中国建研院 环境能源研究院
Institute of Building Environment and Energy

Typical zero-carbon building renovation project based on BIPV technic in China

CABR-ZEB

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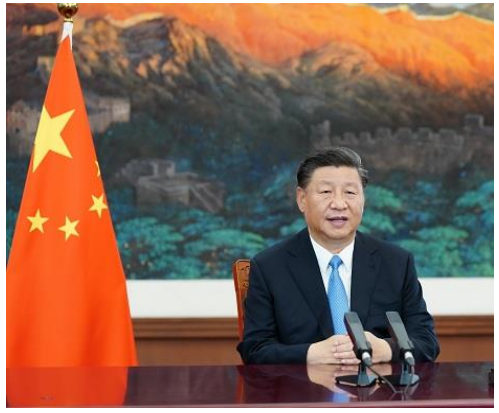
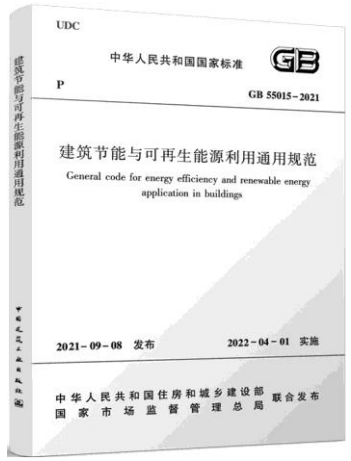
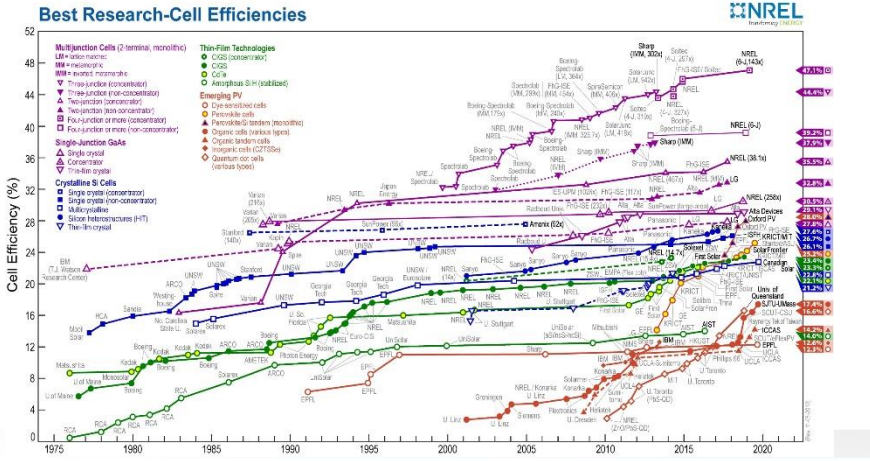
1.1 Carbon neutral by 2060

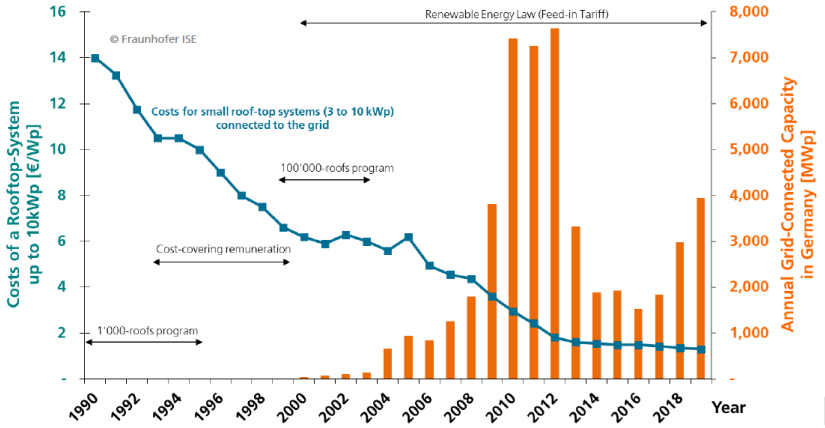


- The State Council
  - ✓ Action plan for carbon peak by 2030 - Photovoltaic coverage rate on the roof of newly-built ≥ 50%
- MOHURD
  - ✓ Building development plan for 14th Five-Year Plan - 50GWp of BIPV newly-installed by 2025



Full–text mandatory standard: Buildings should be equipped with solar system ... comprehensively utilized throughout the year





Efficiency improvement+Cost reduction=Necessary for solar building

1.2 ZCB > ZEB

Zero energy building=Passive house+Efficient equipment+Renewable energy

Light	Cooling	Heating	DHW	Equipment
12kWh/m2	30kWh/m2	20kWh/m2	10kWh/m2	52kWh/m2

Zero carbon building≥ Zero energy building+Carbon balance included equipment

1.3 Project attempt

1.3 Project attempt

- Typical zero-carbon building renovation, built in the 1970s, located in CABR.
- Information
  - ✓ Function: office
  - ✓ Structure: masonry structure
  - ✓ Building area: 2850 m2
  - ✓ Floors: 2 floors, 1 floor locally
  - ✓ Partition: office, conference room, lobby

