2021 IHVAC

The Approach for Chinses zero carbon in building sector

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Main content

- How to achieve zero carbon in building operation？
- Building should change from the electricity consumer to an electricity prosumer
- Zero carbon heat source for heating in North China

Carbon emission in China

- Total carbon emission: 10.5 billion t_{CO2} （2019年）
  - Manufacturing 7 billion t_{CO2},
    - Fossil fire directly 3.5 bill t_{CO2}, Power indirectly 3.2 bill. t_{CO2}, Process 0.3 bill. t_{CO2}
  - Building operation 2.2 billion t_{CO2}
    - Fossil fire directly 0.6 bill. t_{CO2}, Power indirectly 1.1 bill. t_{CO2}, heat indirectly 0.5 bill. t_{CO2},
  - Transportation 1.3 billion t_{CO2}
    - Fuel and gas 1.1 bill. t_{CO2}, Power 0.2 bill. t_{CO2}
- In addition, an equivalent of 1.5 billion t_{CO2} should also be taken into count due to the emission of non-CO2 greenhouse gases

The zero-carbon target for building operation

- Full electrification in building so to eliminate direct emission 0.6 bill. t_{CO2}
- Turn the building functions from pure electricity consumer to producer, consumer and regulator, so to help for the power system carbon neutralization 1.1 billion t_{CO2}
- Carbon neutral heat sources for building heating in winter 0.5 bill. t_{CO2}
- Carry out refrigerant replacement work, and strengthen management to eliminate leakage of refrigerant quality so to eliminate non-CO2 gas emission

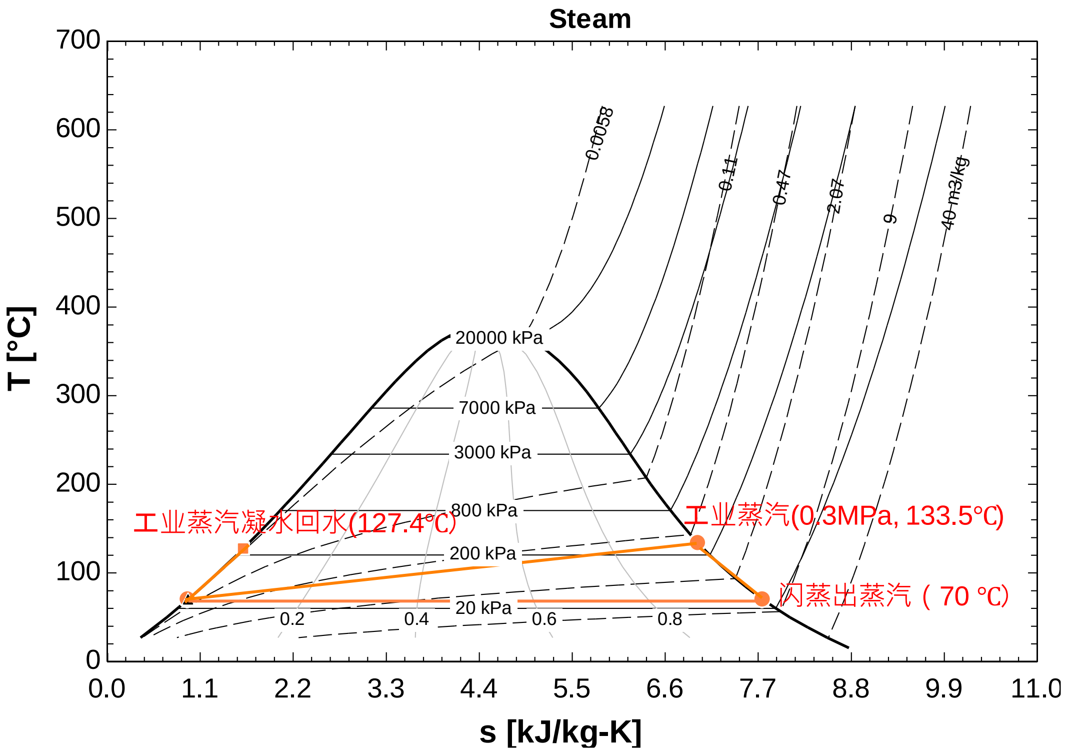
Fully electrification in buildings

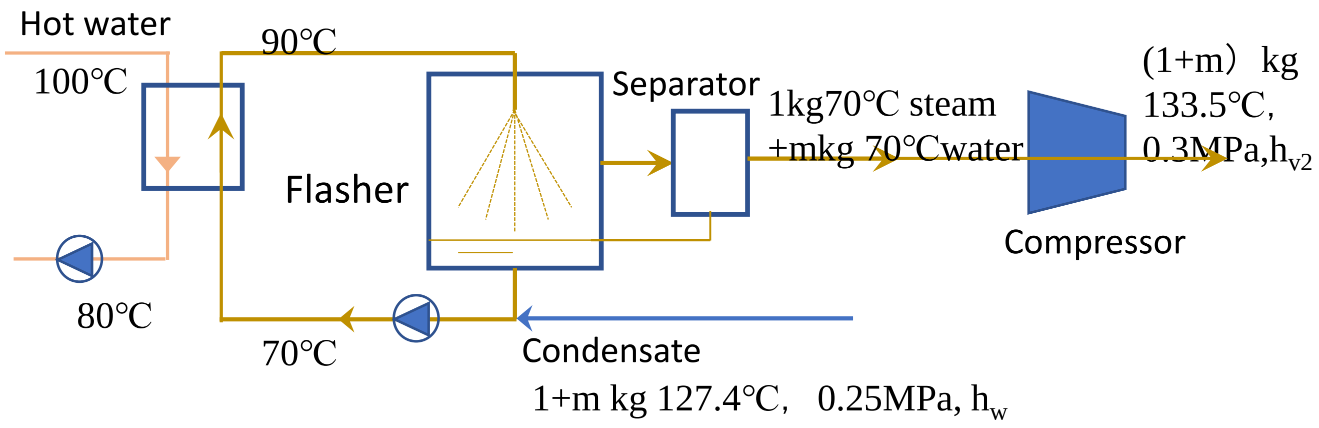
- Current state

0.6 billion tco2 emission in 2019年 due to coal and gas fire directly in buildings

- Emission reduction path
  - Electrification in cooking: full types of electricity cookers have been developed
  - Electrification for domestic hot water ： heat pumps, electricity heaters
  - Replace gas boiler for hot water ： heat pumps, air source
  - The replacement of steam boilers ：
    - Unset central steam system
    - Develop decentralized steam producer with electricity
    - Heat pump for steam producer?
  - In most cases turn gas to electricity can reduce operation cost so the cost in retrofit can be payback within few years

Steam producer with a flash and a steam compressor





$$COP = \frac{Q_{steam} - Q_{condense\ water}}{W} = \frac{(1+m)*(h_{vh} - h_w)}{(1+m)*h_{v2} - h_{v1} - m*h_{w0}} = 3.87$$

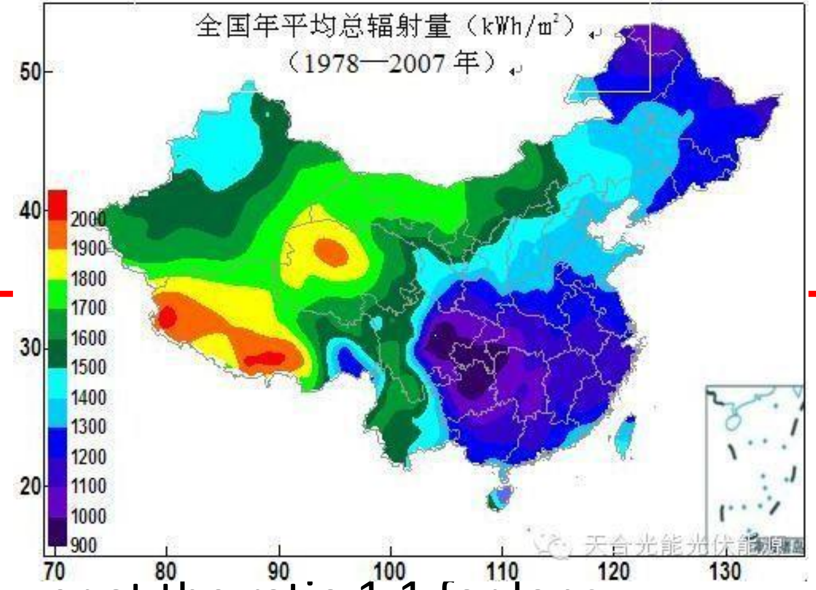
Buildings should be a boost to zero-carbon power

