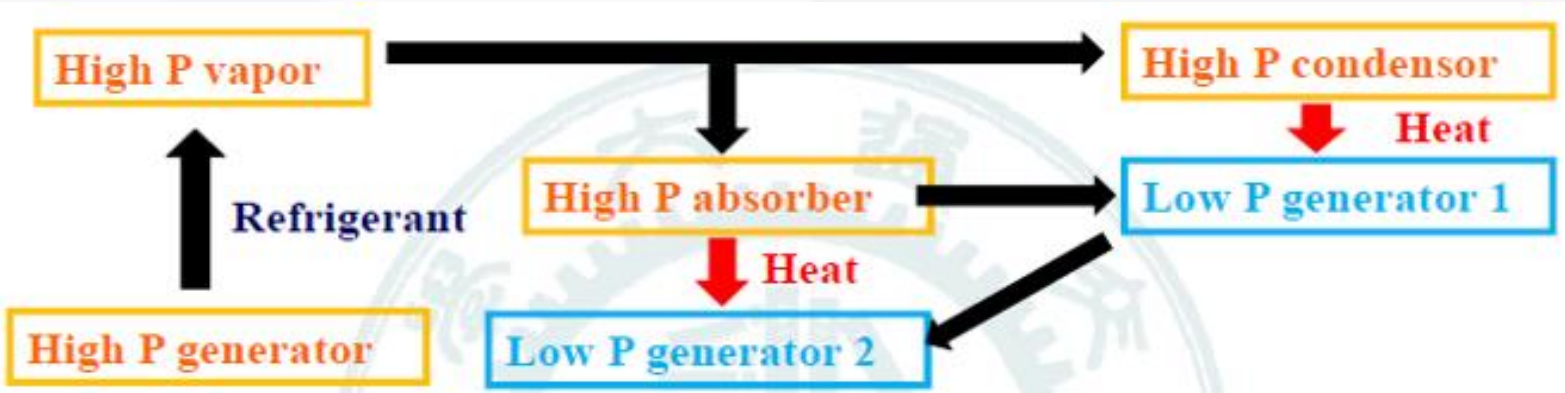
Solar assisted vapor compression air-conditioner

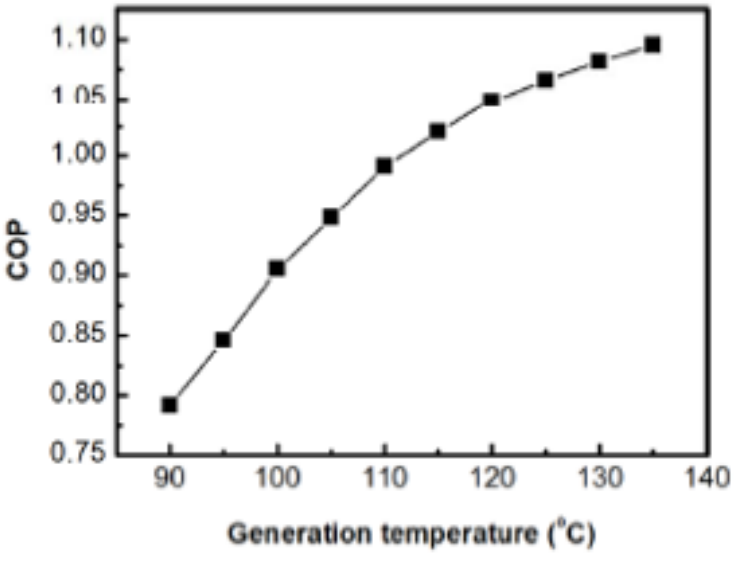


Operation mode:
1.VC cooling
2.Absorption chiller cooling
3.Hybrid cooling

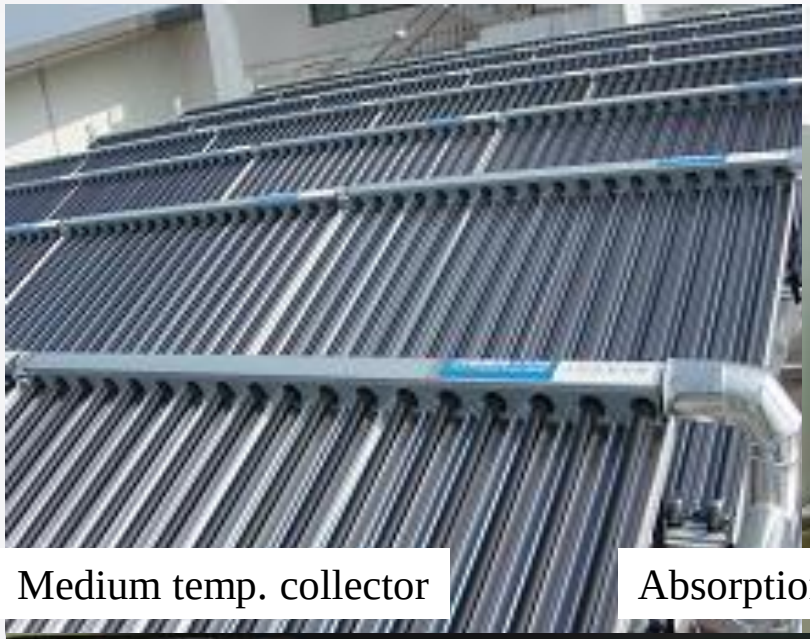


Fresnel solar collector & absorption chiller





Absorption chiller in Linuo-Paradigma

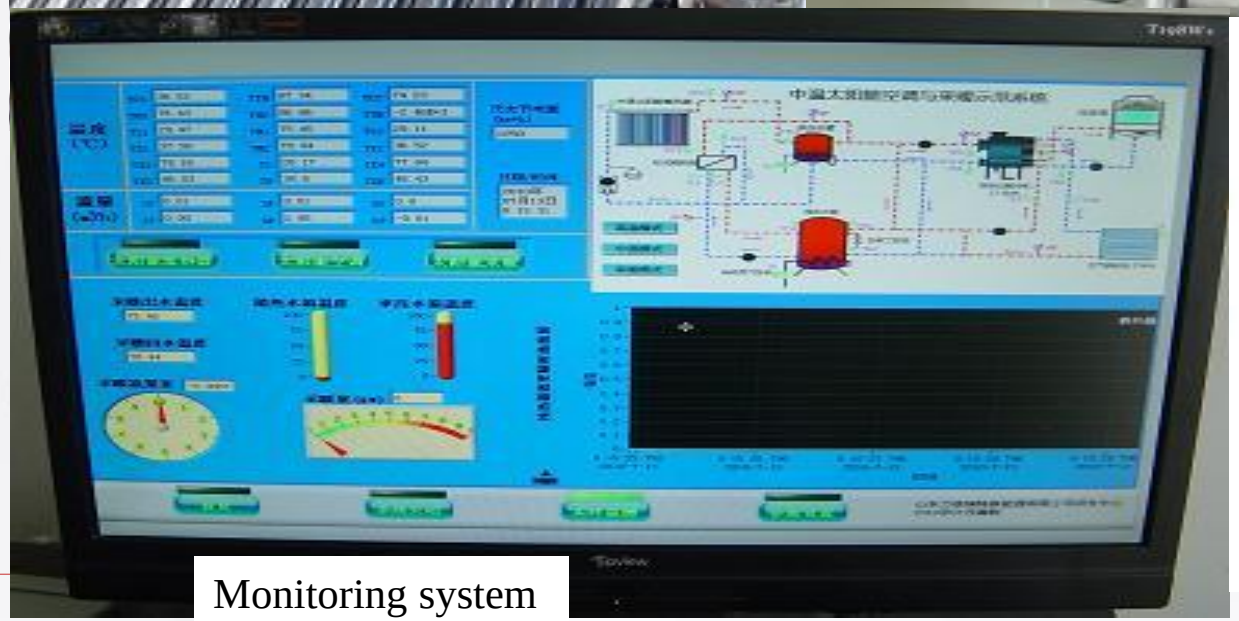


Medium temp. collector

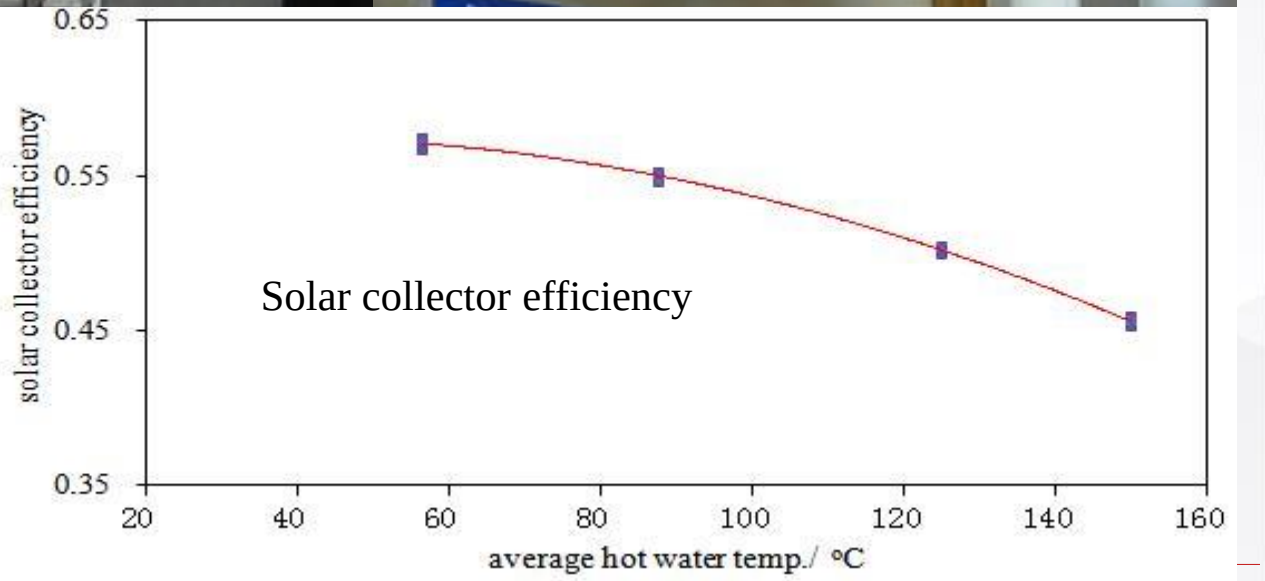
Absorption system

20kW Absorption Chiller

cooled hall



Monitoring system



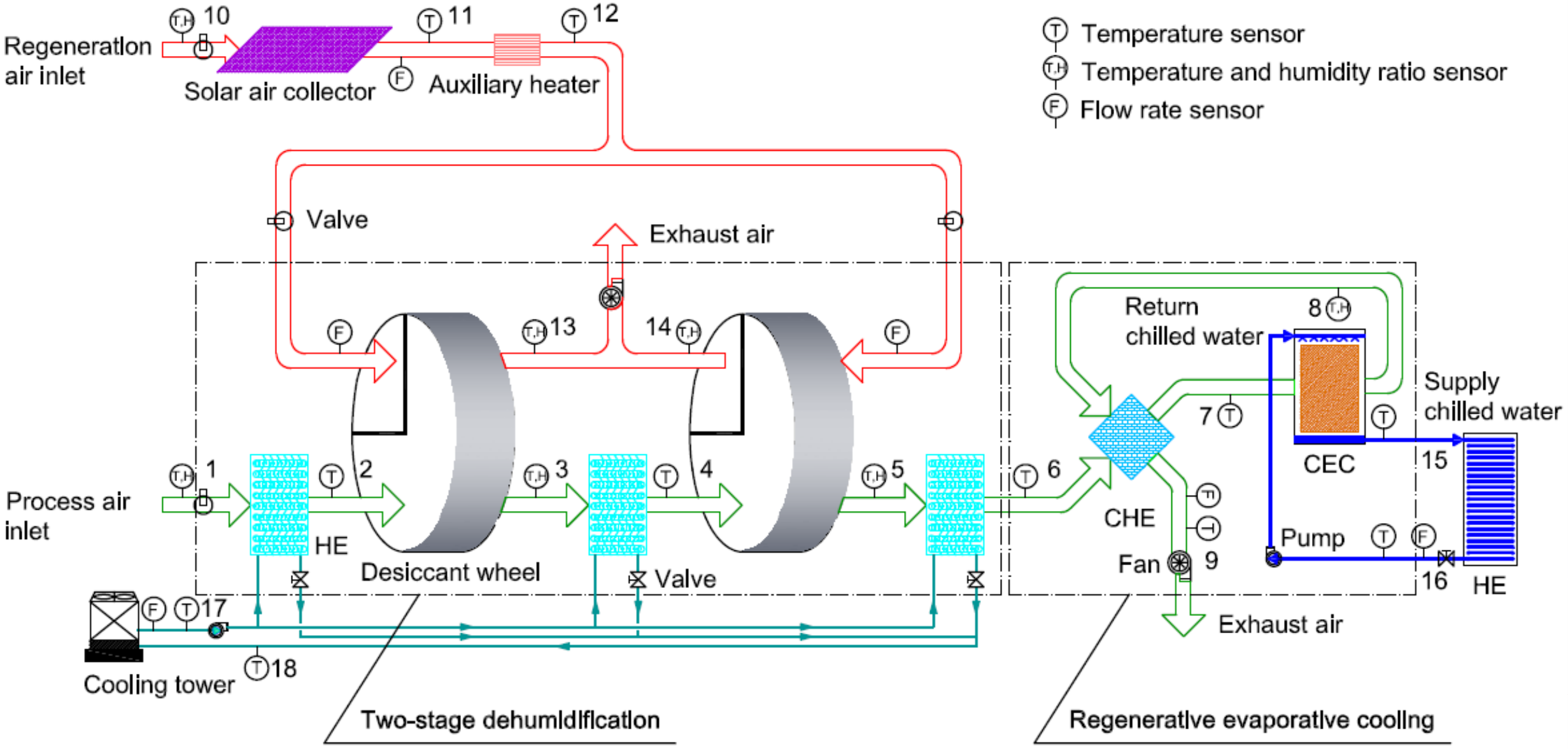
Single/Double effect solar air-conditioner