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2.1 Routes

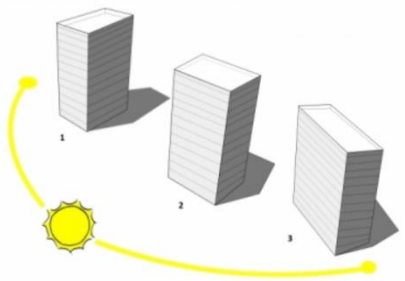
Preliminary planning scheme

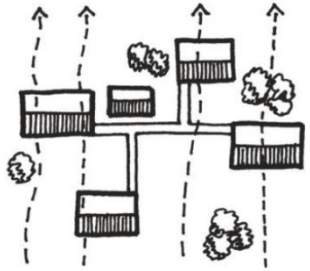
High performance envelope

High efficiency equipment

Renewable energy

Architectural planning

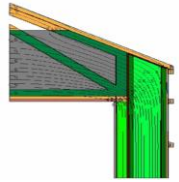




Passive methods

Air tightness

High performance windows



Thermal insulation

Sanshade

No heat bridge

Energy system

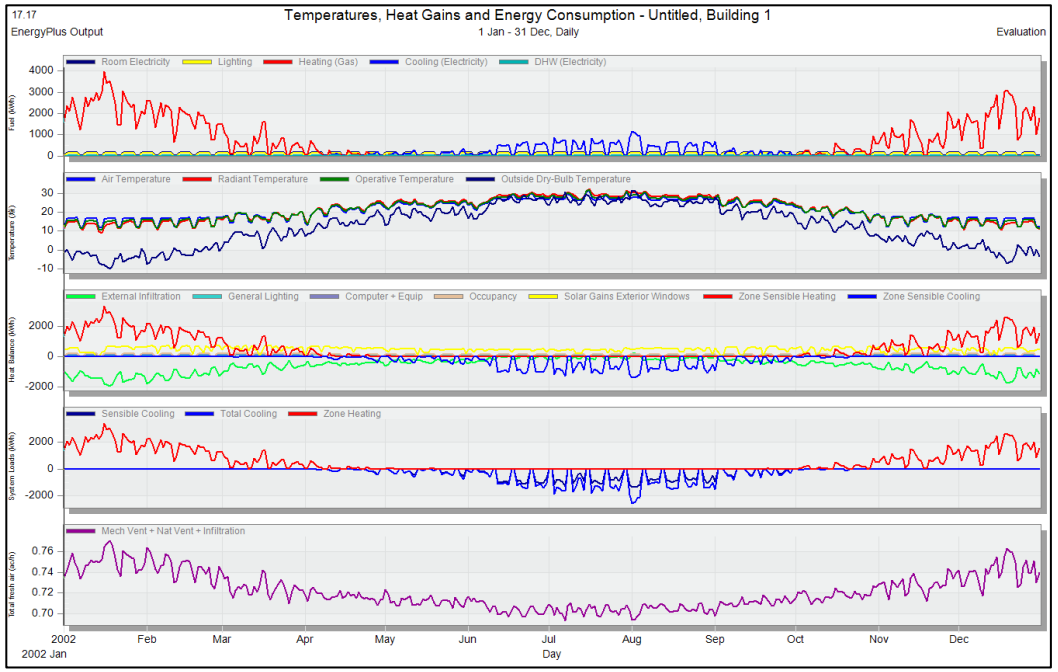
Energy saving equipment

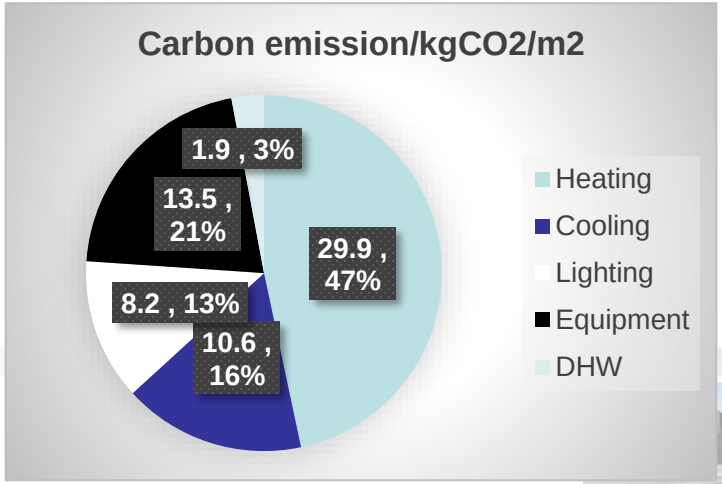
Renewable energy

EMS

2.2 Existing Circumstance

- Analysis based on historical data and building simulation.
- DesignBuilder, core of Energy+ developed by DOE and LBNL.
- Function of graphical interface and simulation design.





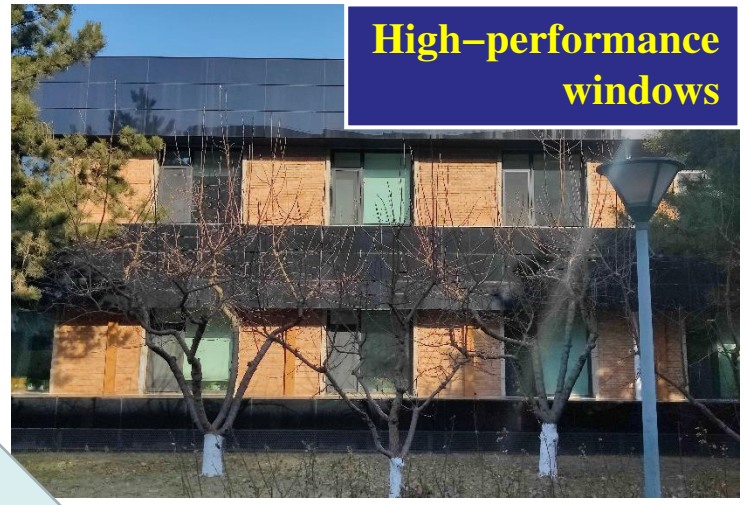
1.Poor thermal insulation & traditional enclosure structure

2.Rhythm and internal heat source affect energy consumption characteristics

3. Solar energy utilization for both power generation and heat transfer improvement



2.3 Building renovation



High–performance windows

Rapid DHW system

Lobby expanded

External sunshade by BIPV

Efficient HVAC & lighting

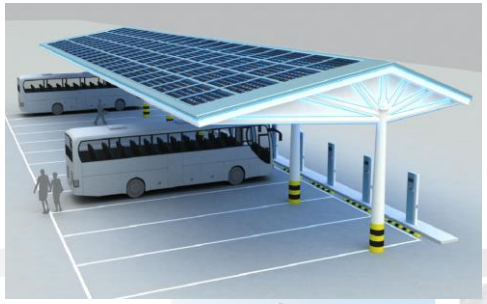
2.4 Multi-scenario BIPV

ZCB: Total carbon emissions, electrical equipment included

Constraint: Special shape & limited roof space for building

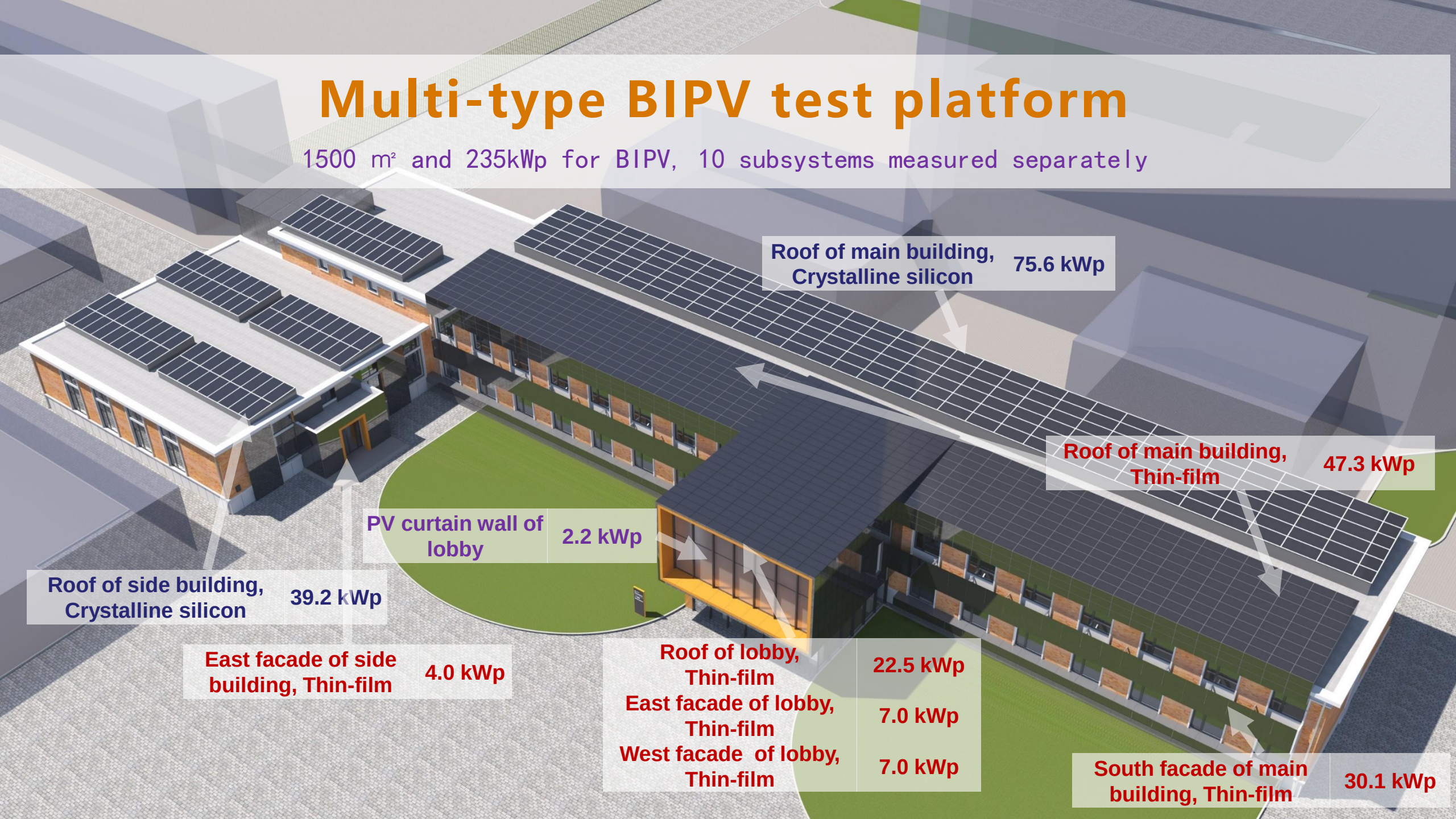
Renovation: More emphasis on energy generation economically