- China power sources 2019 future plan

China power sources	2019		future plan	
Hydrolic	0.38 bill. kW,	1300 bill. kWh	0.5 bill, kW,	2000 bill. kWh
Nuclear	0.05 bil. kW,	350 bill. kWh	0.2 bill. kW,	1500 bill. kWh
Thermal	1.1 bill. kW,	5400 bill. kWh	0.6 bill. kW	1500 bill. kWh
Wind & PV	0.5 bill. kW,	630 bill. kWh	6 bill. kW,	8000 bill. kWh
Total	**2 bill. kW,**	**7600 bill. kWh**	**7~7.5 bill. kW**	**13000~14000 bill. kWh**

- Features of future power sources :
  - large portion of wind & PV, 85% installation, 60% electricity
  - Low density power generation, 100W/m2, 6 bill. kW Wind& PV installation needs 60k square kilometers, 10% of Chinese current farmland, and about 0.6% of total Chinese land
  - Wind & PV power are not adjustable, and the change of power generation is out of sync with the change of electricity demand

Where is the space for PV?

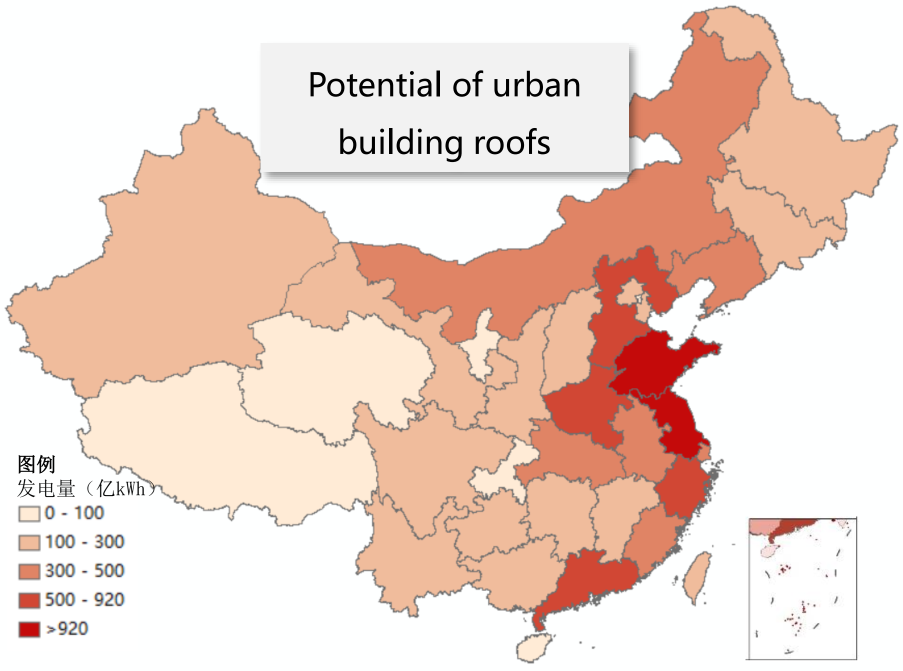


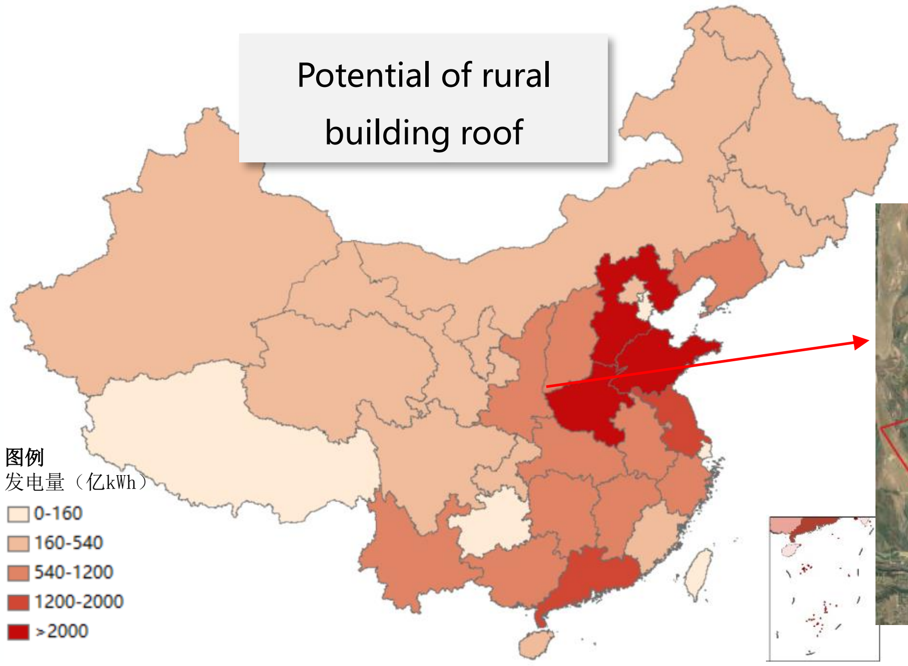
- Northwest Gobi Desert?
  - Rich land resource、rich solar
  - Long distance transportation，high cost
  - Power from PV has to be bundled with hydraulic or thermal power at the ratio 1:1 for long distance transportation
  - Twice peak adjustment may be required due to the load variation in the east
- East-central where is the high-density power load area
  - Solar radiation is about 60%~70% compared with the west
  - As the cost of PV devices falling，the density of solar is not so important to the total economics
  - Avoid long distance transportation, save investment and running cost
  - Match with the load at certain level, so the required capacity for peak adjust is about 50% comparing with the Northwest PV
- Conclusion：
  - 30% of total PV installs on the West and 70% installs on east-cenrtal

The possibility of roof PV and the potential scale

According to the analysis result from Satellite images and onsite investigation

- PV potential installation scale in total roofs in urban is 0.83bill. kW, and can produce 1230 bill. kWh annually, that is about 25%~30% of the power needed for urban buildings operation
- PV potential installation scale in total roofs in rural is 1.97 bill. kW, and can produce 2950 bill. kWh annually , that is more than two times of the power they need





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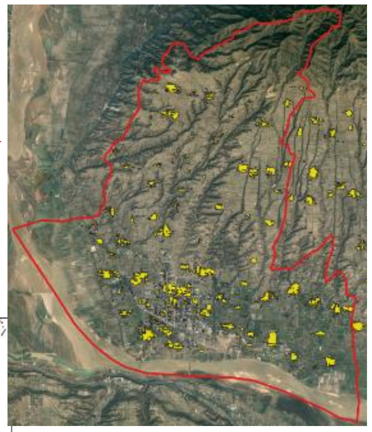
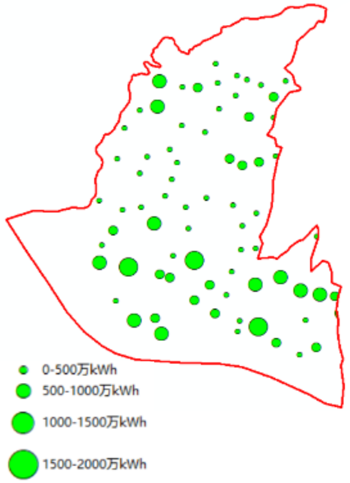