Shandong Changle

PV air-conditioner in Green Energy Laboratory

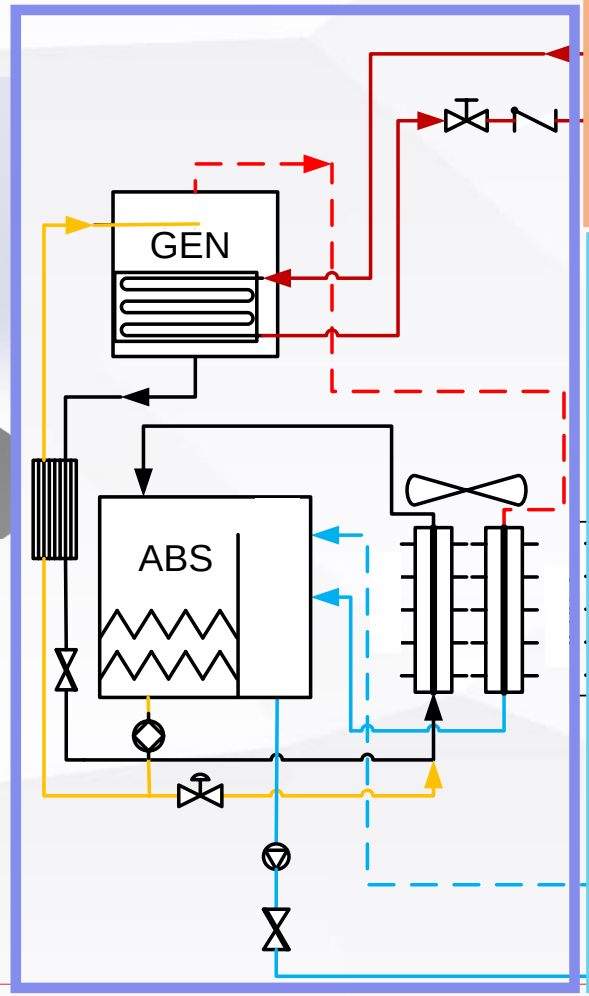
PTC+ Single effect chiller——Wanke Dongguan Center

Solar rotary desiccant air-conditioner system

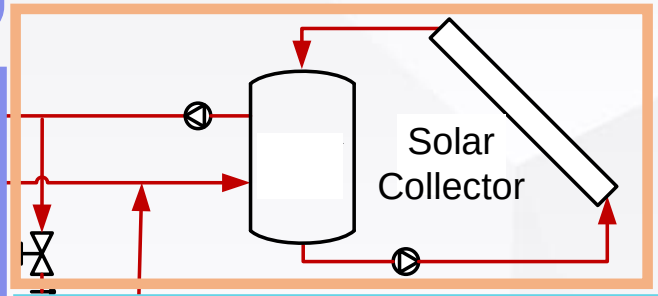


Solar absorption & dehumidification HVAC system

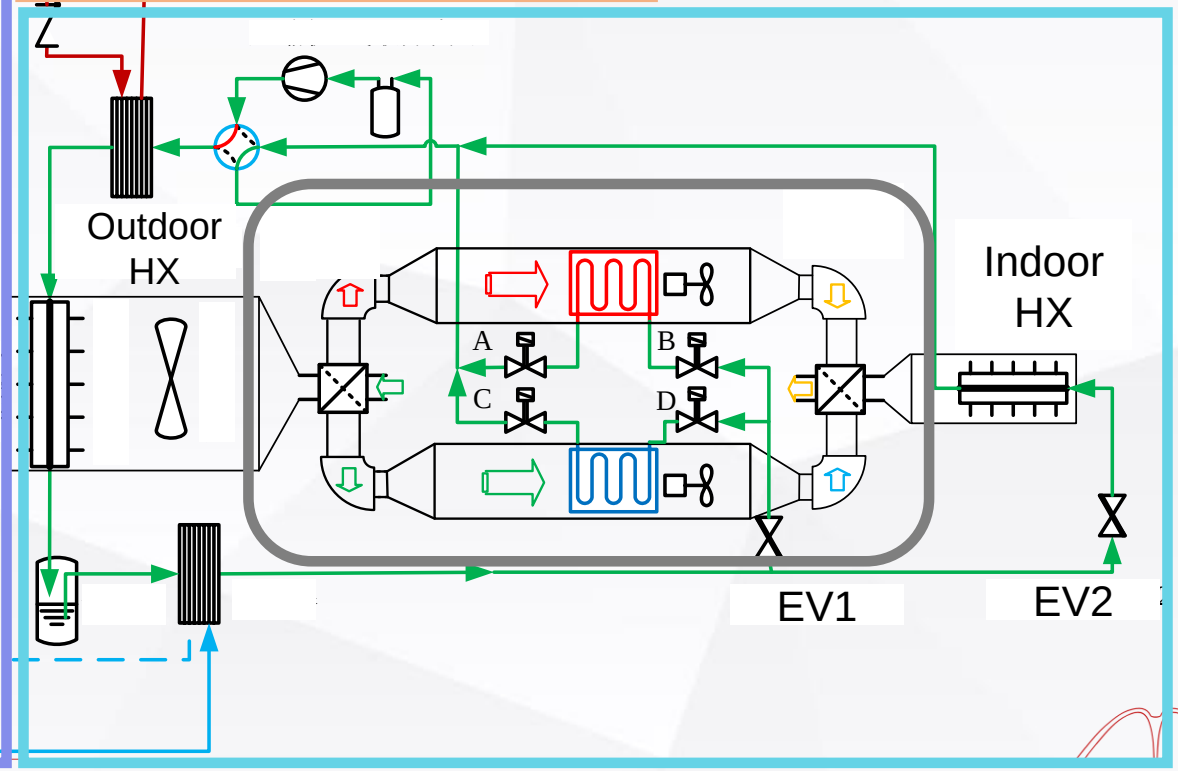
Absorption chiller Module



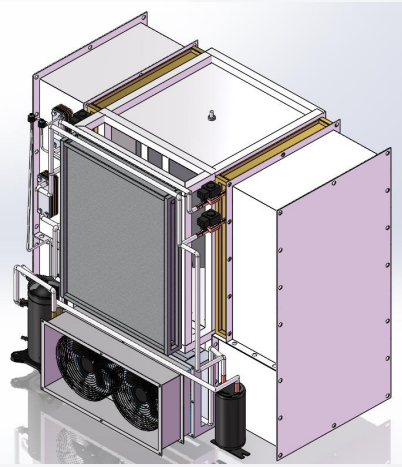
Solar collector Module



Dehumidification HP Module



- Compression cycle
- Solid desiccant module

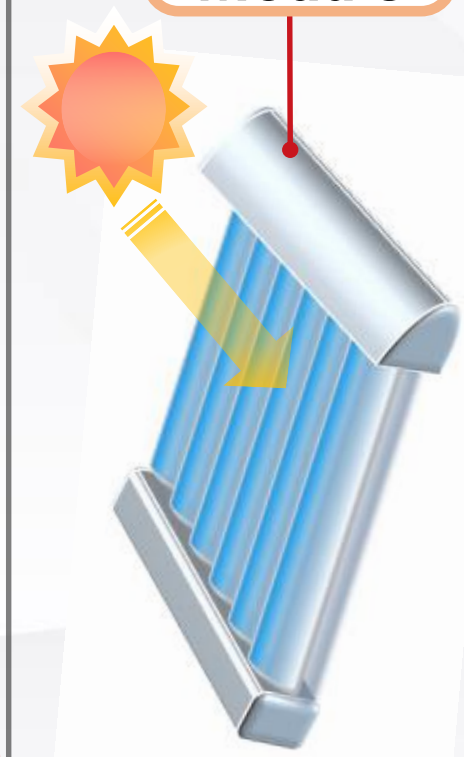
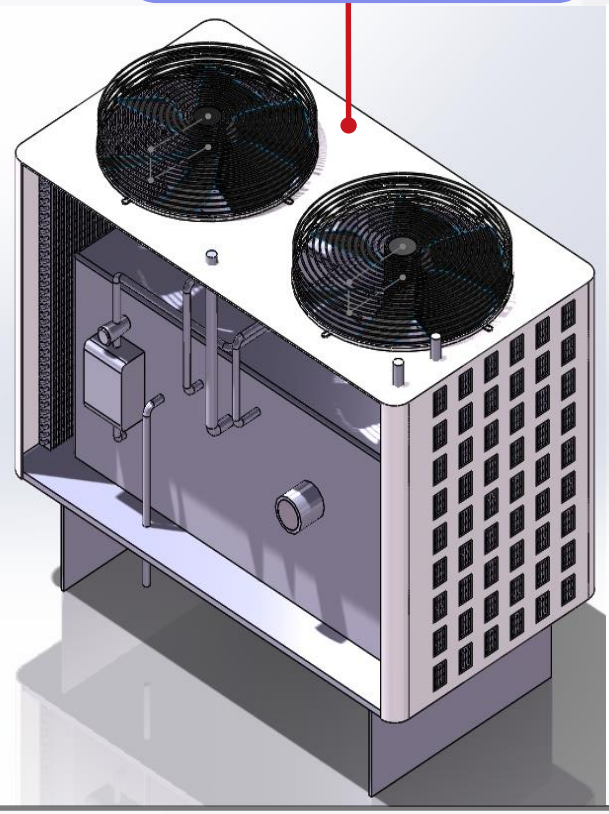
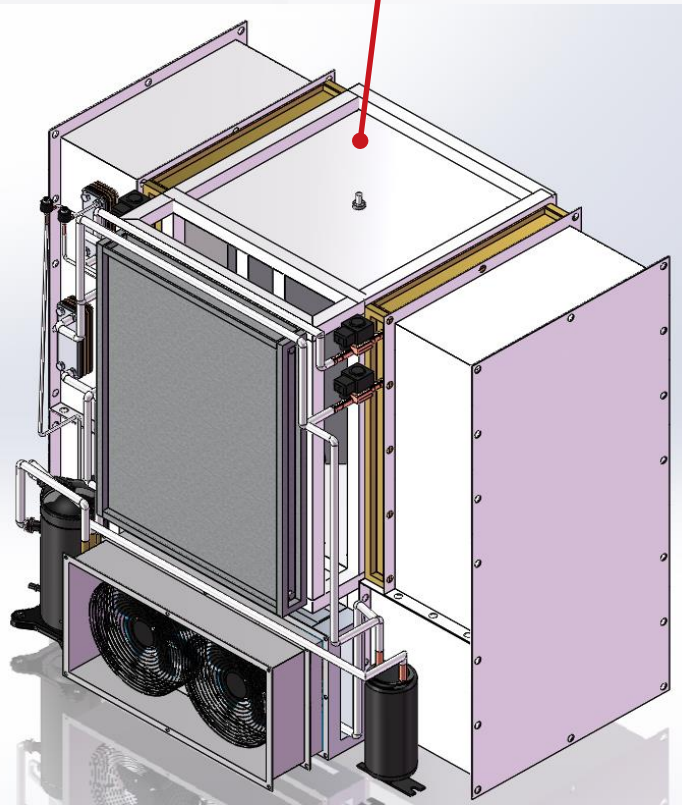