Principle: Applicable, economical, green and beautiful



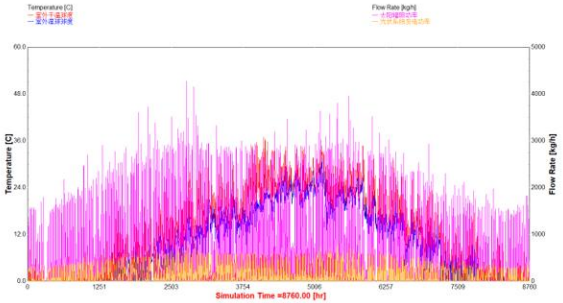
Multi-type BIPV test platform

1500 m² and 235kWp for BIPV, 10 subsystems measured separately

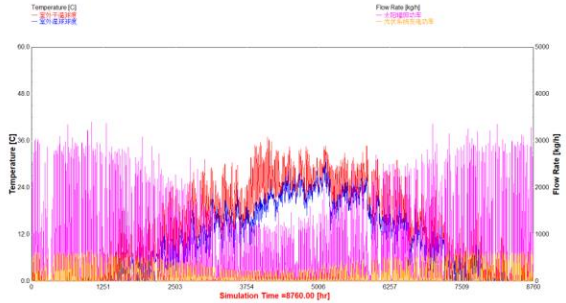


2.4 Multi-scenario BIPV

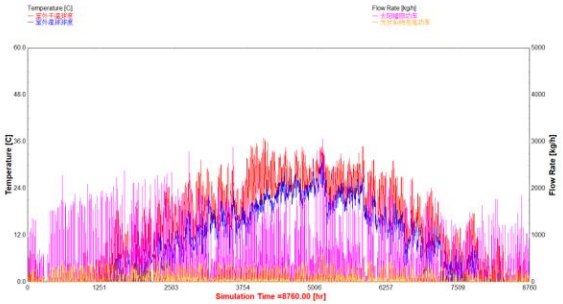
- ✓ Compare the performance of crystalline silicon and thin film PV in different directions and angles.
- ✓ The priority of installation: Roof>South facade>West facade >East facade.
- ✓ For power generation per unit area, crystalline silicon PV WINs.
- ✓ For power generation duration per unit installed power, thin film PV WINs。