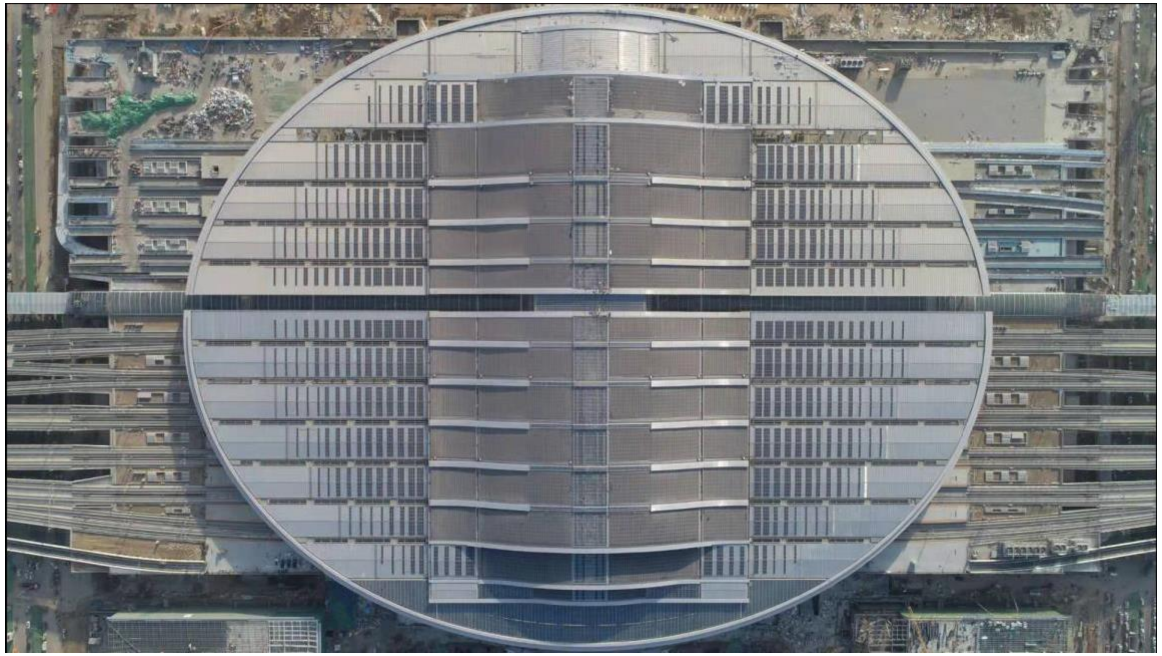
Solar PV integrated with building design

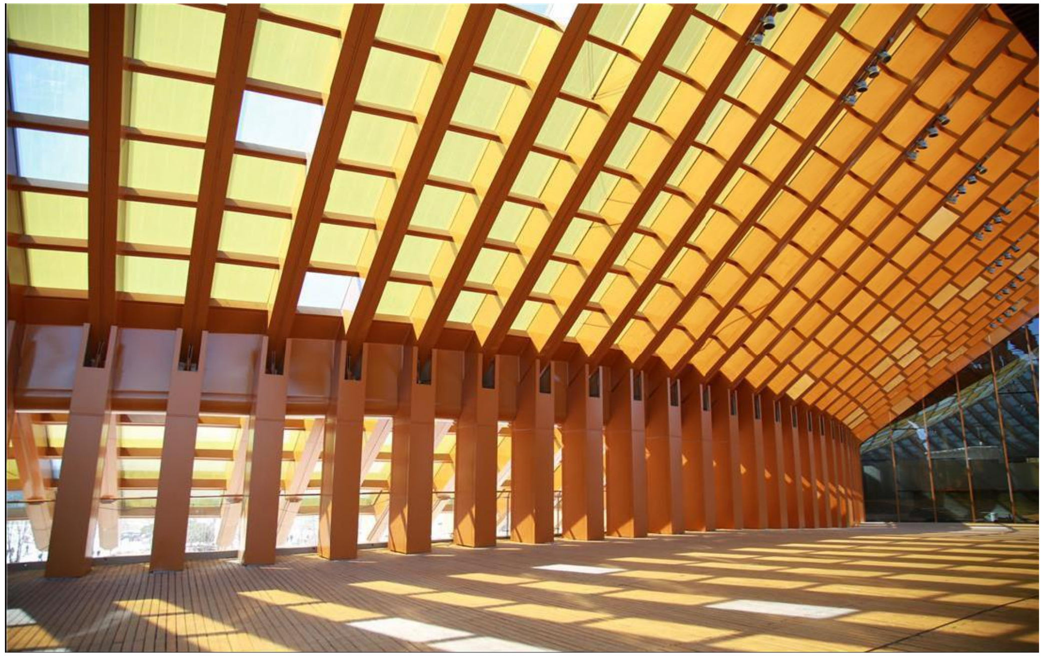
High speed train station at Xiong An：

- Integrated with building roofs
- The fusion of PV and traditional styles with Chinese characteristics
- PV installation **6MW**， Produce electricity 5800 MWh annually,

2019 Beijing World Park China Pavilion

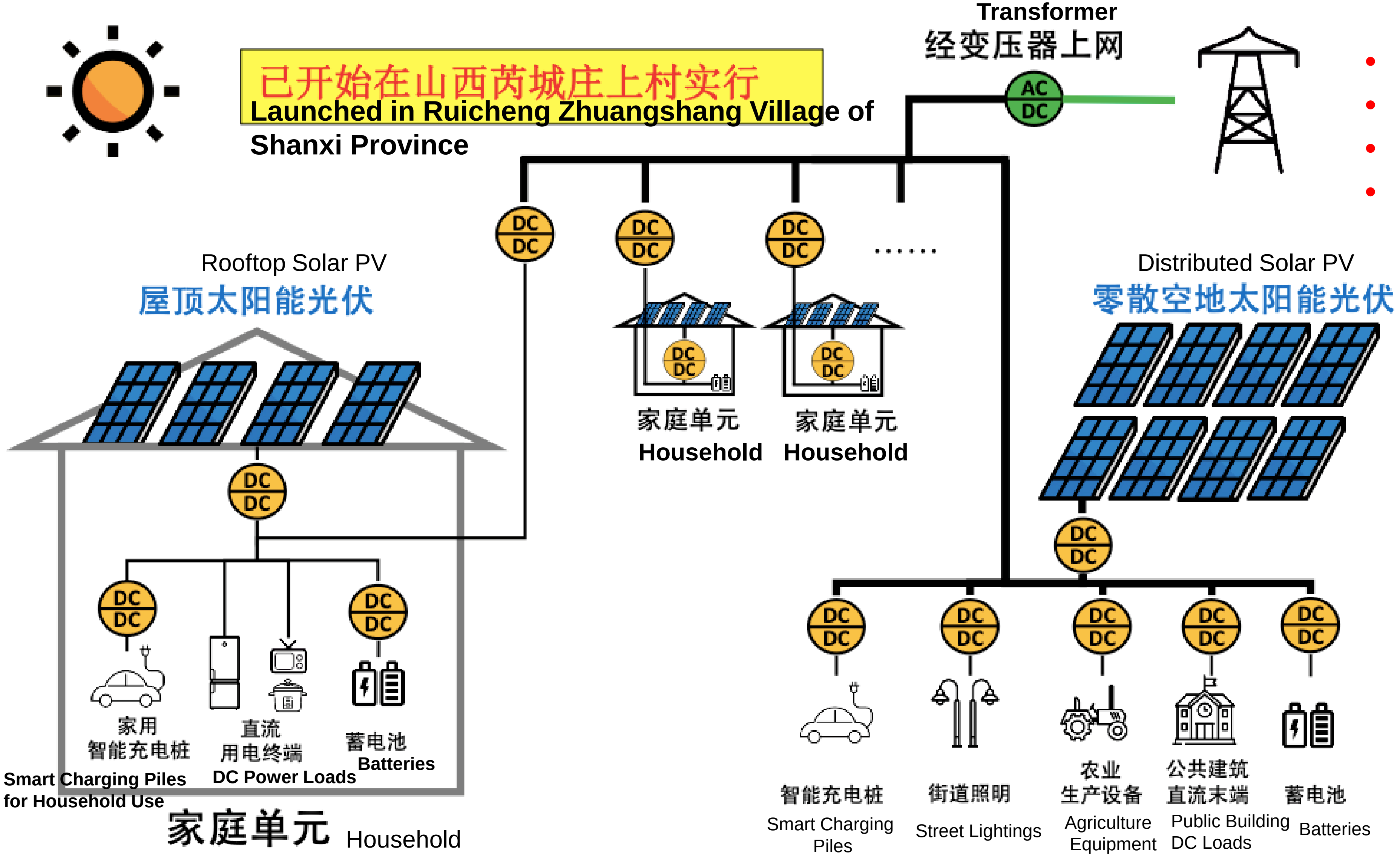
- PV and building integrated at each parts
- Chinese cultural and traditional styles with PV
- Total PV **78kW**， produce electricity **97MWh annually**