Solar absorption & dehumidification HVAC system

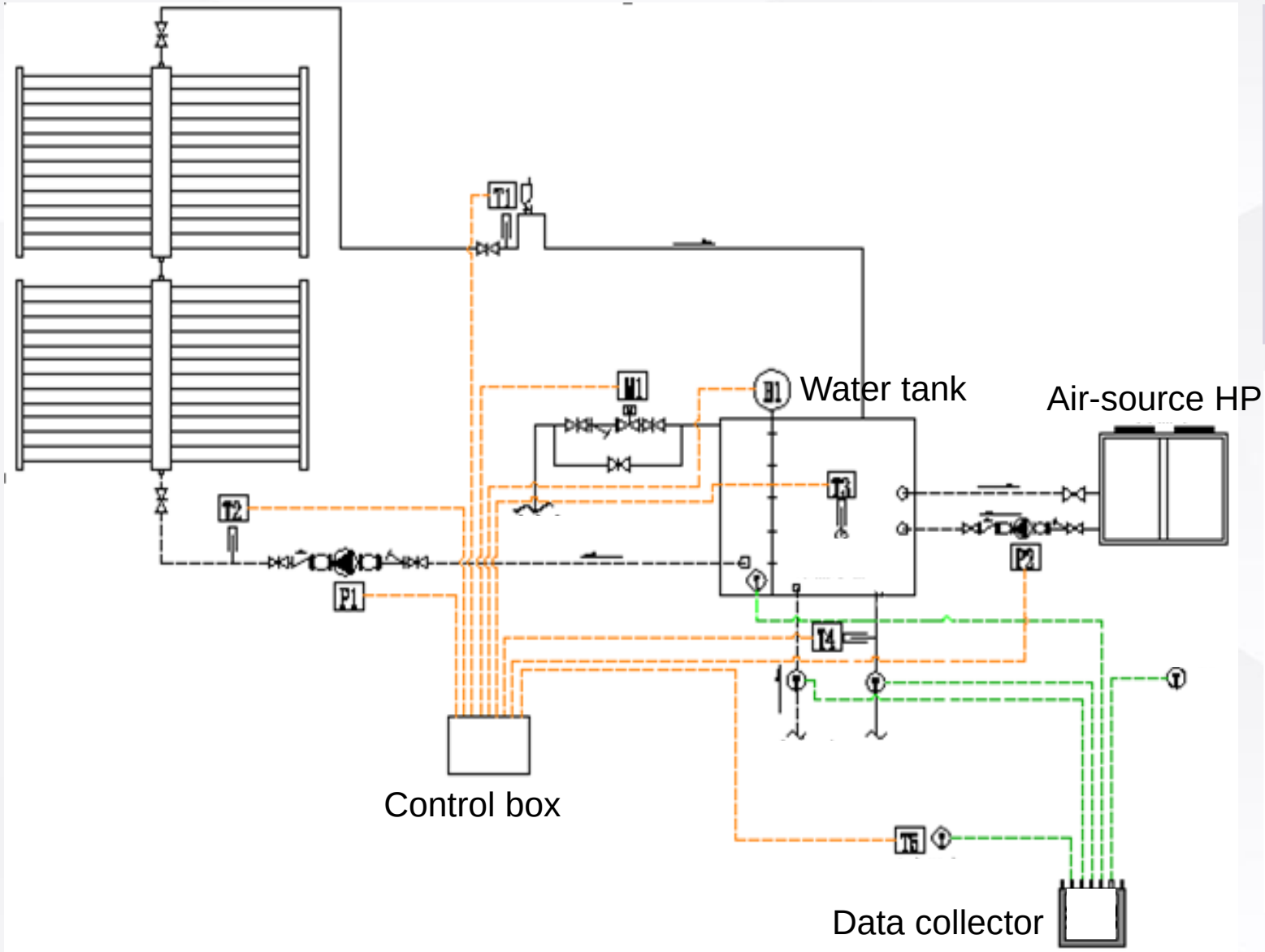
Heating
Domestic hot water
Cooling
Dehumidification

Solar Collector Module
Absorption Chiller Module
Dehumidification HP Module

Spring
Summer
Winter
Autumn

Solar energy combined with air-source HP system



- **Low-temperature HP module**
- **High-efficiency solar module**
- **Multi-energy complementary module**
- **Heating module**

Heating system	Solar & air-source HP	Gas boiler	Electric boiler
Energy consumption	77.5kWh	19.8 Nm³	190.6 kWh
Heating cost per day	$38.7/d	¥ 49.5/d	¥ 69.8/d
Heating cost per area	$46.47/㎡	¥ 59.4/㎡	¥ 83.8/㎡

Solar combined air-source HP system application

Huairou in Hebei Province

- Heating area：100㎡
- Low-temperature air conditioner：6P

Daxing in Hebei Province

- Heating area：60㎡
- Low-temperature air conditioner：3P

Solar combined air-source HP system application

Tangshan, Hebei Province
Area:220 m^2,
38 m^2 solar collector
5 P low-temperature air-conditioner

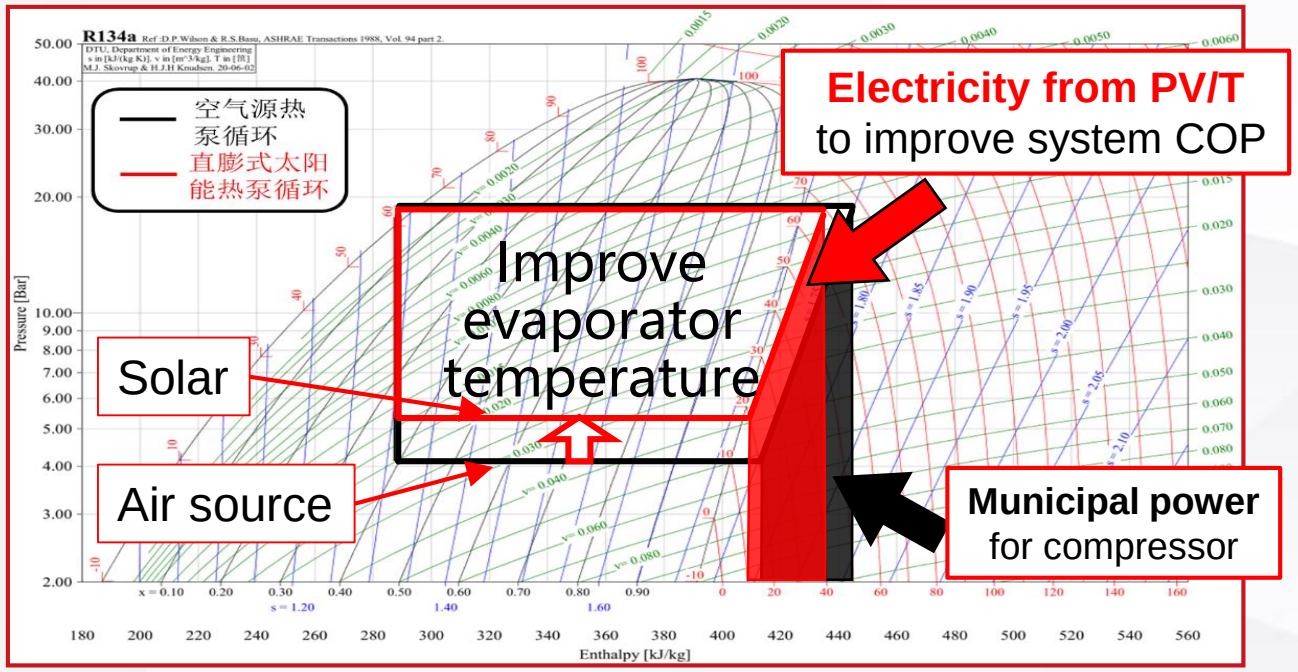
PVT heat pump system

- By combining PVT module with heat pump system , high-efficiency heat and power cogeneration of building could be achieved;
- Comprehensive utilization efficiency of solar energy is improved greatly

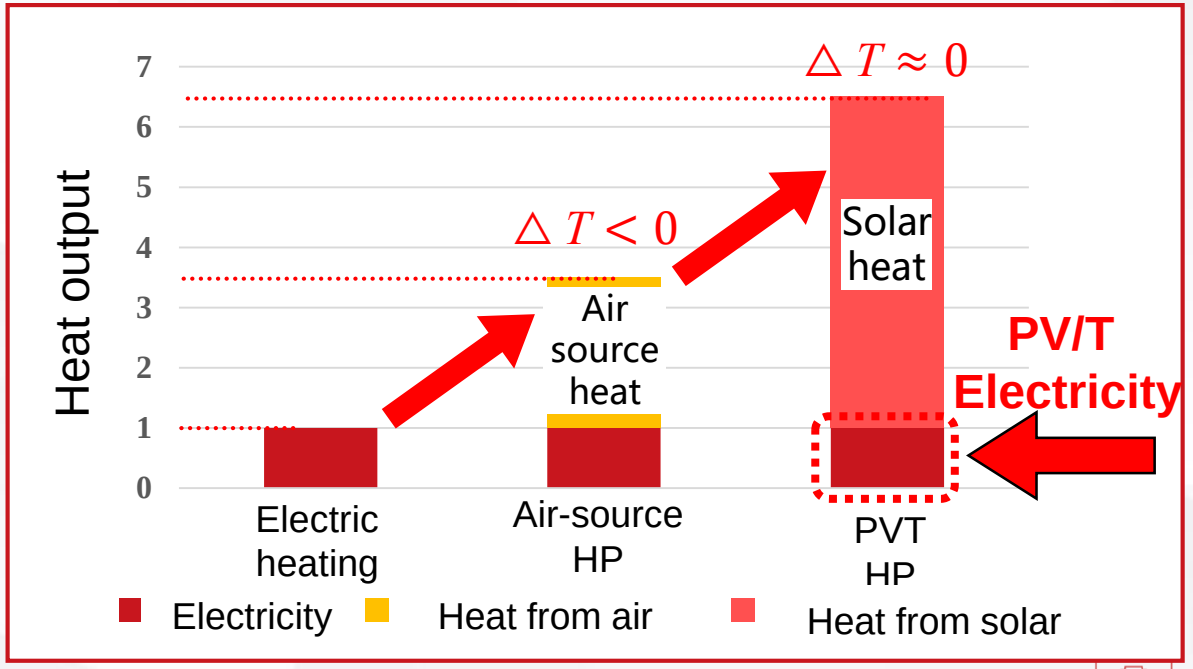
PV system efficiency:14%

PT system efficiency:50%

PV/T system:
PV efficiency18% + PT efficiency 60% = Comprehensive utilization 78%