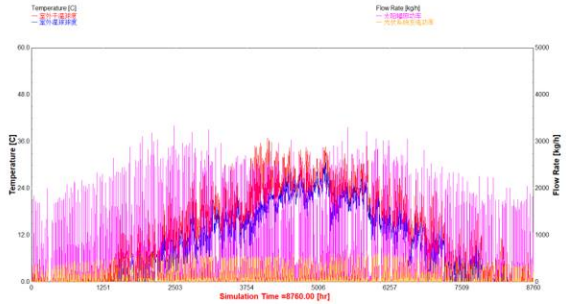
（a）Horizontal



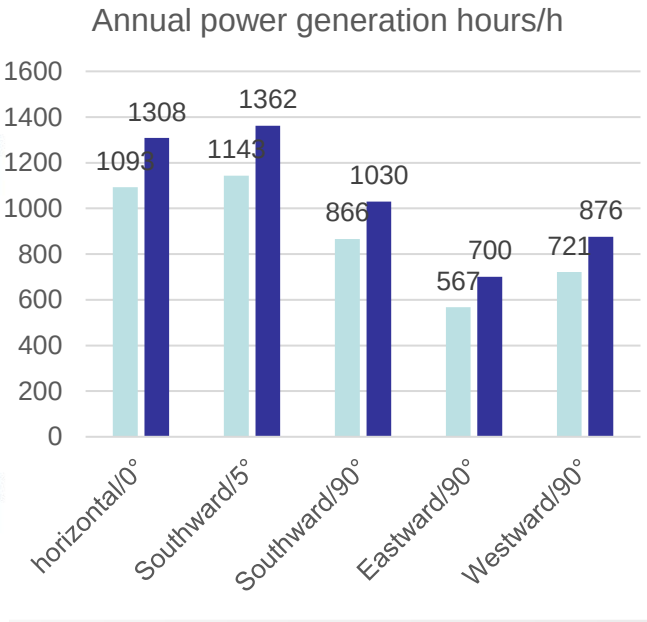
（b）Southward

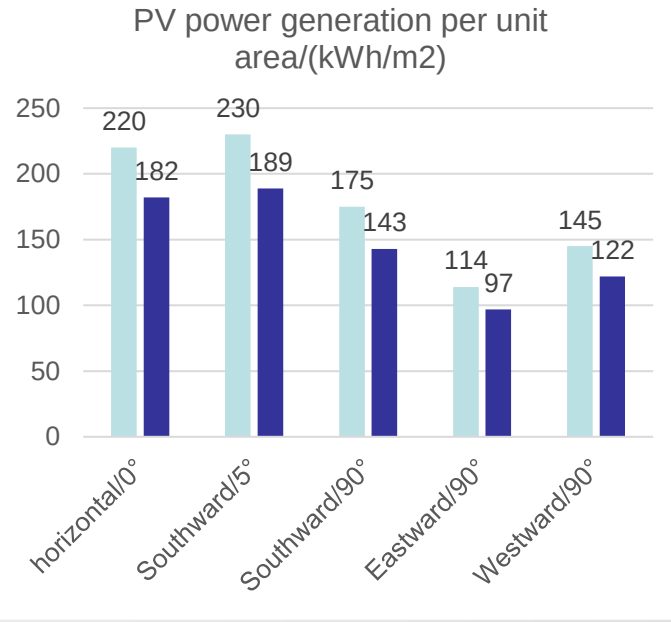


（c）Eastward



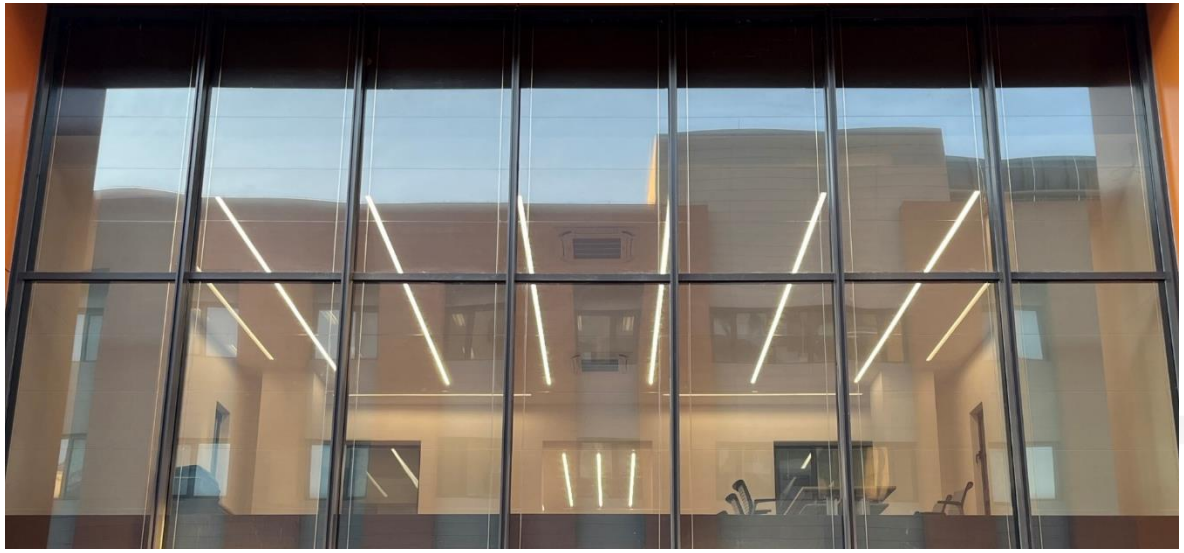
（d）Wastward



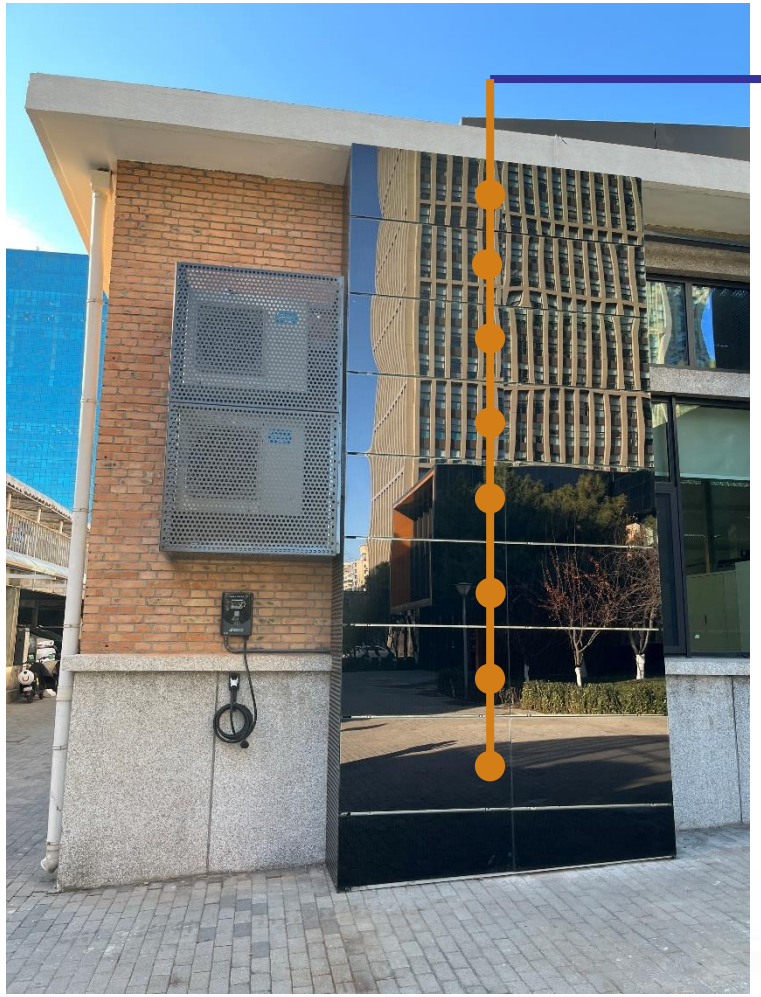


2.5 Highly integrated

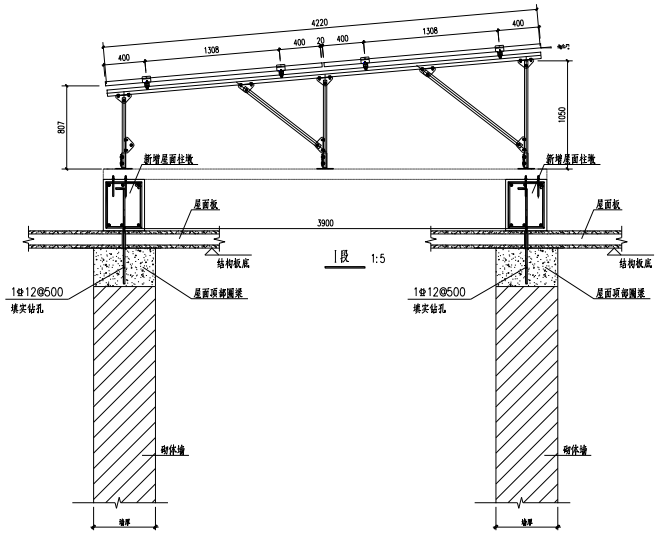
- PV & facade highly integrated based on concrete structure for new extension.
- Transparent PV curtain wall
  - ✓ Area 51.6 ㎡
  - ✓ Installed capacity 2.2 kWp
  - ✓ Light transmission ratio 70%
  - ✓ Annual power generation 1500 kWh
- More integrated, more hidden appearance