PEDF for rural buildings

- P: PV on roof
- E: Energy storage
- D: DC current
- F: Flexible load

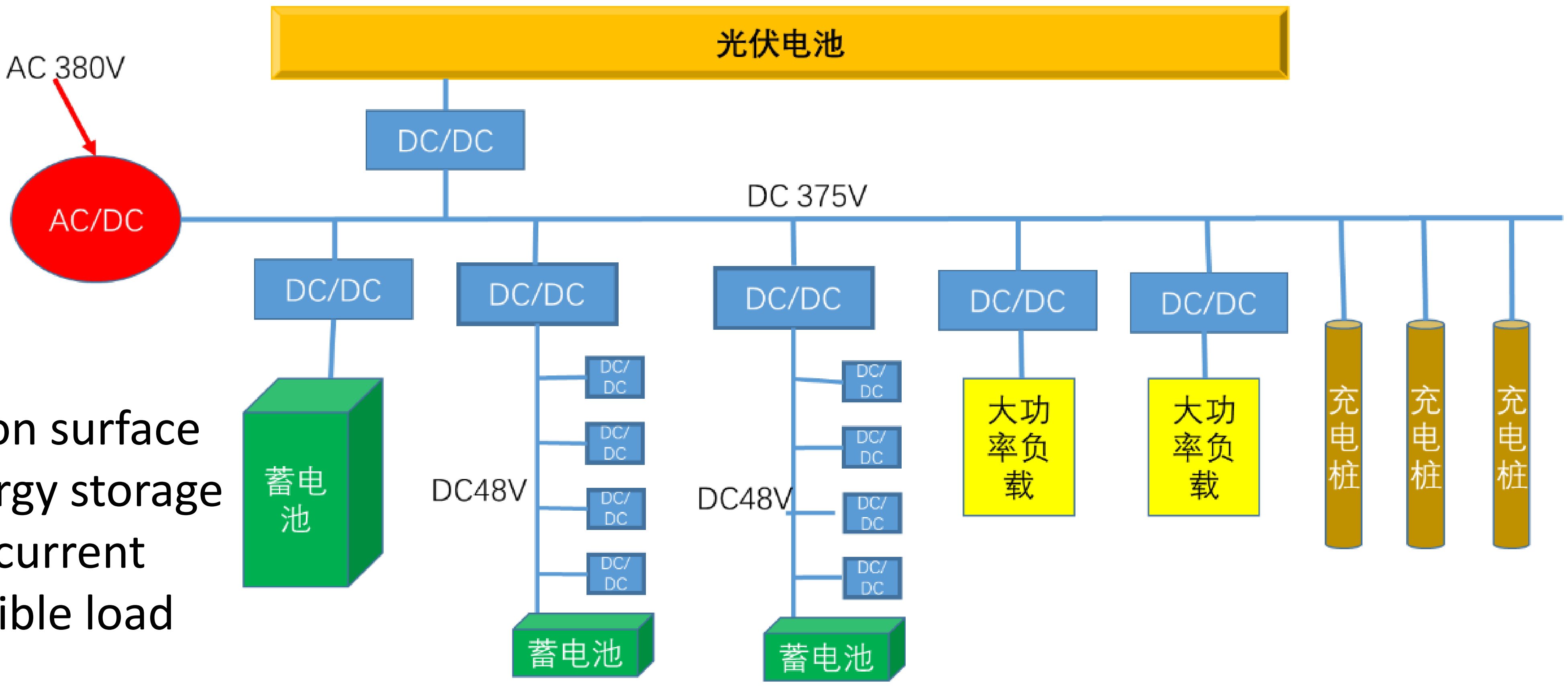


PEDF for rural buildings

- Scale: >20kW PV per householder
- Provide enough energy for daily life（Include cook, heating and hot water）
- Charging for vehicles
- Agricultural tools、process for farm products
- Generates power 22 MWh/a annually
- In additional of fully self support, outputs 10MWh power to the grid
- Most of the load can work at demand response mode according to the PV output
- Investment about is about 100K~120 K RMB per householder, or 15K~20K dollars