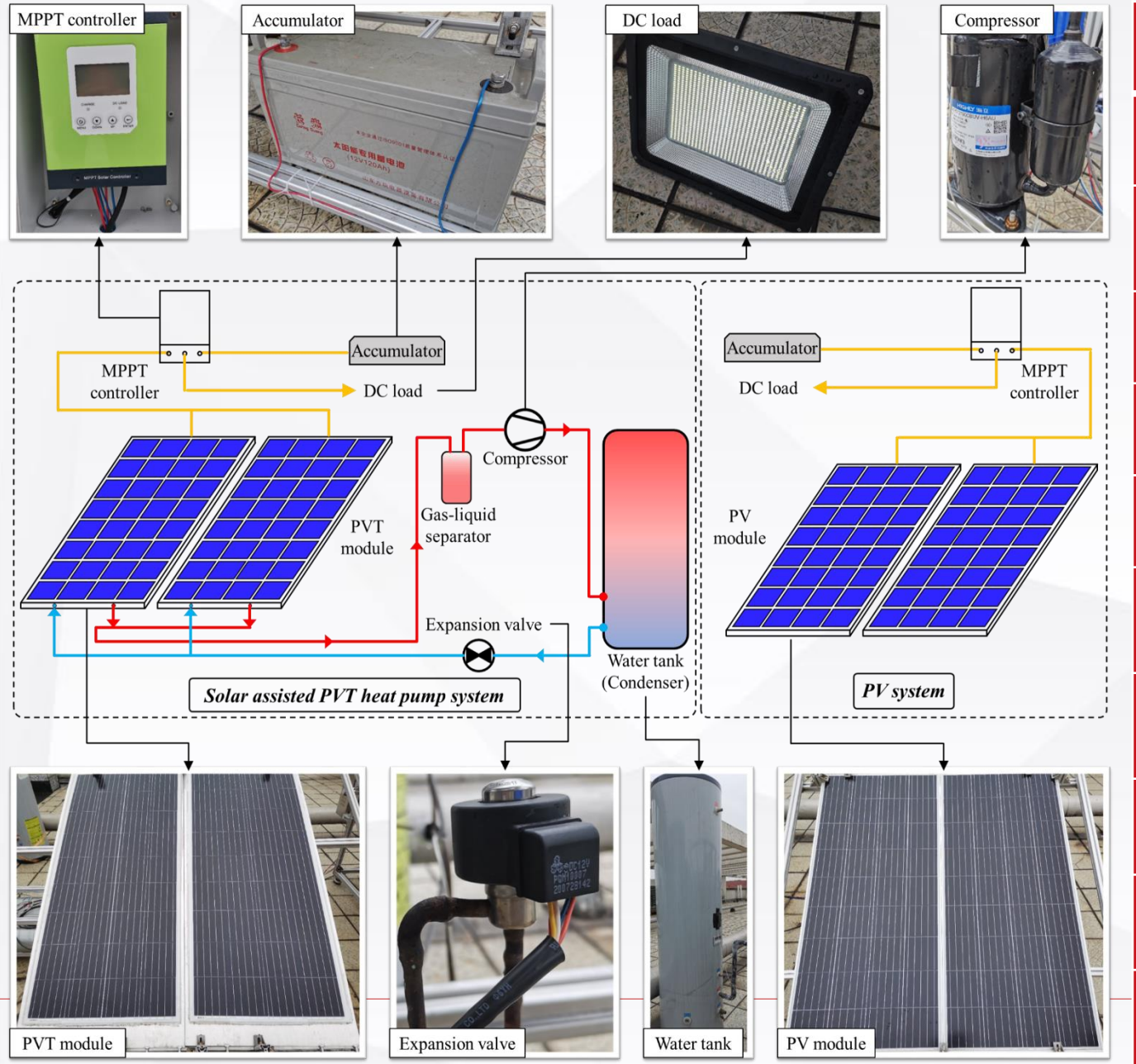


P-h Diagram of air source HP and PVT HP



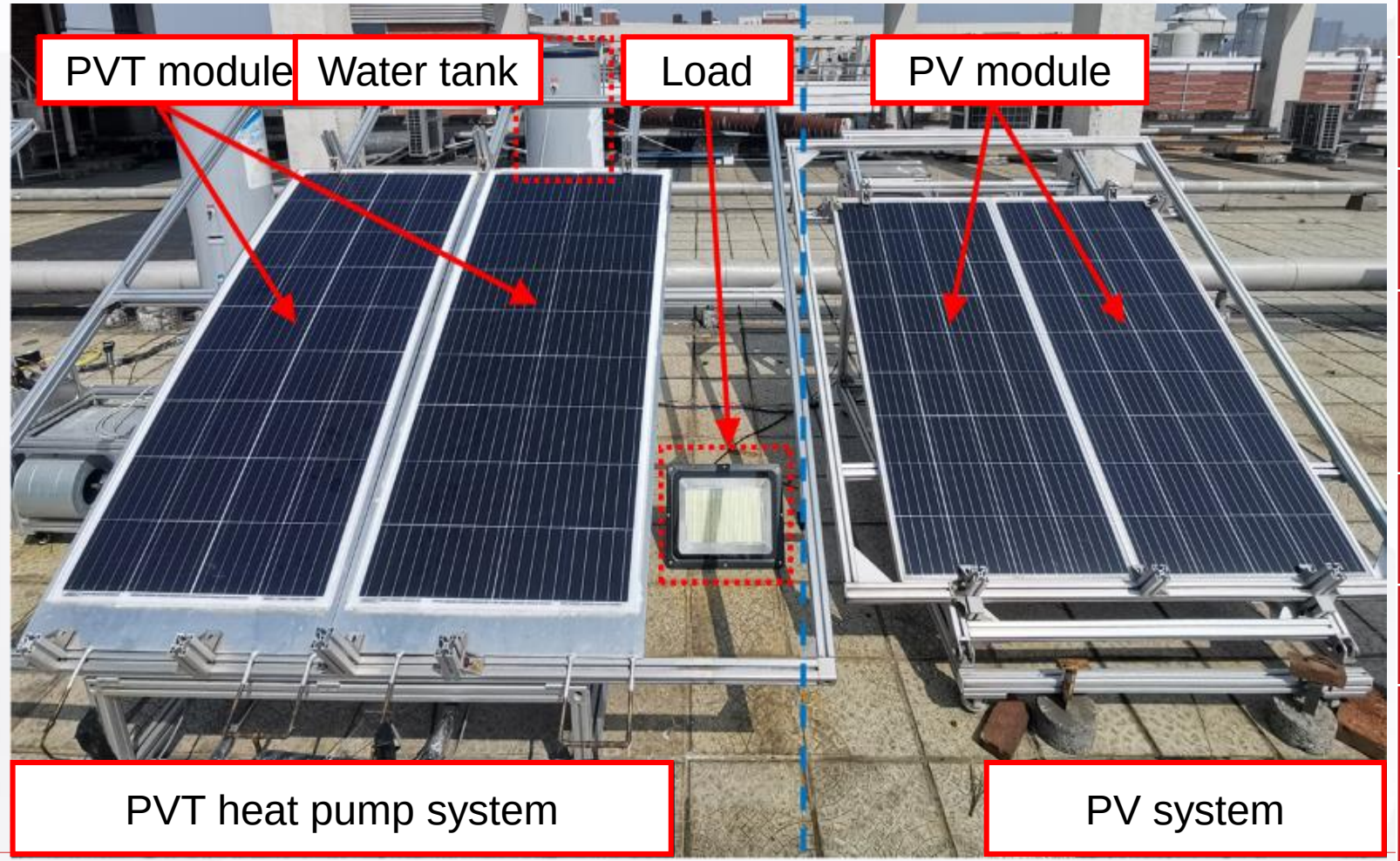
Heat output of different systems

PVT heat pump system



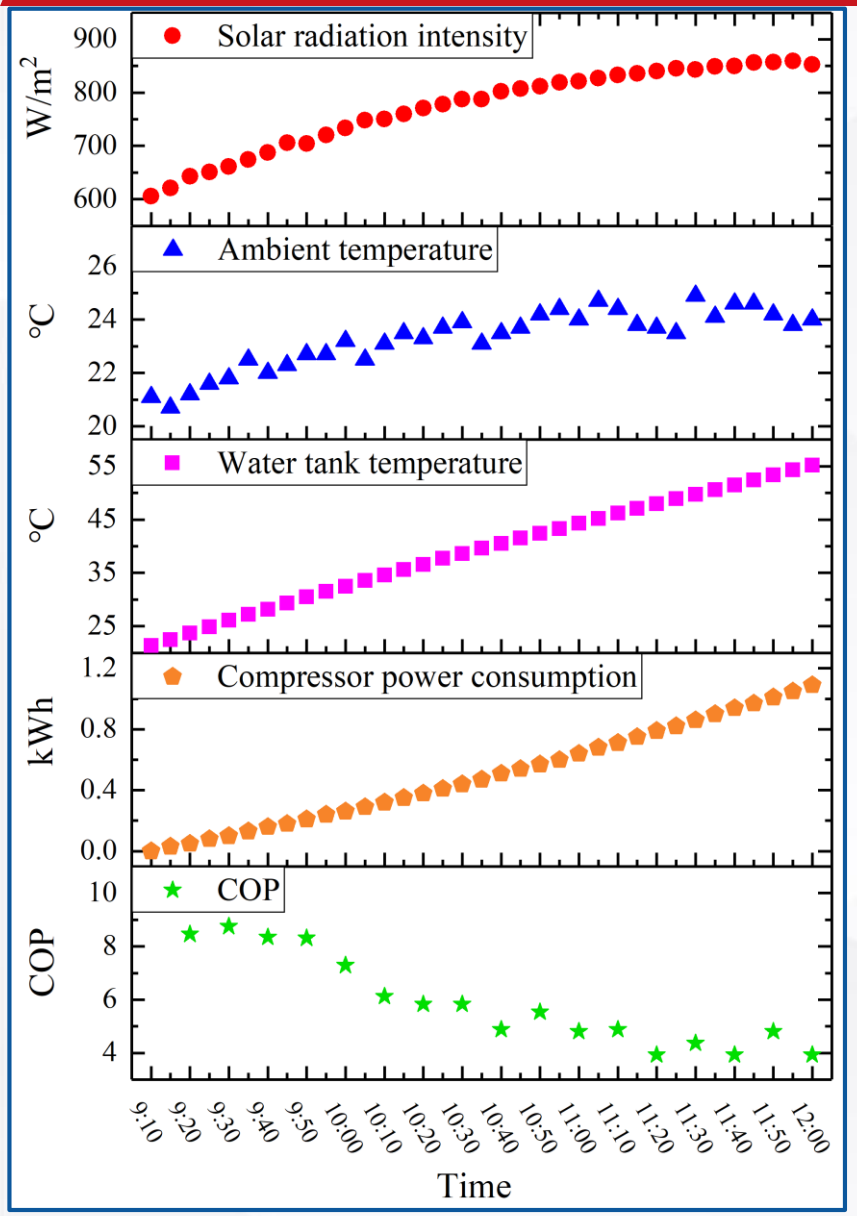
Parameter	Value	Unit
Tank volume	150	L
Compressor type	WHP01900BU V-H6AU	[-]
Compressor power	460	W
Refrigeration type	R134a	[-]
PVT number	2	[-]
PVT area	1.58m*0.72m =1.14	m^2
PV area	1.48m*0.68m =1.01	m^2
PV coefficient	-0.53	%/℃
Solar cell type	Silicon	[-]
PV per power	175	W

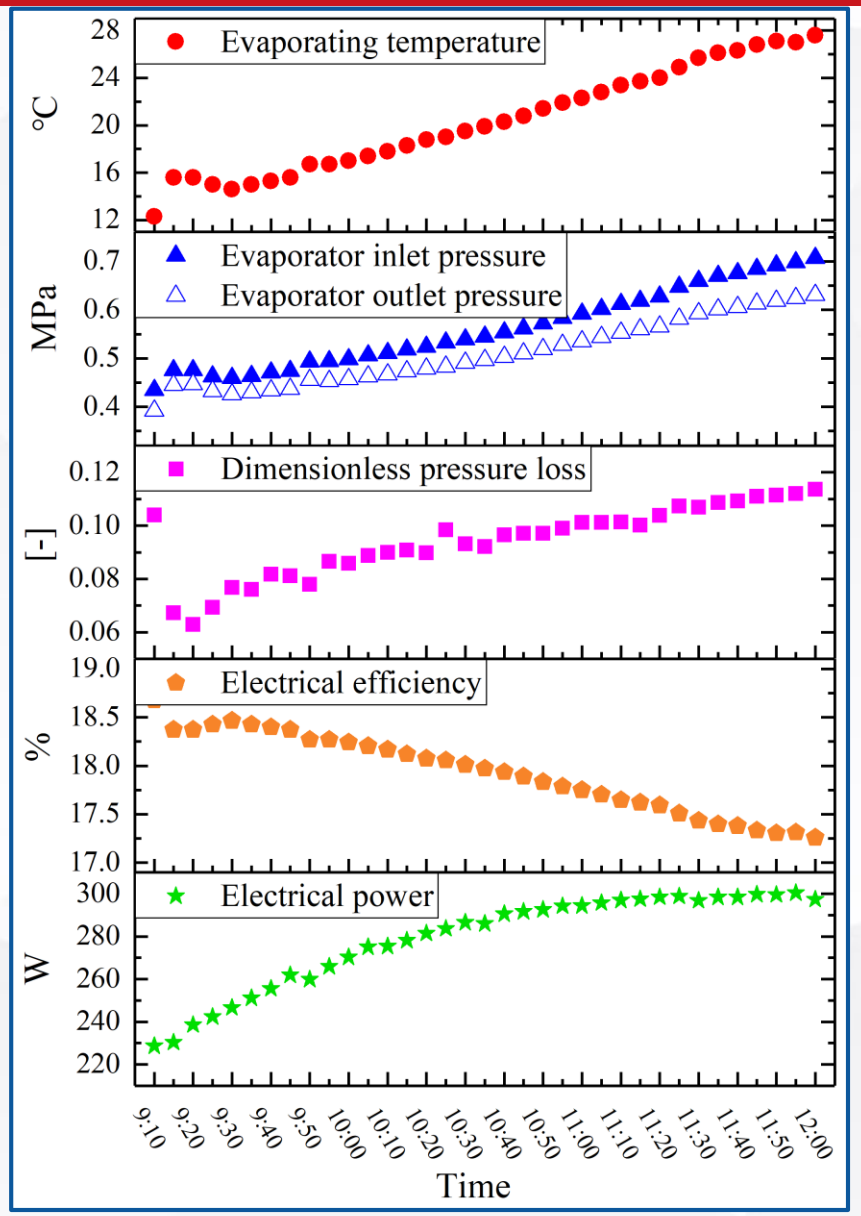
PVT heat pump system experimental setup

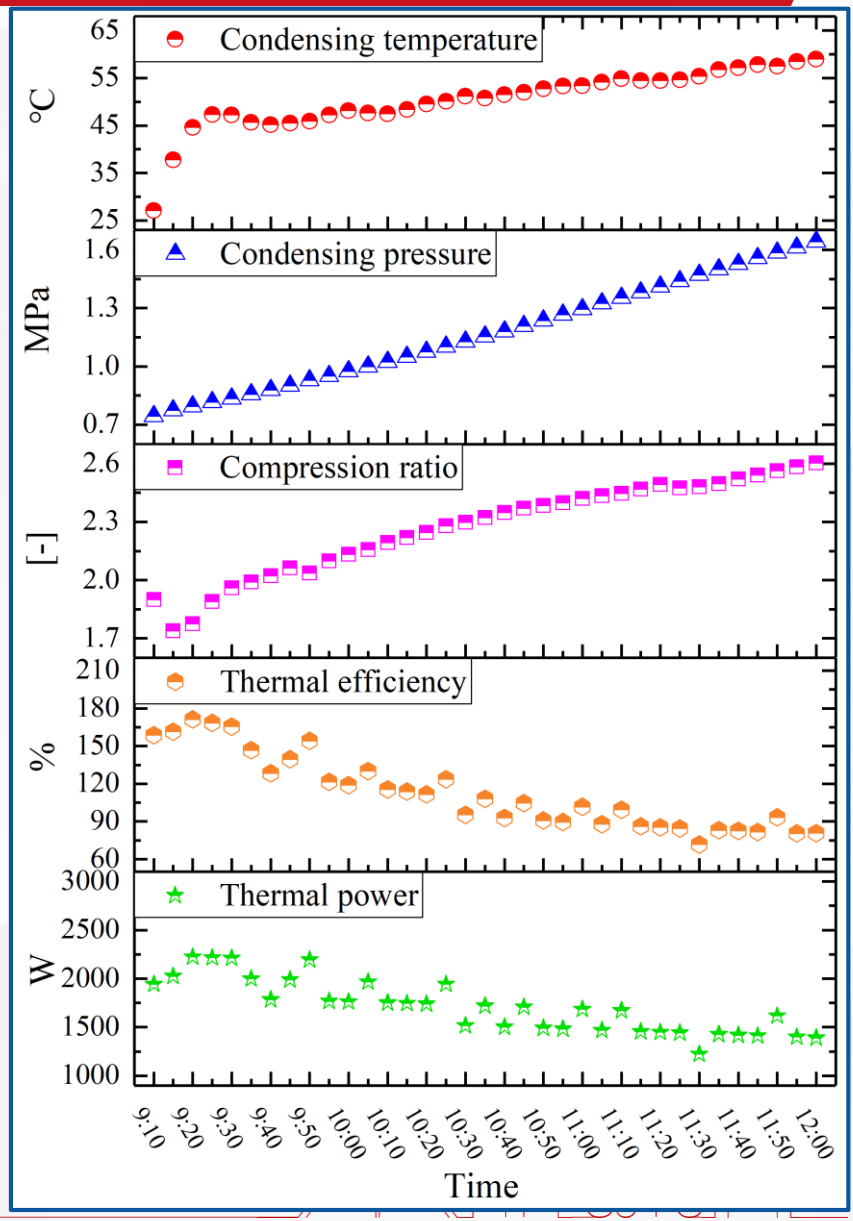


Parameter	Value	Unit
Date	2021.03.29	[-]
Operating time	09:10-12:00	[-]
Ambient temperature	21	℃
Average intensity	771.4	W/m^2
Wind velocity	2-5	m/s
Angle	30	degrees
Water tank temperature	19.6	℃