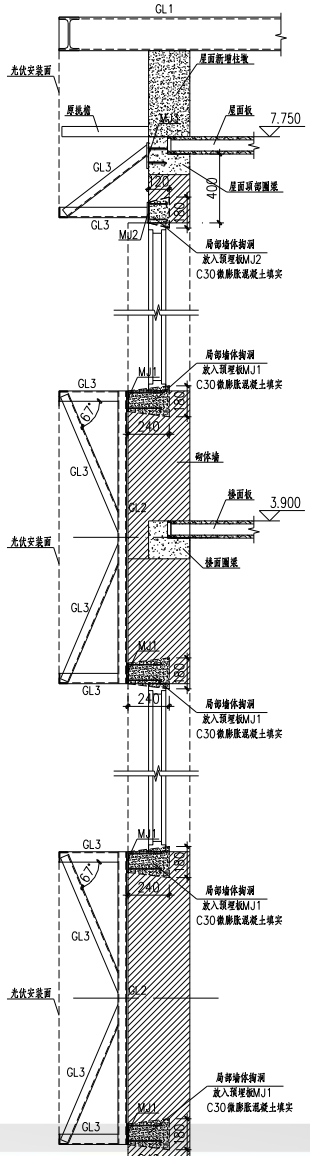


2.6 Safety performance guarantee



- **Thermal Performance test**
  - ✓ Measurement of roof and facade PV modules
  - ✓ Temperature change at different heights
  - ✓ Recommendations for the best installation
  - ✓ Safeguard for building



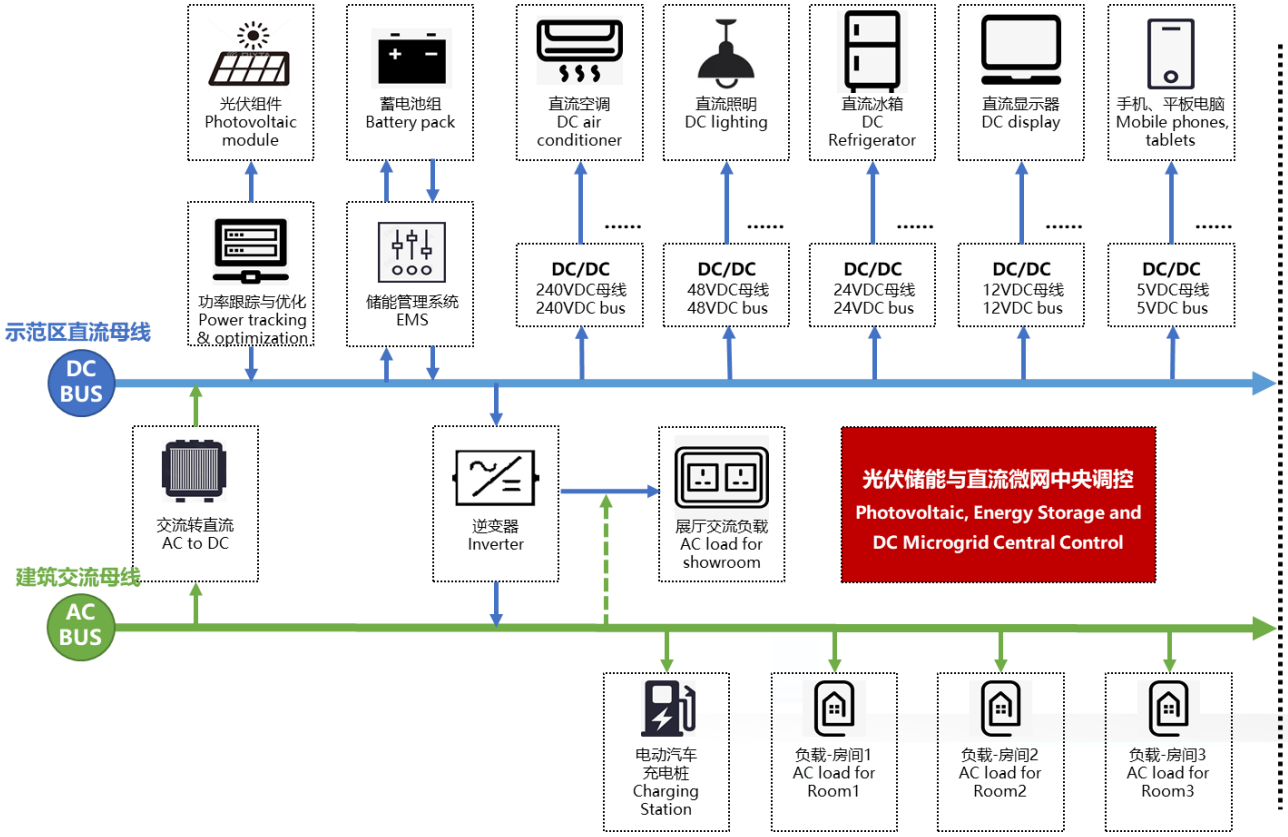


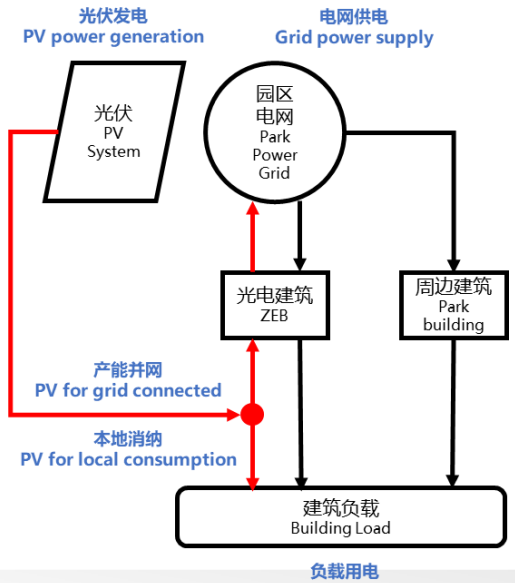
- **Structure design for existing buildings**
  - ✓ Brick-concrete structure
  - ✓ Roof and facade bearing system
  - ✓ Safeguard for structural safety

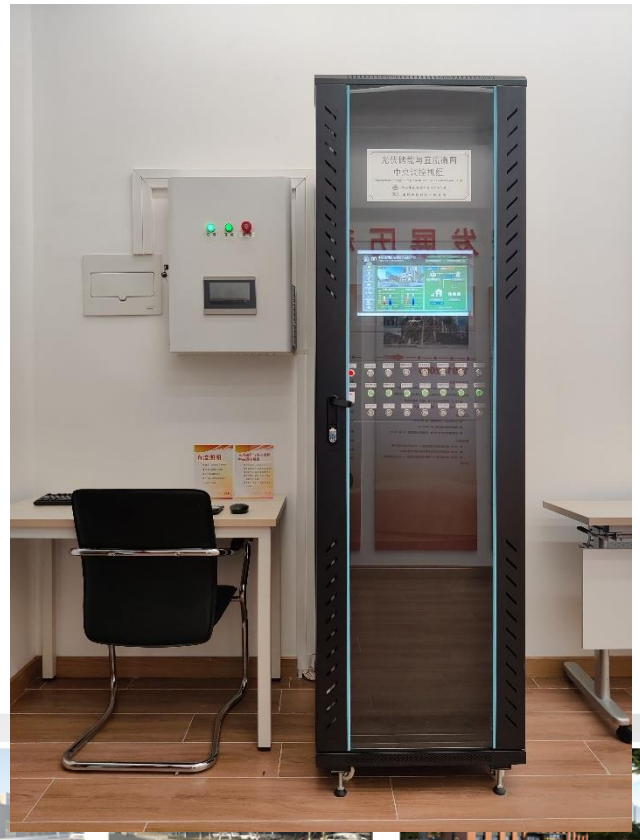


2.7 DC storage and supply

- ✓ Photovoltaic, Energy storage, Direct current, Flexibility (PEDF).
- ✓ Direct utilization and regulation of BIPV.
- ✓ Power generation will be preferentially consumed locally, the rest flexibly supplies for surrounding buildings and electric vehicles, so as to improve the coordination of supply and consumption.