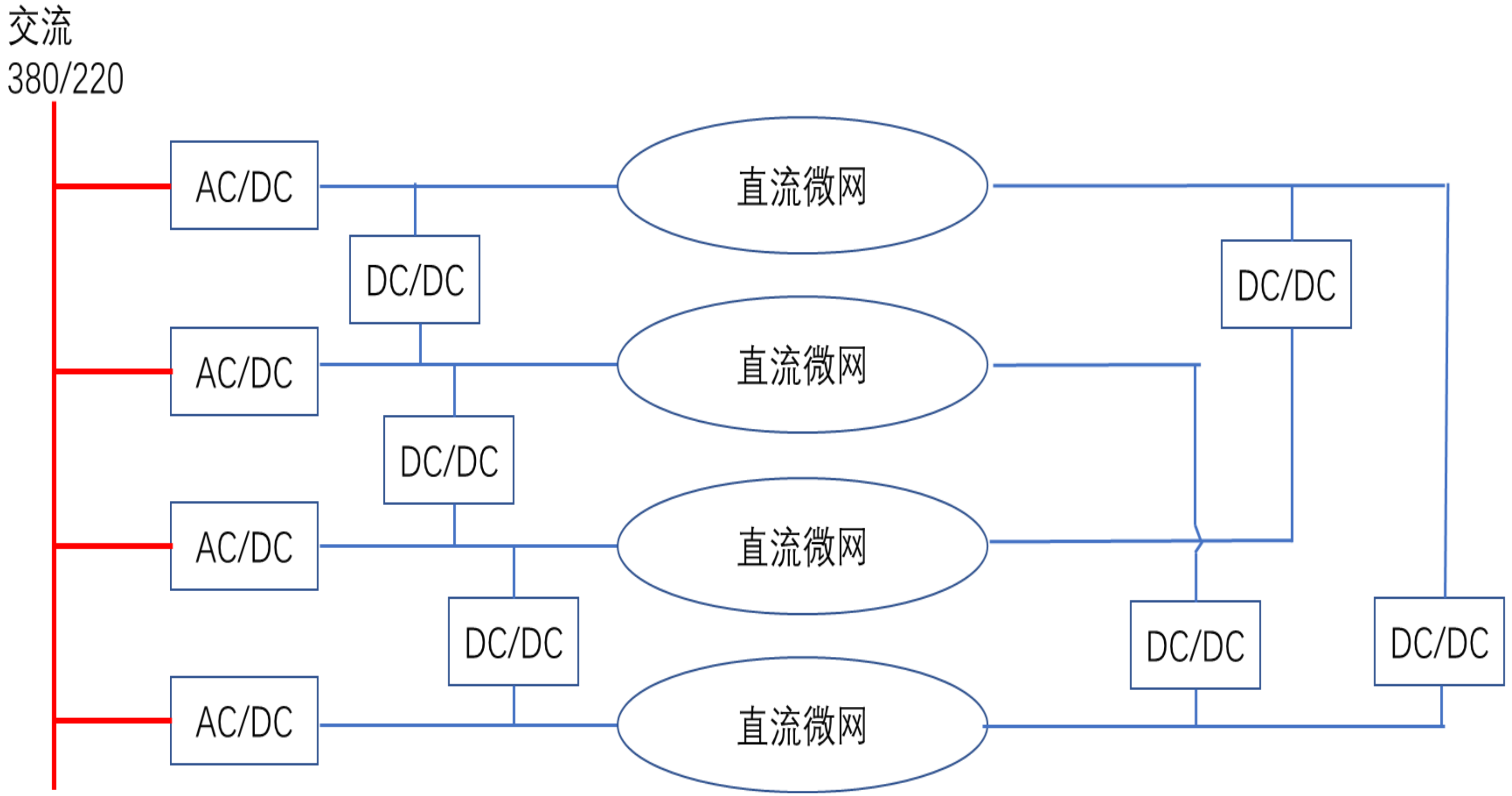
PEDF for urban buildings

P：PV on surface
E：Energy storage
D：DC current
F：Flexible load



建筑“光储直柔”配电系统

The inter-connection between PEDF’s

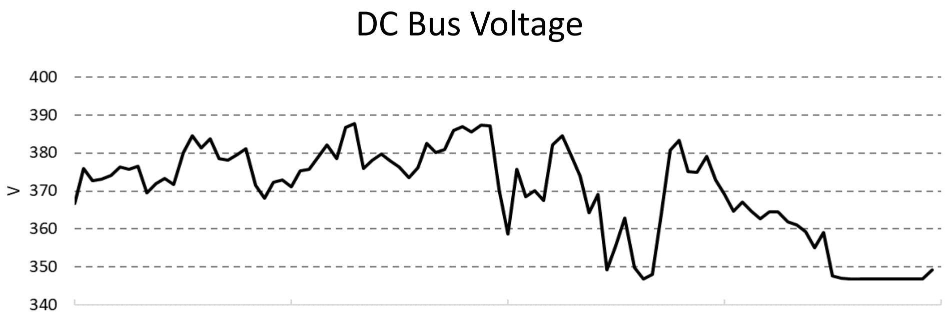


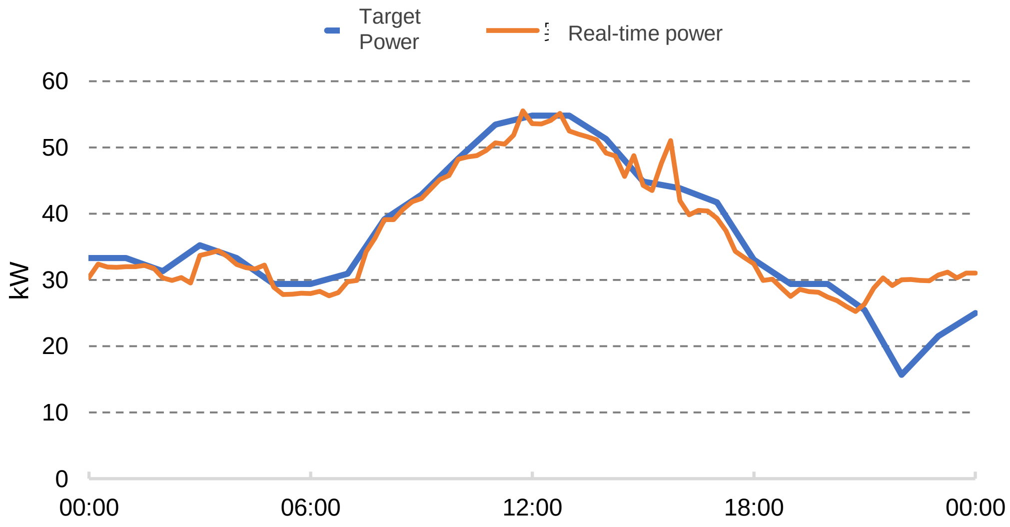
The purposes of PEDF building in urban

- The PV can only provide 25%~30% of total power required
- PEDF is a flexible power load from the point of view of the grid
- The input power from the grid can be varied according to the command from power dispatch
- The AC/DC at the inlet can change the DC voltage so to adjust the input power to the required
- When the voltage of DC rises, each terminals will try to increase their input power, while when the voltage of DC falls down, each terminals will try to reduce their input power.
- This is why the PEDF building becomes load flexible building

The real operation data: Shenzhen office building

- Designed voltage of DC ： 375V
- Battery capacity ： 200kWh
- No charging piles

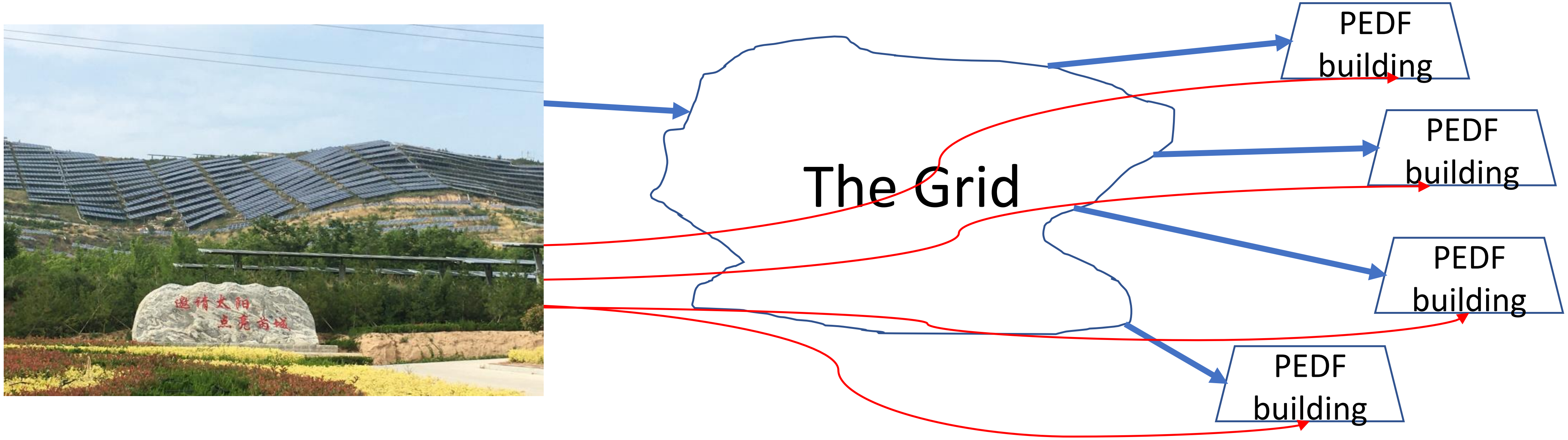




- 引自深圳建科院郝斌的PPT ： PEDF – Future or Reality， 2021. 08. 31

PEDF building can be operated with zero carbon power

- There are wind & PV power generation base within hundreds kilometers
- PEDF buildings report their total electricity needed for the next day and the predicted daily curve to the W&P power base center every night
- The W&PV center gives the command of required curve of power use for each PEDF buildings according to the prediction of the W&P generation on the next day
- If each PEDF buildings get the power from the grid exactly the same as the control center required, the PEDF building can be regarded as full zero carbon operation