PVT heat pump system performance

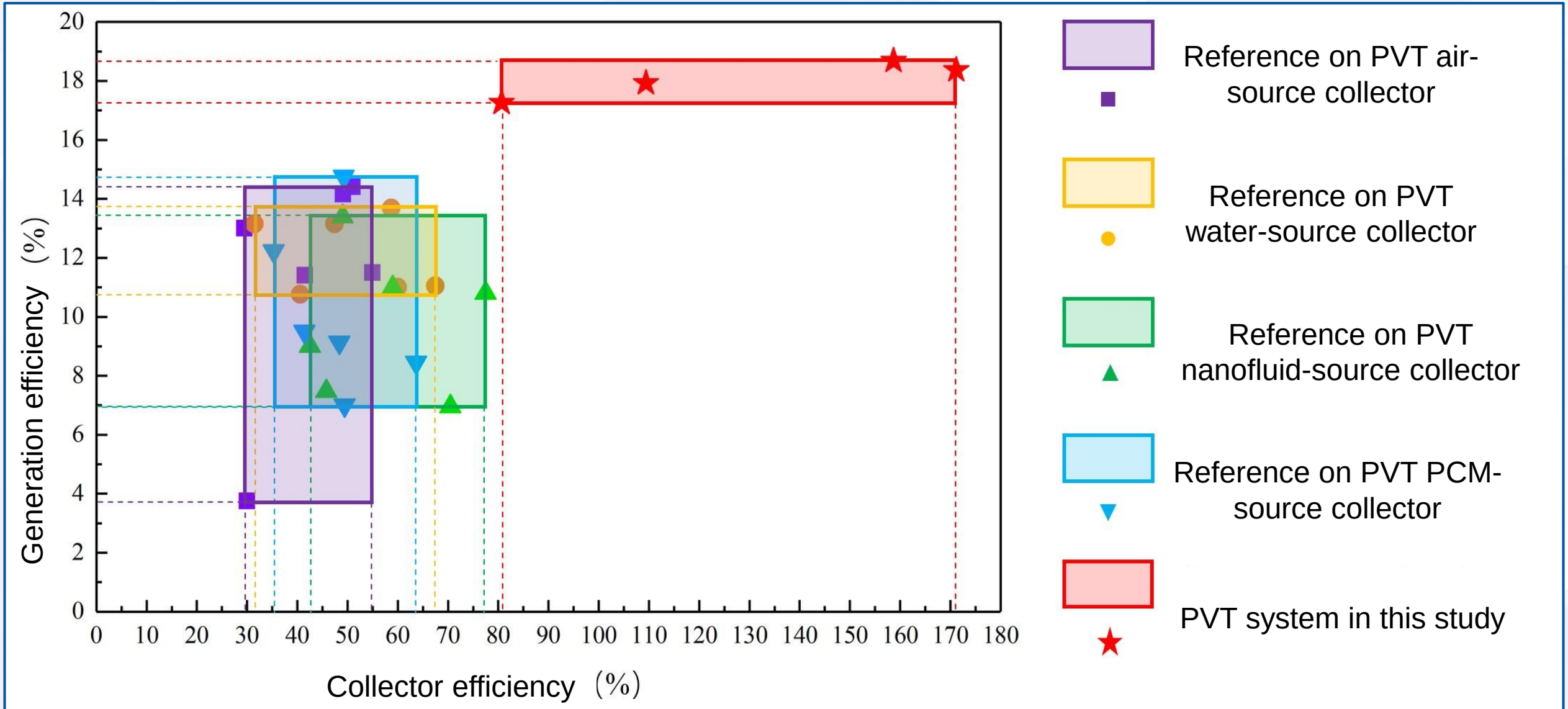






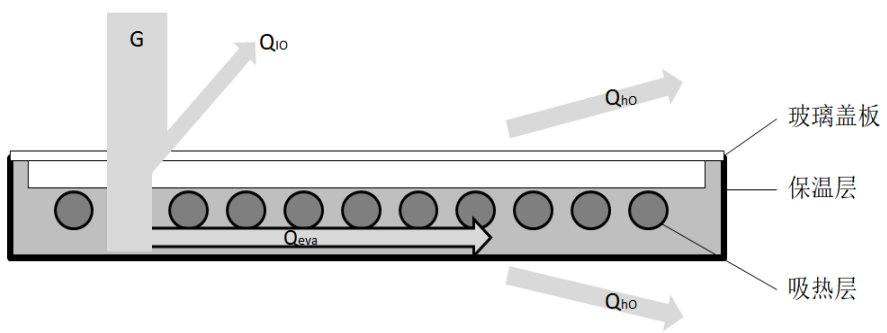
◆ **System max COP8.75; average heat gaining factor109.4%; average generation efficiency17.93%;**

PVT heat pump system



◆ **Compared to other PVT technology，performance of generation and collector improve greatly**

PVT heat pump system application

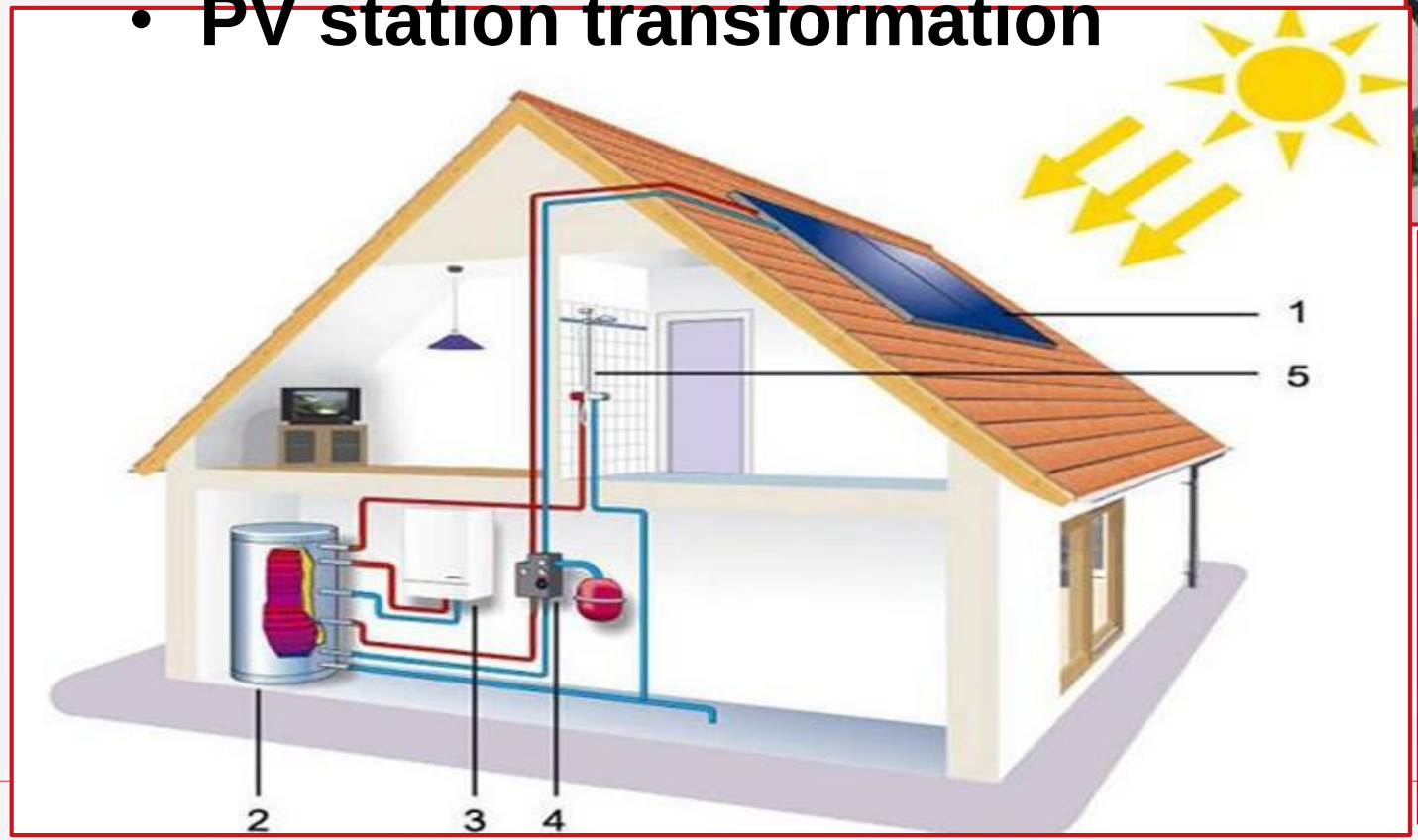


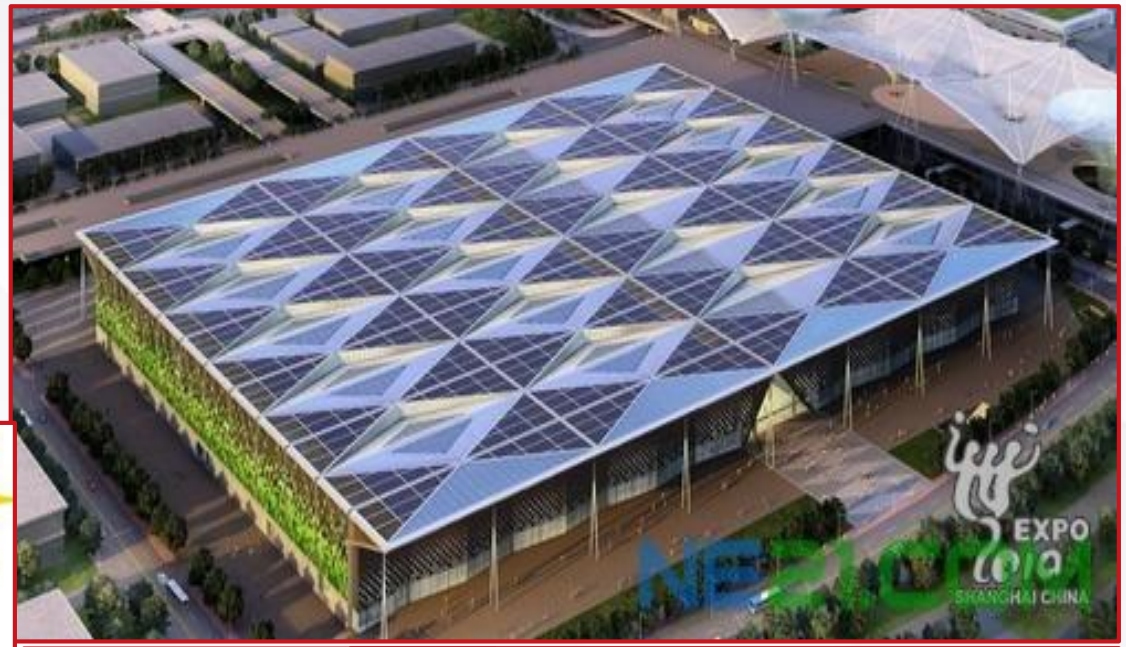
- The traditional solar collector is difficult to work in rainy days; Traditional solar heat pump has low cop and low energy utilization.
- Using PVT coupled with heat pump system and photovoltaic power generation to supply compressor can greatly improve cop to more than 10;
- In rainy weather, the ambient air can be used as the heat source, and the water temperature can also be heated above 50 ℃.The heat pump cycle is used to cool the photovoltaic panel, reduce the efficiency loss of the module at high temperature, and prolong its service life.