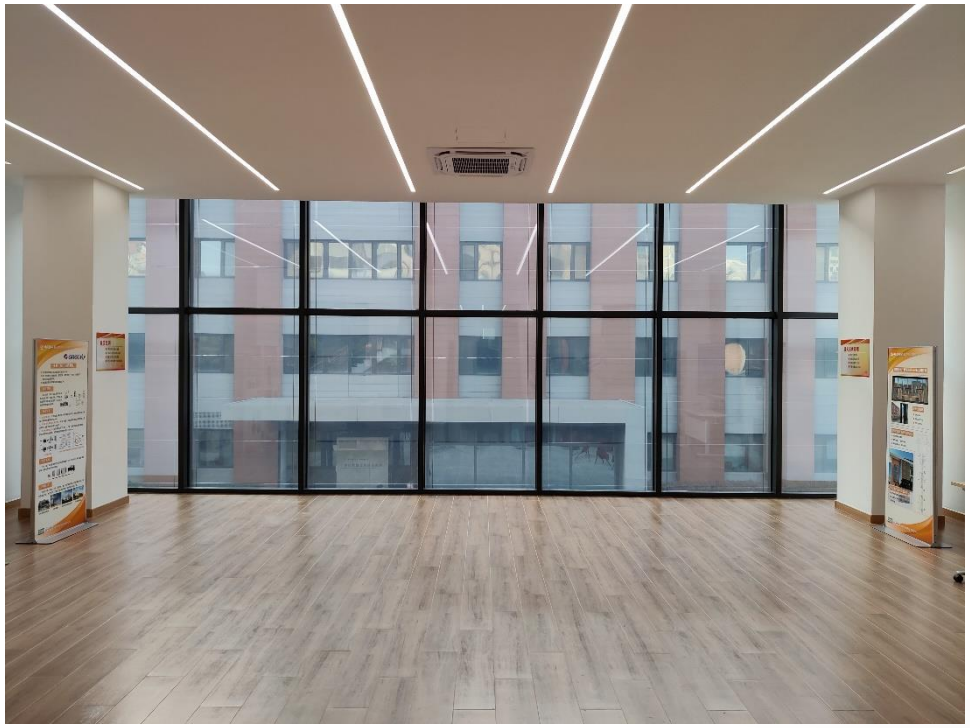


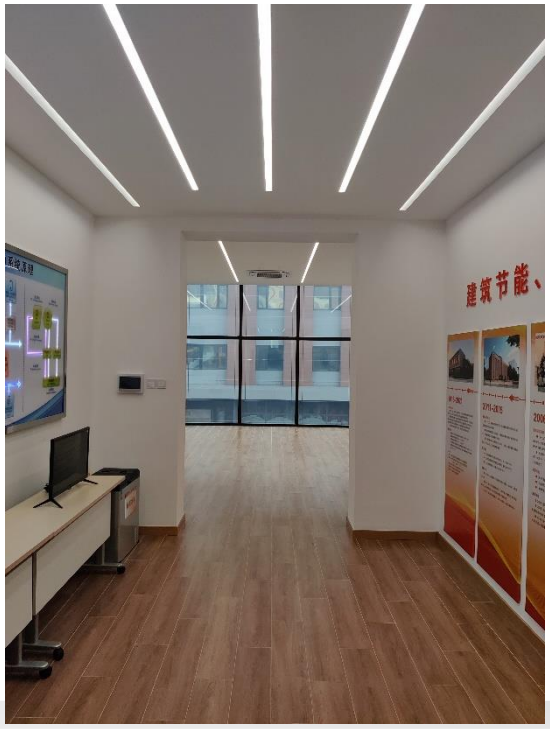




2.7 DC storage and supply

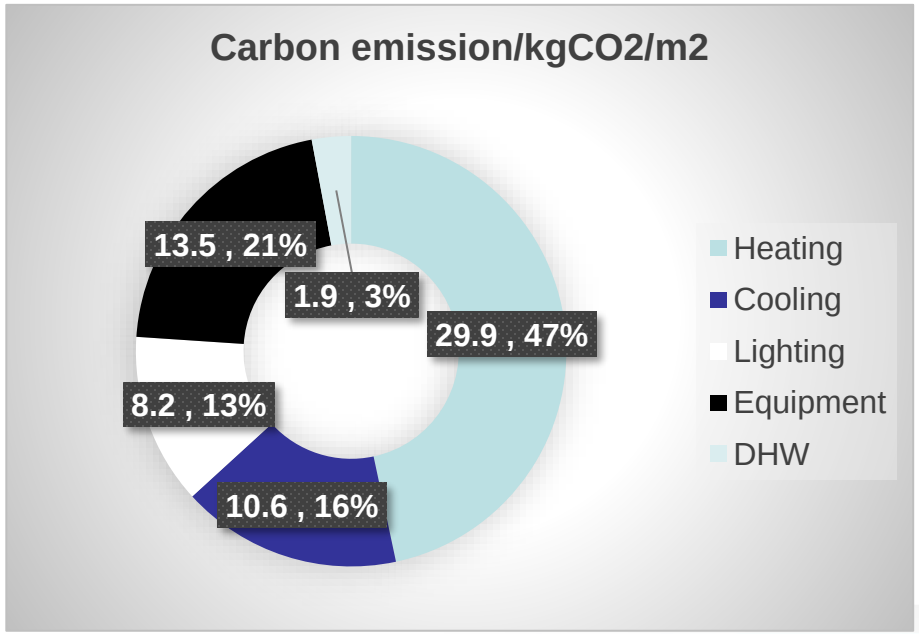
- Optical distributed microgrid with DC and AC double-bus.
- Advanced power storage, PV air conditioning, DC lighting and DC electrical appliances.
- Intelligent control system for power generation, storage, allocation and consumption.