How large variation in power the PEDF building can do

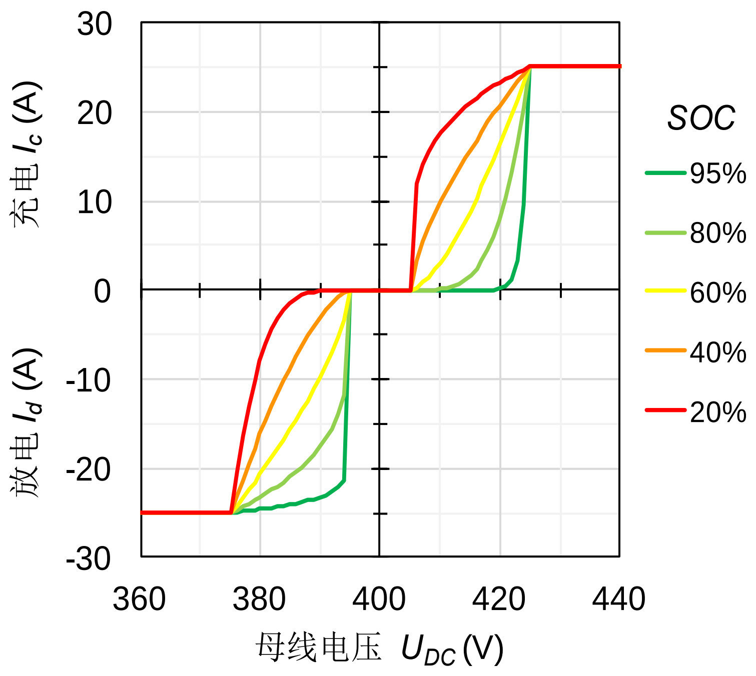
- The e-cars at the carpark near the building ：
  - Battery capacity for each e-car：50~100kWh
  - Annual travel distance：10K to 15K kilometers， needs 2000~3000kWh， that is charging/discharging once tendays to a week
  - Annual utilization rate：10%~15% only； if charging/discharging can be once a day
- If fully electrification cars by 2030 or 2035
  - An office building with 10k square meters floor space and 100 parking space can make the inlet power from the grid vary within 0~1MW during a whole day
  - More than 80% of time during a day the car is parked at the parking place rather than on the road
  - “one parking space one pile ”， As soon as the car is parked, the connection should be made
  - The charging/discharging process should be controlled by the pile rather than by the BMS in the e-car

The flexibility of other loads in building

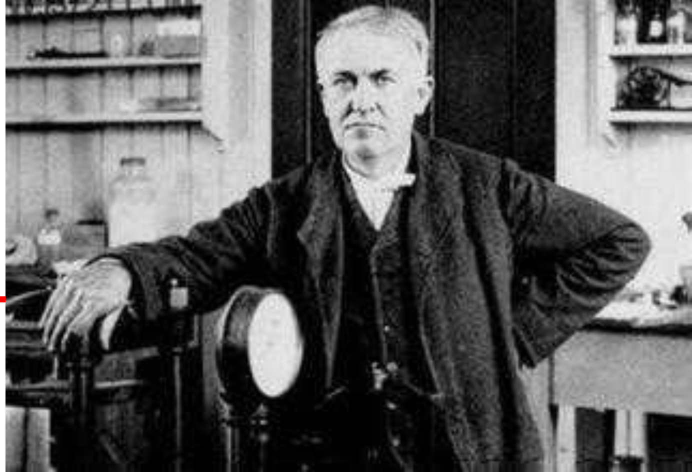
- Distributed battery： 100Wh/m2
- Thermal storage: ice storage, water storage and so on；
- Change cooling/heating sources：causes room temperature change a bit
- Shift load with a period：freezer、cloth washer, etc.
- Fans, pumps, lift, escalators: change the speed by changing frequency
- Batteries in movable building appliances
- Etc.

Logic for building terminals

- Charging/discharging piles:
  - According to the voltage to decide if in the state of charge/discharge, and the power of charge/discharge
  - The SOC of each car should also be the factor to decide the charge/discharge power
- Distributed batteries
  - Similar as charging piles, but AI learning should be taken place to know when need large charge and when need large discharge during a day, so to prepare enough space beforehand



Building should turn from AC to DC



- Edison's DC and AC battle with Tesla
  - Advantage for AC: transformer, Rotate the magnetic field
  - Revolutionary in power electronics technology : DC/DC, DC/AC
- Buildings are fully adapted to DC power supply
  - LED lighting, avoid damage of AC/DC so to extend life
  - IT types of appliances: DC can be connected directly
  - Motors: the trend direction is variable frequency, EC motor
  - Heaters: can be connected directly, and the heating power can be adjusted
  - Batteries: they need DC
- DC system can improve the safety and reliability
  - New type of ground connection
  - DC 48V can be provided for small power applications
  - Battery can provide extra reliability, If the grid can provide 99.9%, battery can turn it into 99.999%
- Voltage of DC can be varied at relative large range so to able to bring adjusting message to each terminals

The contribution of PEDF building to the grid

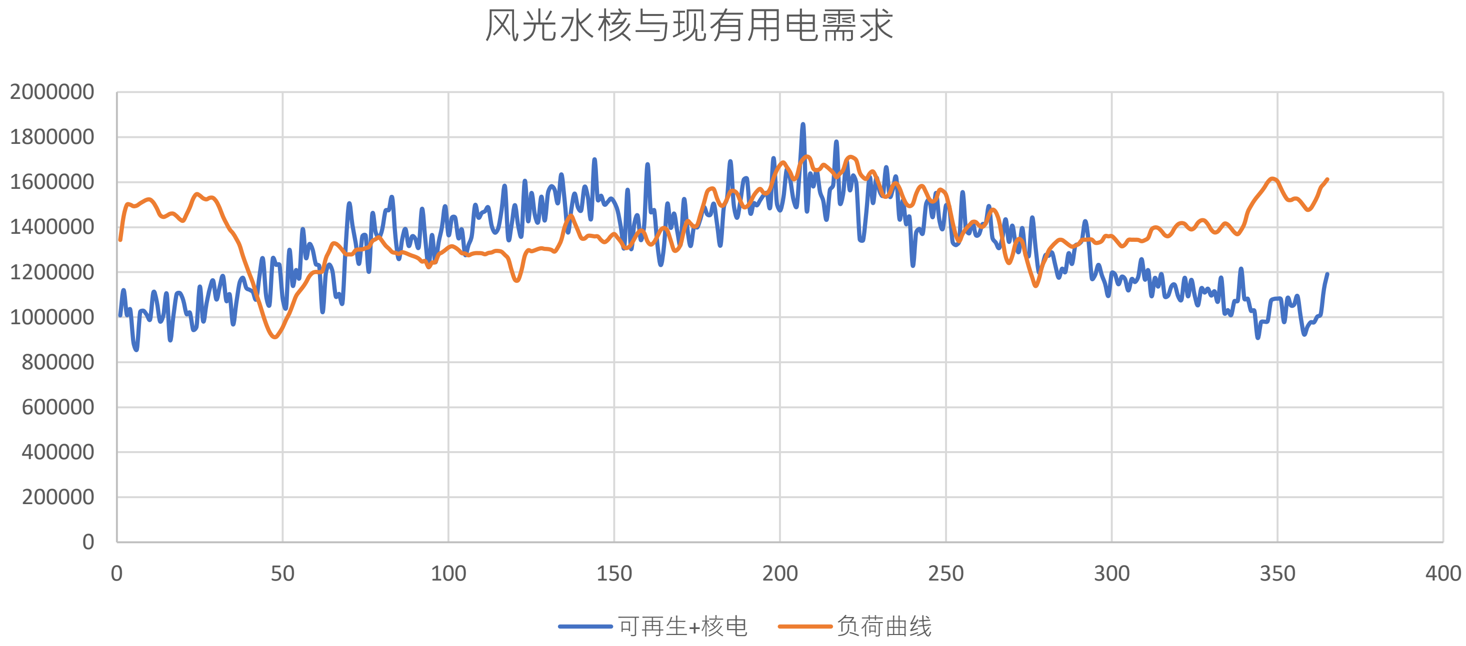
- Reduce the required capacity of the grid
  - Great reduction can be made on the building inlet capacity (unless absorb large power of peak from the grid is needed)
  - Connect large amount of charging piles for e-car without increasing total inlet capacity, otherwise the capacity has to be doubled
- The bridge to link building power system with e-cars
  - Either carparks in residential district, in offices buildings, and in factories piles should installed for each parking place， and connected to PEDF
- Cut peaks to fill valleys and become virtual power plants
  - Peak power consumption can respond to grid requirements to significantly reduce the power consumption
  - Increase the power input during when the load in the grids low