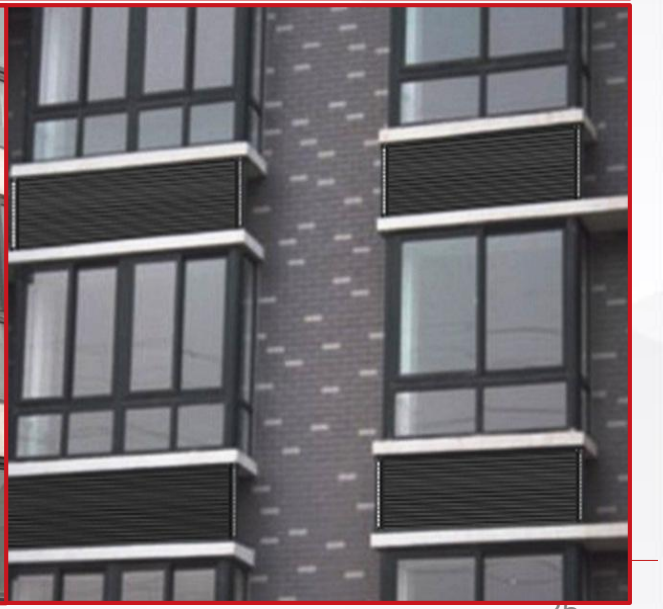
PVT application in building

◆Solar building component

- Roof, façade, balcony;
- Distributed cogeneration system;
- PV station transformation







BIPV technologies

- **Building material type：** PV roof coil, glass PV curtain wall, etc；
- **Component type：** awning components, sunshade components, etc;
- **Installation with roof & wall：** installation on flat roof, sloping roof, etc

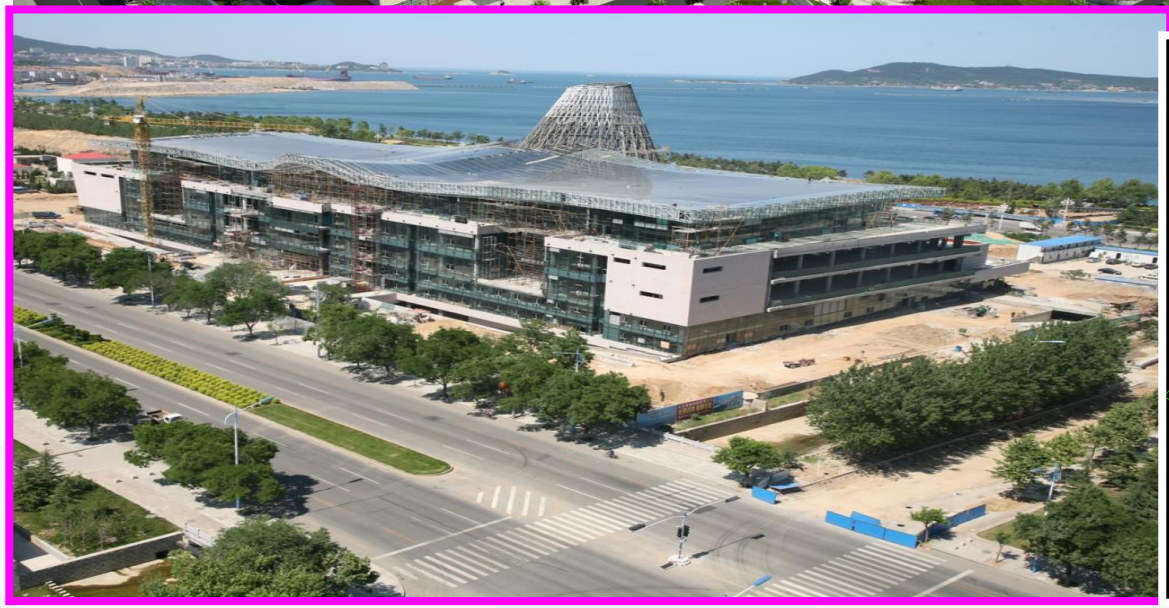
PV roof-Qingdao Railway Station
(A-si， 103 kW On-grid system)

Glass PV curtain wall-Weihai Lanxing Office Building
(A-si， 161 kW On-grid system)

BIPV case study

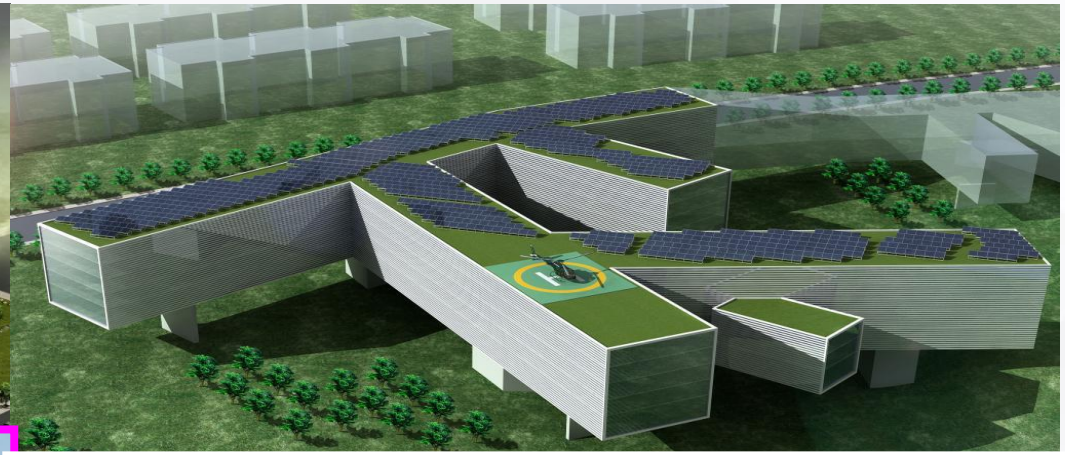
WeiHai the public cultural centers

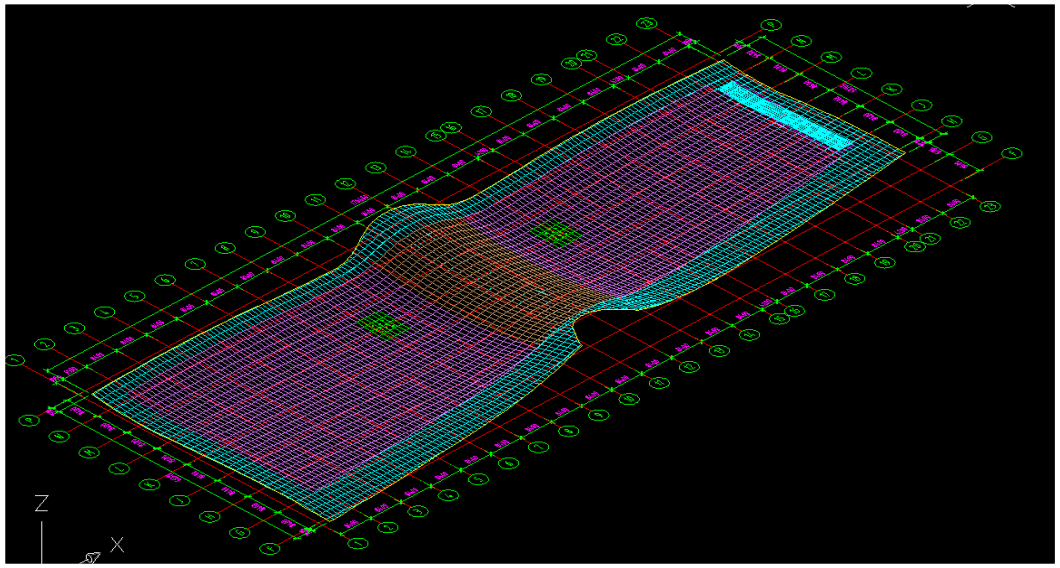
480kW On-grid system PC area：8000m²



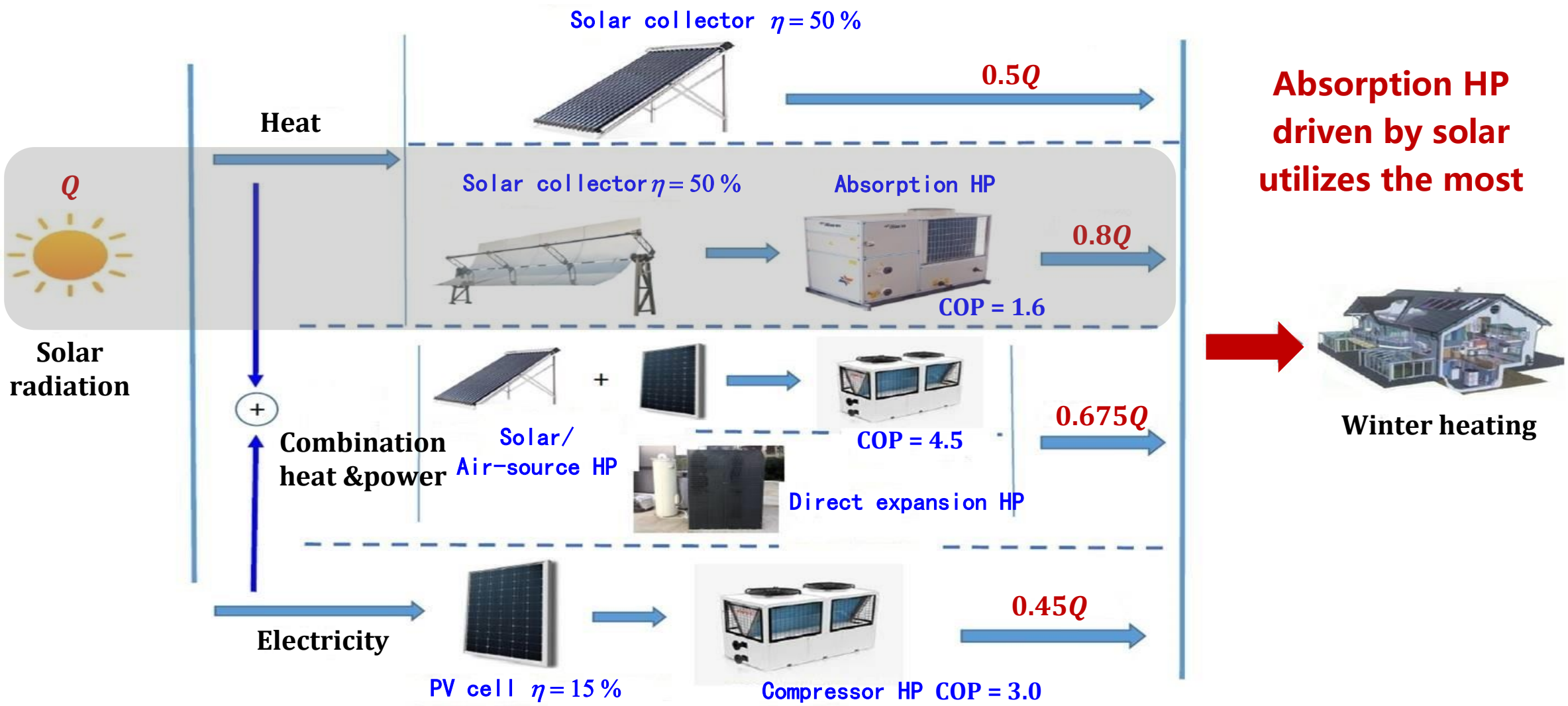
Wanke headquarters office

267.2kW On –grid system PC area: 1940m²





Absorption-resorption heat pump system



GAX- Absorption HP driven by PTC

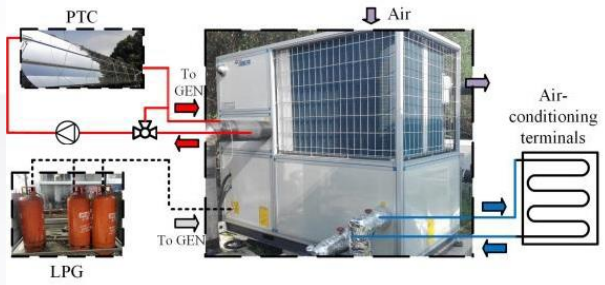
PTC

GAX absorption heat pump

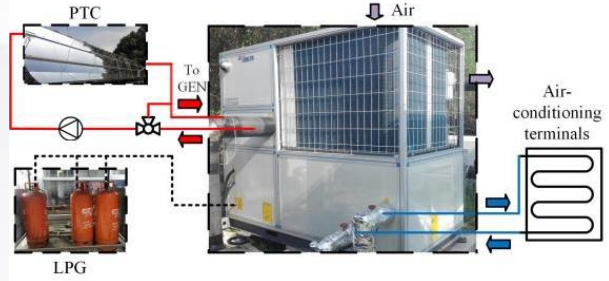
Assisted heat source (Gas)

- Ammonia-water solution
- Ammonia refrigerator
- Heat transfer oil
- Supply/Return water
- Ambient air