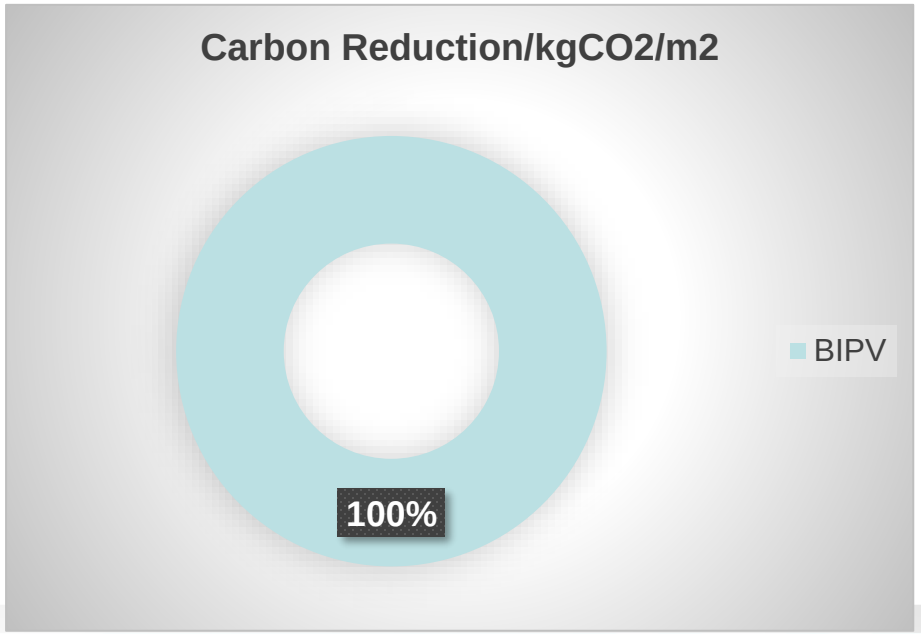




2.8 Effect prediction

- Annual power consumption of heating, cooling, lighting, equipment, DWH is 43.4 kWh/m2. Heating demand reaches 80.9 kWh/m2. Annual CO2 emission will be 64.2 kgCO2/m2.
- The PV system of roof, facade and curtain wall has an annual power generation of 64.6kW/m2, with the reduction of CO2 emission will be 64.6kgCO2/m2.







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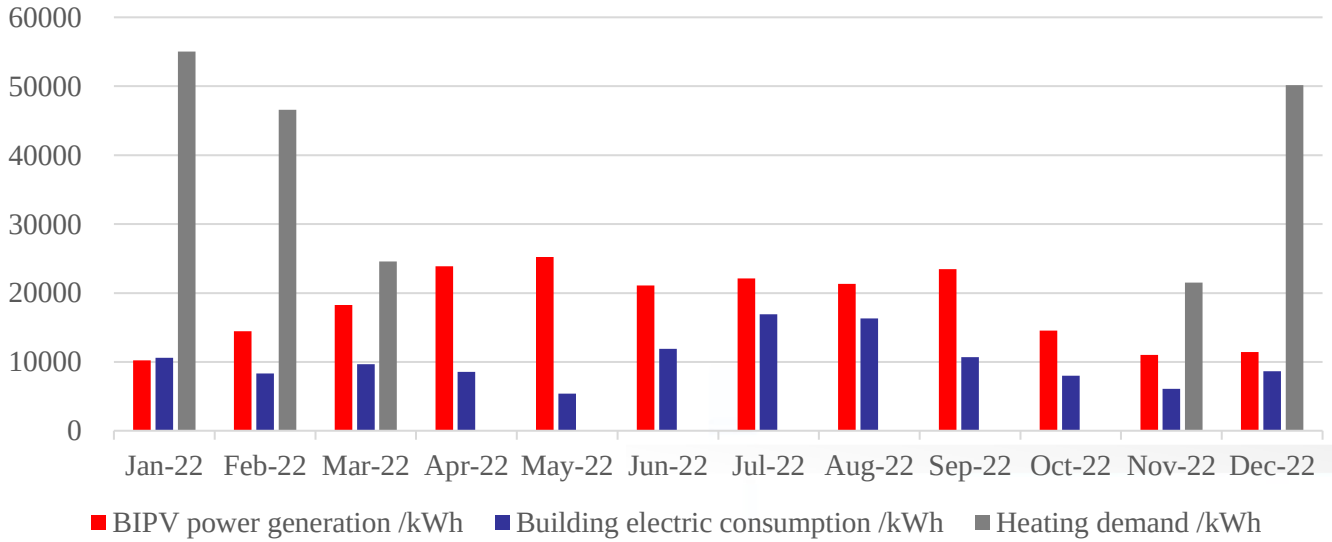
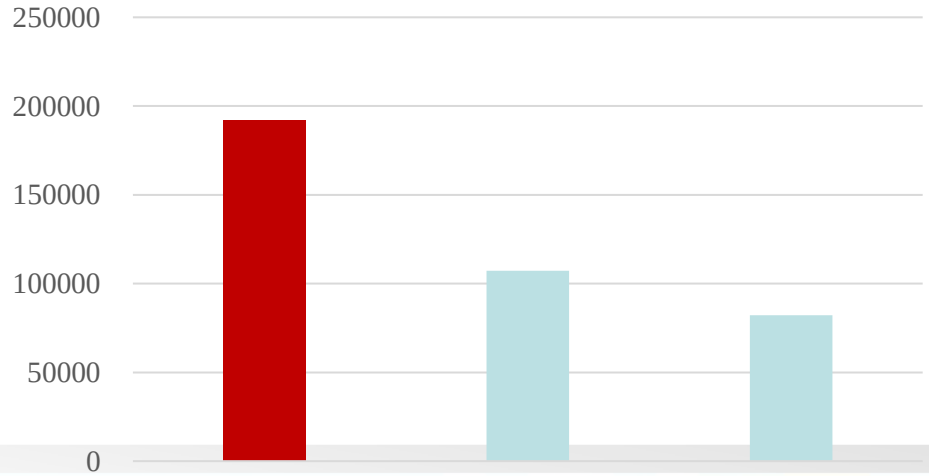
3.1 Overall

System
- The system operates safely, stably and efficiently all year round, achieving the expected effect.

Energy
- BIPV power generation reaches 217MWh(233MWh predicted) , building electric consumption is 121MWh(123MWh predicted) and heating demand is 197MWh(230MWh predicted) .