Carbon neutral heat sources for space heating

Current heat sources in Chinese North urban

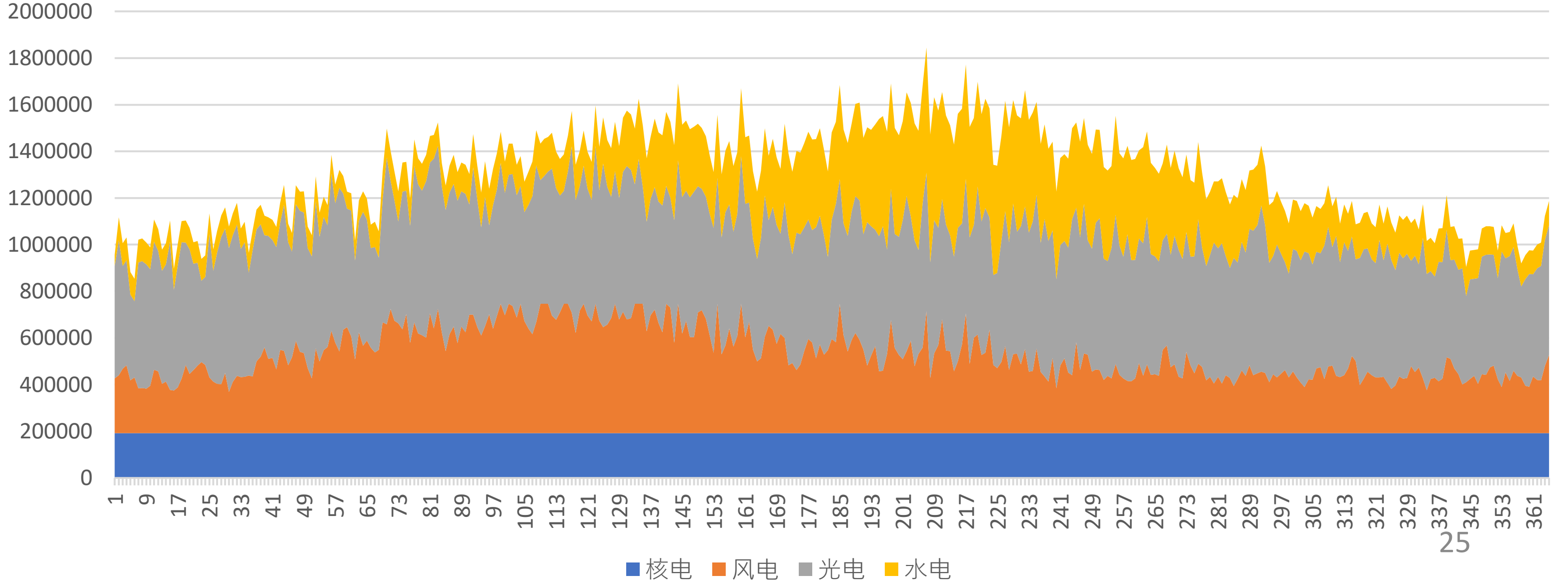
- Required heating floor area: 16 billion square meters
- Required heat supplied：0.35GJ/m2， total 5.6 billion GJ
- Current heat sources：
  - District heating 12 billion square meters， 60% by CHP， 40% by boilers
  - Small gas boilers 2.5 billion square meters
  - Heat pumps and waste heat from industry: 1.5 billion square meters
- Possible two approaches for zero carbon
  - Fully electrification, based on all types of heat pumps
  - Recover all types of waste heat: nuclear, thermal power、industry、data center、Waste incineration etc.

The balance of zero carbon power and the electricity load



年补电量（火电发电量亿kWh
11865
火电装机（MW
638599
燃料 万tce
35000
碳排放 万t
3亿~7亿tco2

- Hydrolic：It is only 40% in winter comparing summer
- PV：less operation hours in winter than in summer
- Wind power：no significant different between winter and summer
- The gap in winter is about 0.65 billion kW



The approach to solve the seasonal difference of power supply

- Increase W&PV installation capacity to meet the demand in winter, and abandon the extra power in other seasons
  - 1billion W&PV is needed to be installed， more than 5000~8000 billions RBM
- Hydrogen, storage hydrogen in summer and release it in winter
  - 10000 billion RBM is needed
- 0.6 billion kW thermal power for winter, provide 1500 bill. kWh annually
  - Biomass, coal, natural gas can be used as fuel and recover the CO2 from the exhaust through CCS
  - Investment: less than 2000 billion RMB including CCS
  - 6 billion GJ extra heat can also be produced in winter by CHP as heating sources
  - provides safe and stable power supply to the grid throughout the year

The heat zero carbon sources for heating

- Option A: Multiple heat pumps (air, water, ground)
  - 20 billion square meters building floor area, 40W/m2， if COP = 4
  - Power load: 10W/m2 X 20 bill. = 0.2 bill kW
  - Enlarge the shortfall of power in winter from 0.6 bill. kW to 0.8 bill. kW
  - Abandoned the district heating networks, which have been completed over most towns in the North
- Option B: Rely on cogeneration, industrial waste heat, waste treatment residual heat etc.
  - 20 billion square meters, 6 billion GJ heat
  - Nuclear power 0.2 bill. kW， There will be 0.1 bill. kW at least located on the north， 0.13 bill. kW heat can be provided， 1.4 billion GJ can be provided during winter
  - Thermal power, CHP: 0.3 bill. kW located at north, at least， 0.4 bill. kW heat， 2.4 b. GJ
  - All kinds of industry waste heat：1.2 billion GJ in winter
  - 80% load can be meeted, heat pumps can be added for the remainder

The heat zero carbon sources for heating

- If build large scale seasonal heat storage system
  - Collect all kinds of residual heat over the year as the heat sources for winter
  - If 2.5 billion GJ can be collected and storage during the no-heating seasons, it would be enough for heating in the winter
  - Water can be used as the medium, 90/20℃,   3.5m3/GJ,   2.5 billion GJ needs 9 billion m3 space to store water,   investment 1000 billion RMB
  - All problems can be solved: heat sources, transportation, reliability, peak adjusting for heat and for power,
  - CHP at coastal can also be used to provide large amount of fresh water
- Conclusion: option B with large scale seasonal heat storages