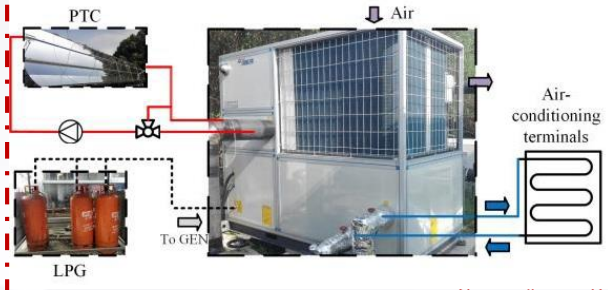
Solar-gas combined driven mode



Solar driven mode



Gas driven mode

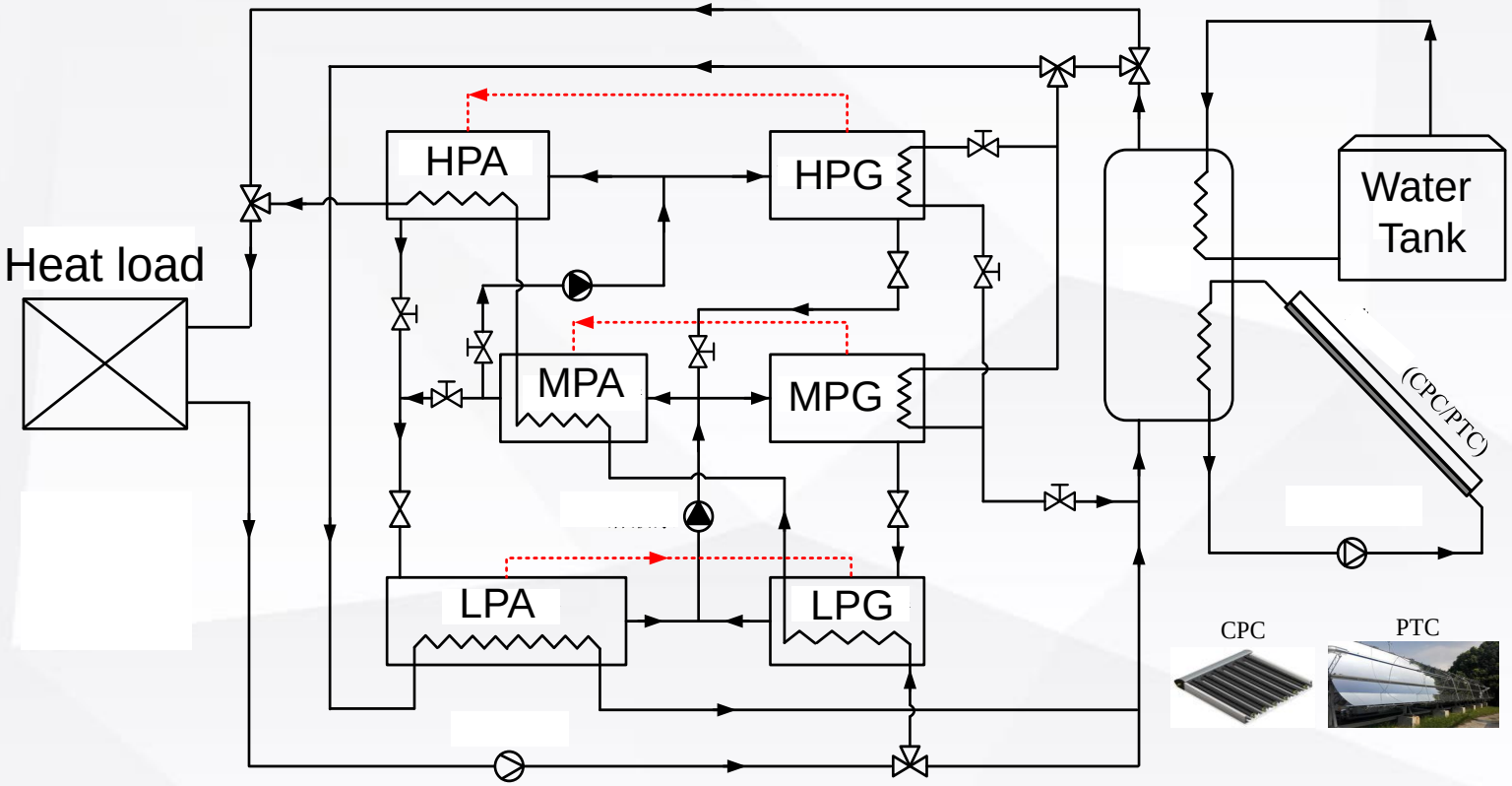


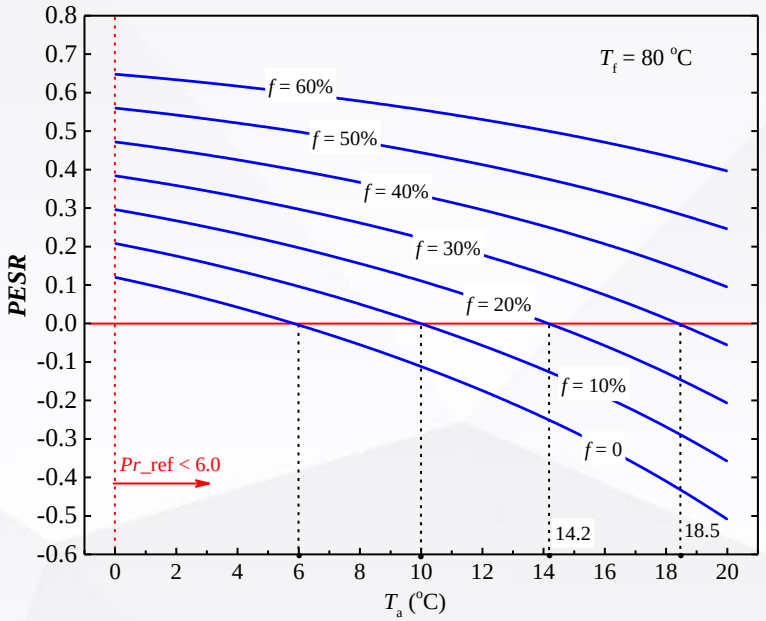
Absorption-resorption heat pump system

Full utilization of solar energy

Collector temperature

- **Higher than 70 ℃ , Combined with HPG, heating by HP;**
- **35~70 ℃, heating by solar collector directly;**
- **10~35 ℃ , Combined with LPG, heating by HP**





- *When f > 40%*, the primary energy utilization performance is better than that of the common system.

Solar combined air-duhumidification HP system

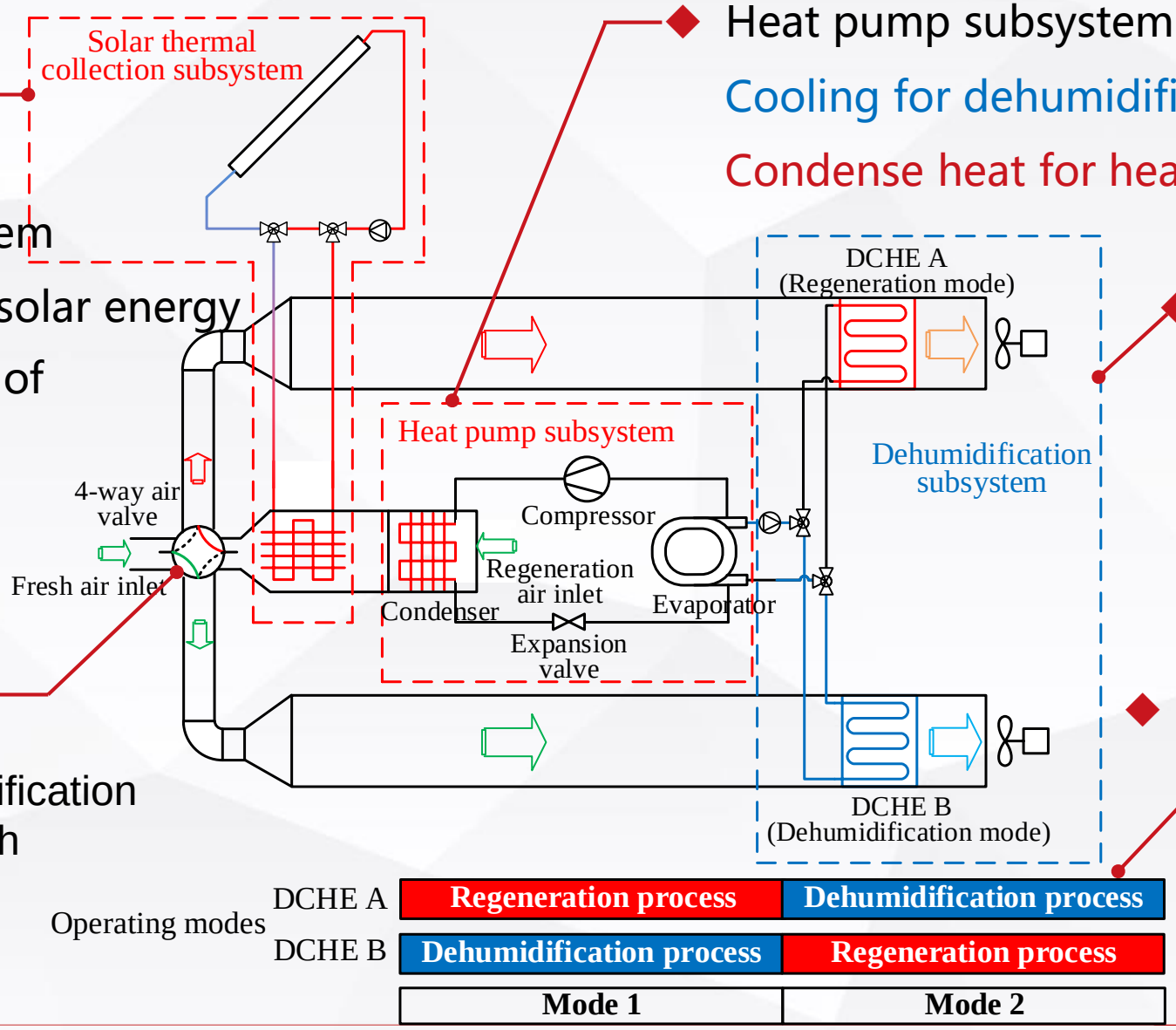
- Solar collector subsystem

  Secondary heating by solar energy

  increases temperature of regeneration air

- 4-way valve

  Used to switch dehumidification and regeneration air path



- Heat pump subsystem

  Cooling for dehumidificaiton

  Condense heat for heating regeneration air

- Dehumidification subsystem

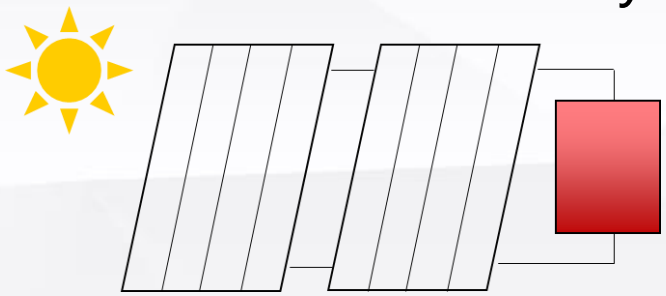
  Dehumidification and regeneration process

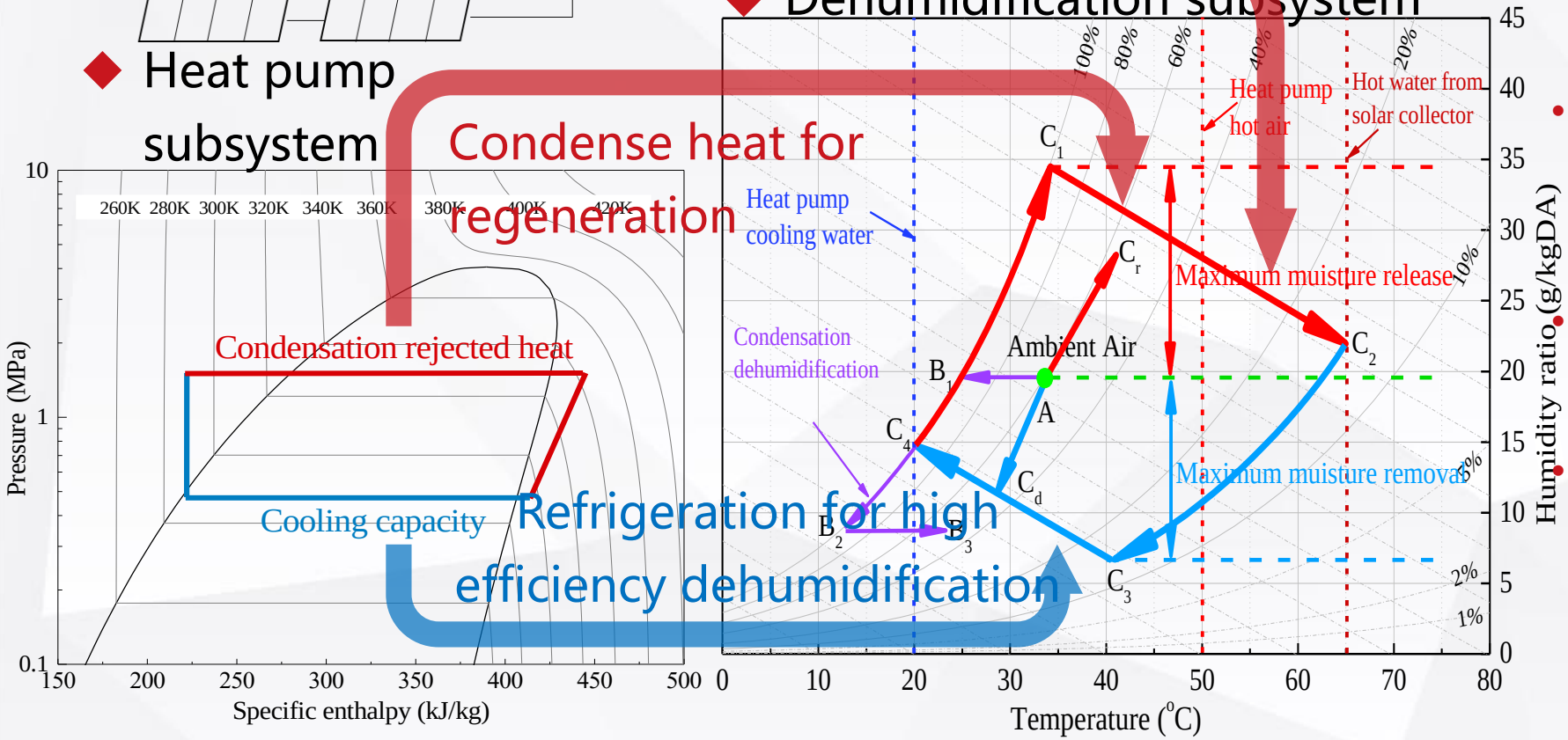
- Switch operating mode

  Continuous dehumidification process

Solar combined air-duhumidification HP system

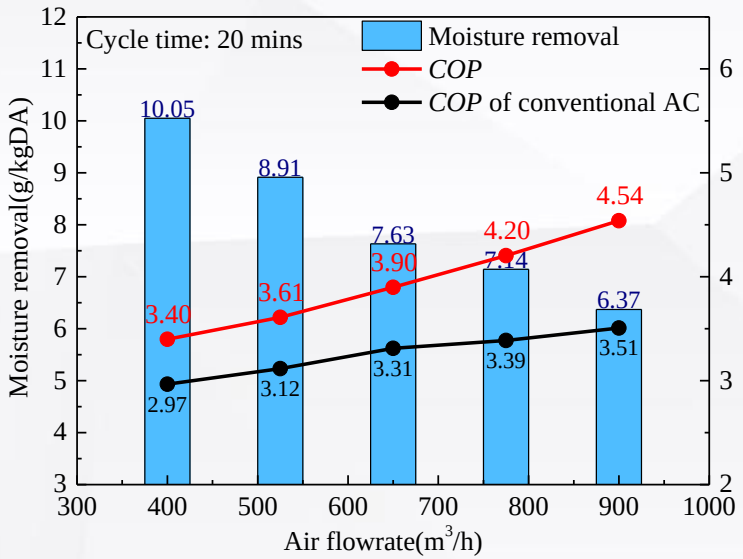
- Solar collector subsytem
- Heat pump subsystem
- Dehumidification subsystem

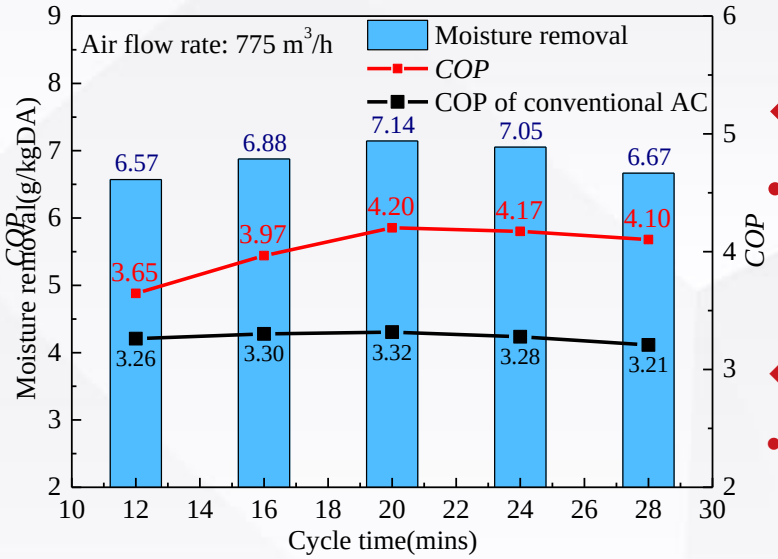


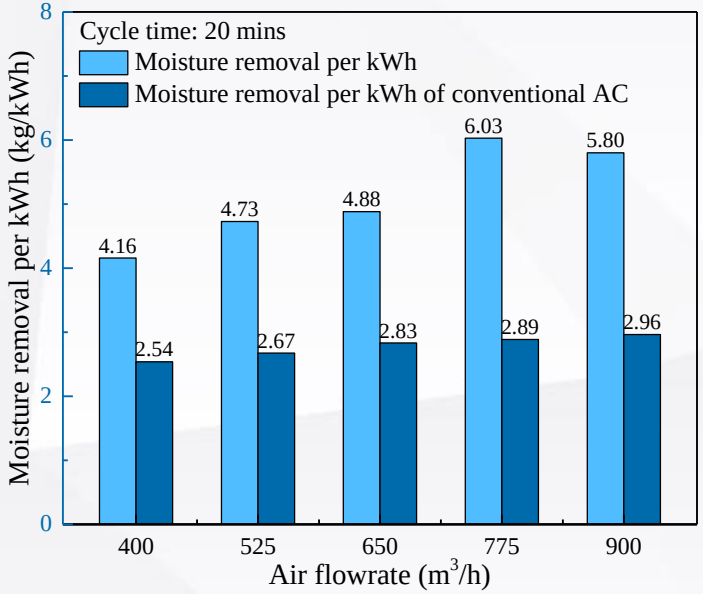


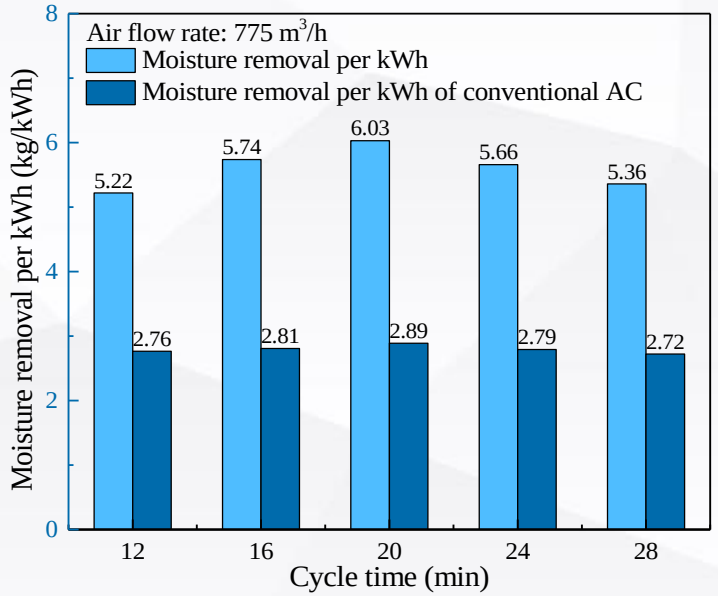
- Air cycle in system
- $C_4 \rightarrow C_1$:
  Saturated desiccant regeneration
- $C_1 \rightarrow C_2$:
  Maximum regeneration capacity
- $C_2 \rightarrow C_3$:
  Start dehumidification process
- $C_3 \rightarrow C_4$:
  Maximum instantaneous dehumidification capacity

Solar combined air-duhumidification HP system





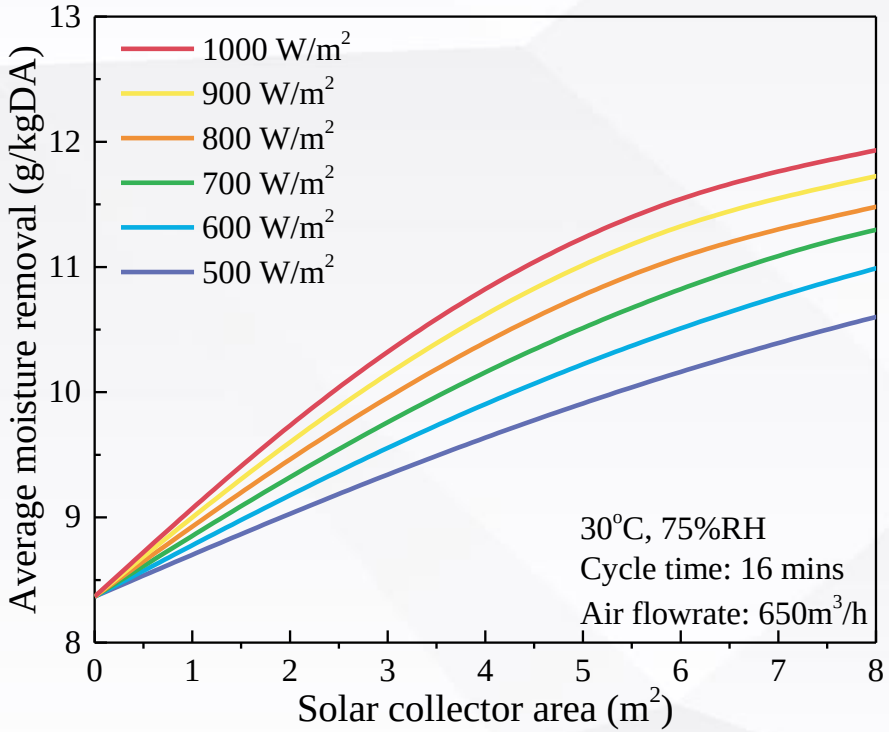




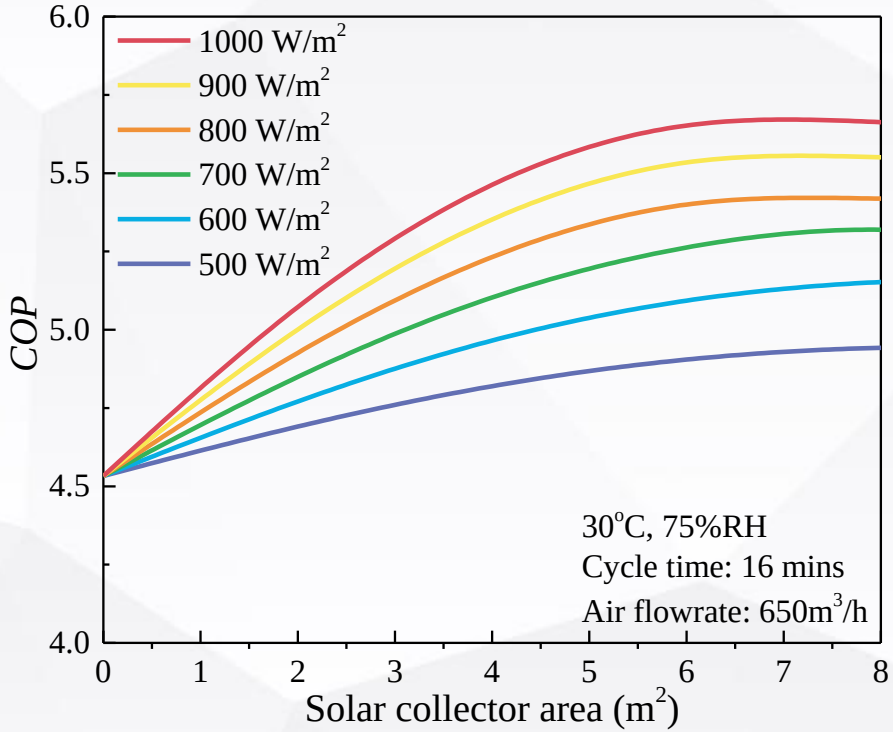
- Experiment condition:
  - 27.5°C, 78.4%RH 18.24g/kgDA
- Result:
  - Dehumidification capacity: 6.37~8.94 g/kgDA;
  - System COP: 3.40~4.54;
  - Compared to conventional technology, system COP improved by 14.5%~29.3%;
  - Unit electricity dehumidification value: 4.16~6.03 kg/kWh;
  - Unit electricity dehumidification capacity is 1.89-2.09 times that of conventional system

Solar combined air-duhumidification HP system

- Effect of radiation intensity and collector area on system dehumidification capacity



- Effect of radiation intensity and collector area on system COP



- The change of cop is similar to that of dehumidification, which increases with the increase of solar radiation intensity and heat collecting area, but the increase range is smaller;
- Under suitable heat collecting area and irradiation intensity, the dehumidification capacity of the system can reach 10 ~ 12 g / kgda and COP can reach 5.0 ~ 5.7.

Conclusions

- Solar cooker is welcome in rural areas, as well as tourist spots;
- Solar heating and cooling is very helpful for energy saving in building section;
- Solar PVT is one of the highest way to harvest solar energy;
- BIPV is important direction in solar energy utilization.

上海交通大學

SHANGHAI JIAO TONG UNIVERSITY

Thanks

饮 水 思 源　　爱 国 荣 校