Timetable for zero carbon heating sources in North

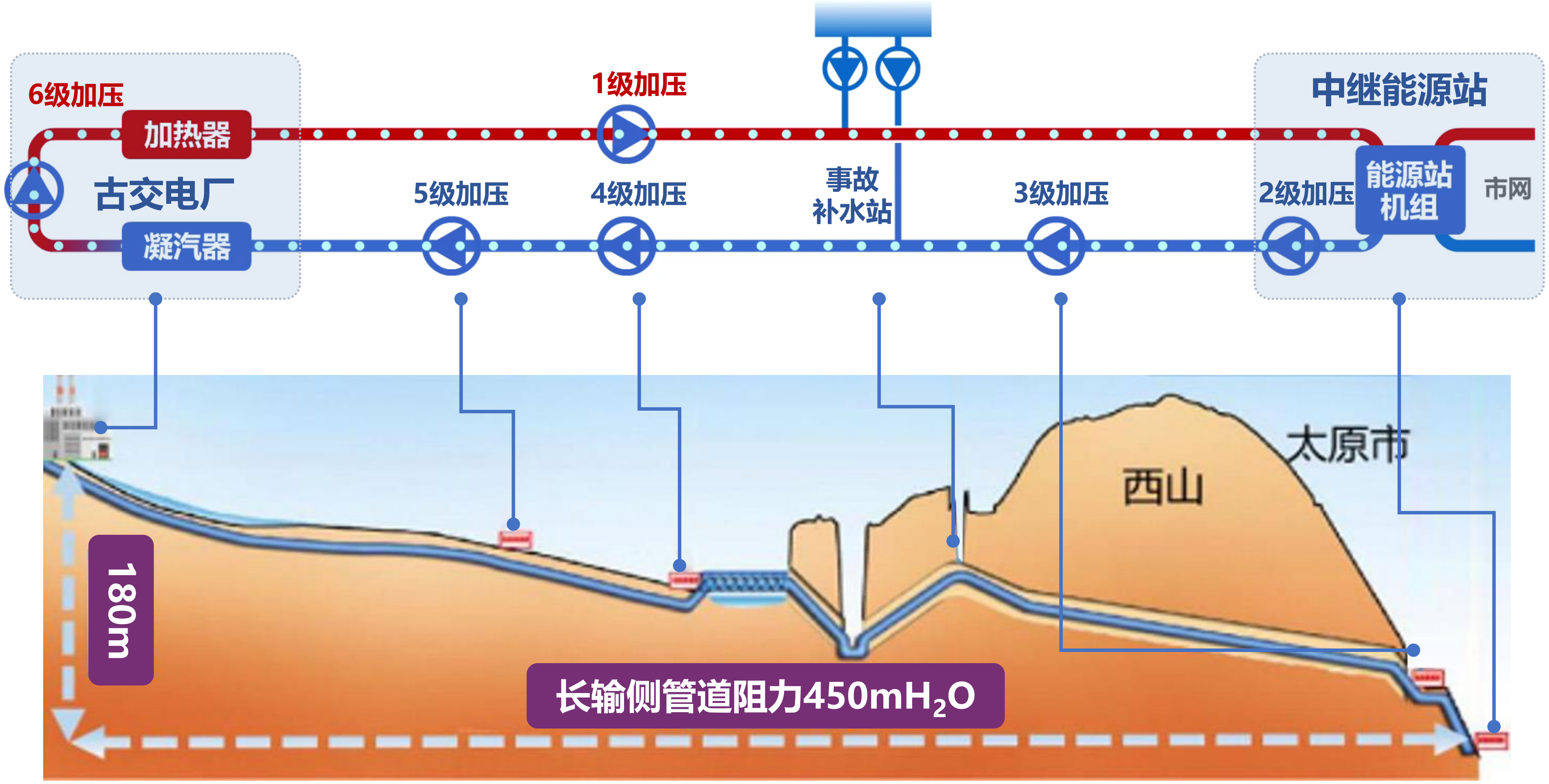
- Before 2030：
  - Lowing the temperature of return water, from ~50 ℃ down to ~20 ℃, by retrofit the district heating system， employs absorb heat exchangers
  - Low temperature water can then reclaim low grade heat from CHP as well as from industry waist
  - Meet the increased demand by increasing the recovered low grade heat, stop to install any new boilers nor new CHP
- After 2030：
  - Remove some CHP and replaced with wind & PV power for electricity
  - Start to build large scale seasonal heat storage system as the replacement
  - By 2050， thermal power will be reduced from 1.2 billion kW down to 0.65 billion kw， while 6 billion m3 heat storage will be built

Challenges for reclaim CHP and industry waste heat

- Unmatch between the location of heat production and the heat demand

- Current situation： most large cities of north can find enough heat resources within the radius of 100 kilometers except Beijing,
- Beijing can also find enough heat source if enlarge the radius to 150 kilometers
- Technologies for long distance heat transportation with low cost and low loss has been developed

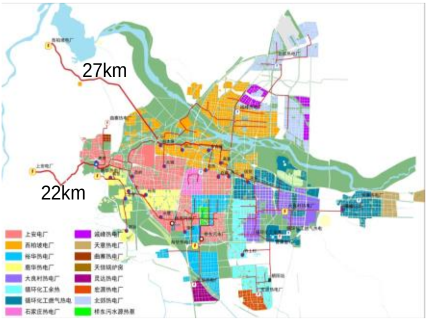
Taigu—Taiyuan long distance heat transportation project



构建**六级**泵循环加压工艺，实现了**长输侧直连高差 180m**的热网安全经济运行。

The on going long distance heat transportation projects

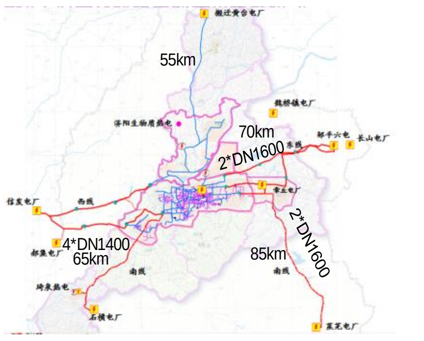
太原
供热面积：10600万㎡



石家庄
供热面积：18500万㎡

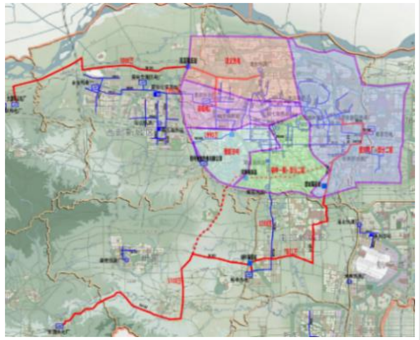
呼和浩特
供热面积： 9000万㎡

西安
供热面积： 7500万㎡



济南
供热面积：28000万㎡

银川
供热面积：11219万㎡



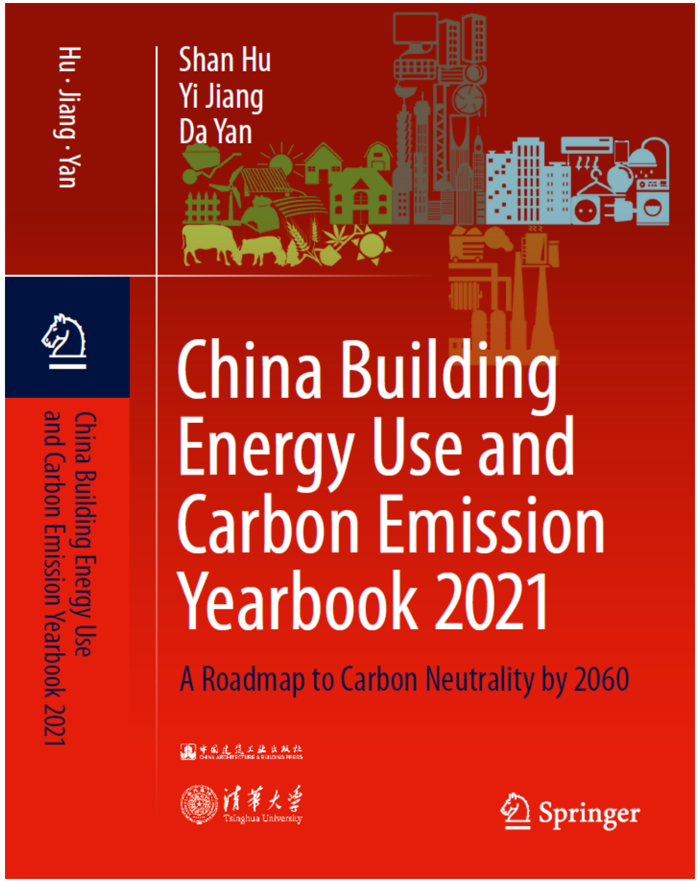
郑州
供热面积：12000万㎡

乌鲁木齐
供热面积：6000万㎡

Conclusion: The tasks for carbon neutral

- Final target： Change the energy structure
- The tasks required：
  - Rebuild the Power system： zero carbon sources， new grid, new operation manner
  - New rural energy system: from a pure consumer to a producer
  - Building electrification、flexible retrofit、
  - Rebuild zero carbon heating sources
  - Vehicle electrification， fully use the resources of battery in e-cars
  - Retrofit industry： turn from fuel based into electricity based

Release of the China Building Energy Use and Carbon Emission Yearbook 2021



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