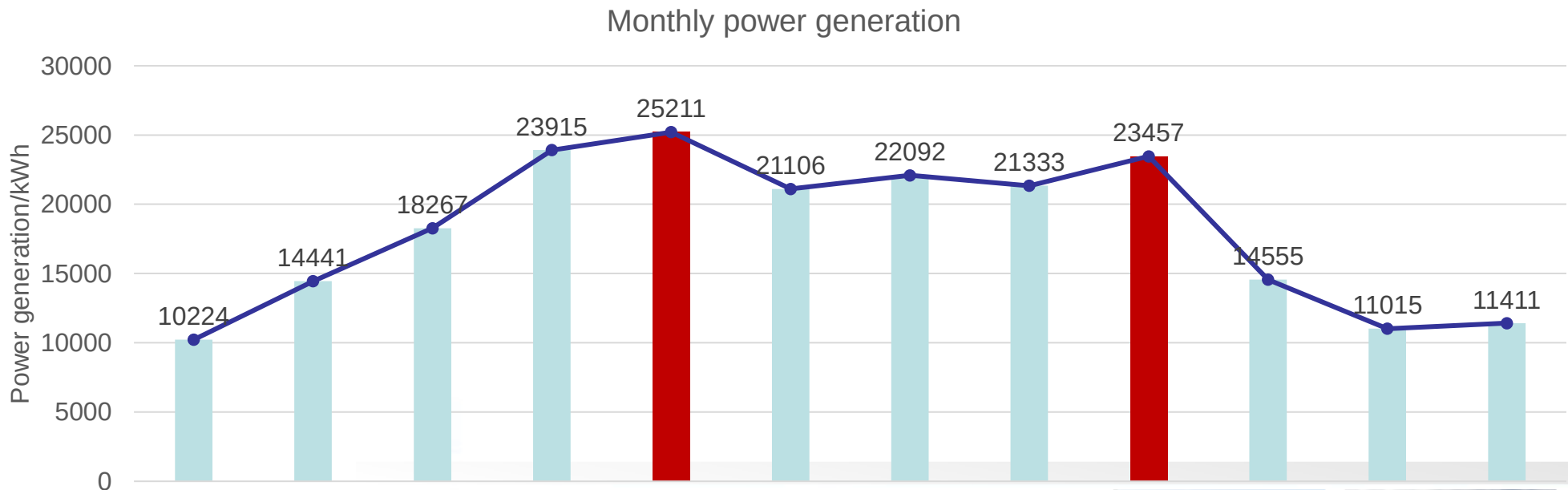
CO2
- The carbon emission is 189tCO2, and the carbon reduction by BIPV accounts to 192tCO2, achieving zero carbon emission in operation.





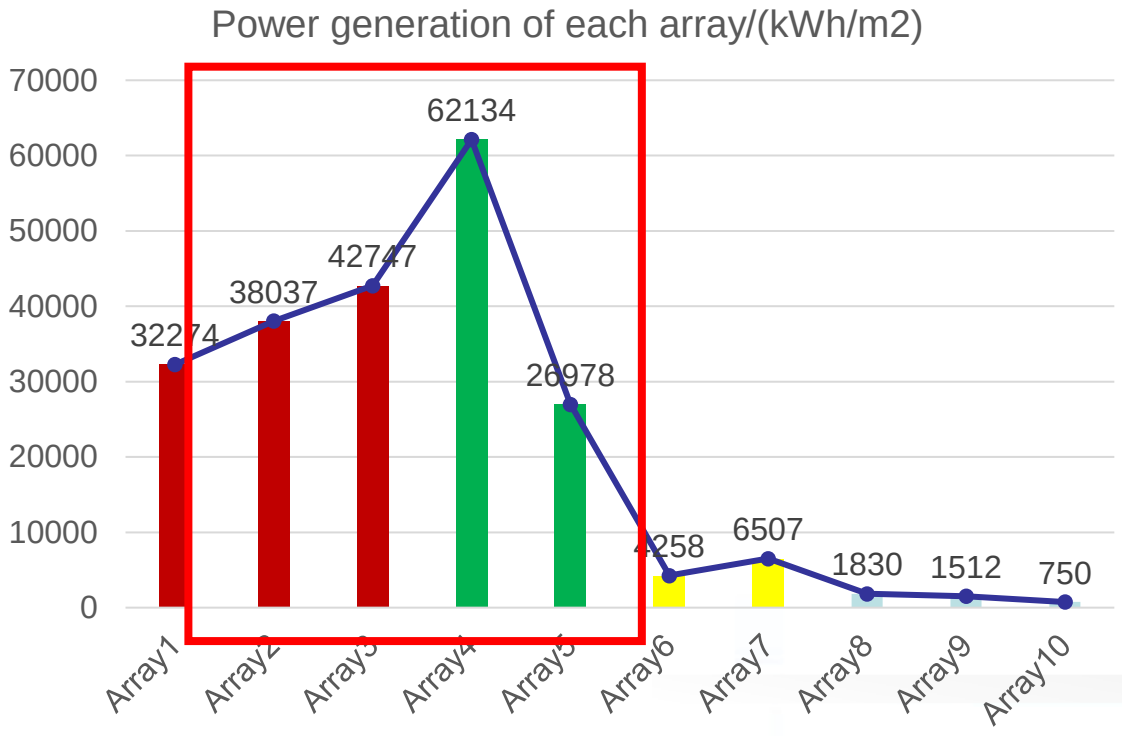
3.2 Monthly variation

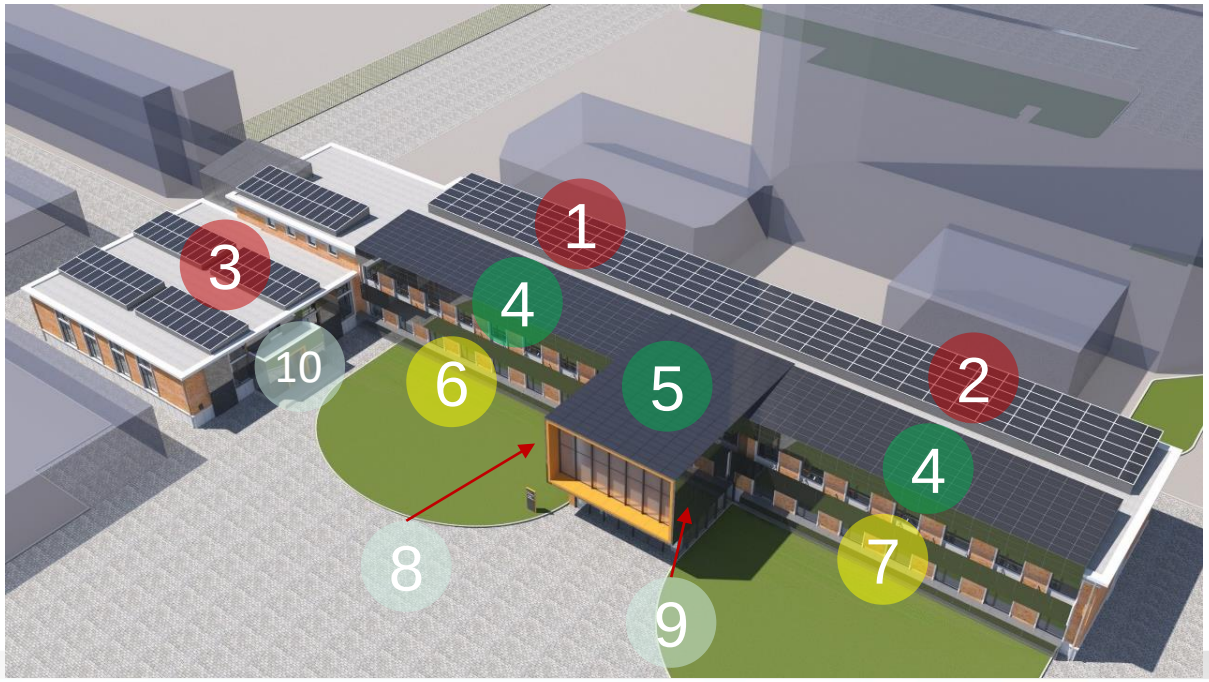
- PV power generation has gradually increased since January, peaked in May, then remained at a high level from June to August with a slight decline.
- September is another peak of power generation, followed by rapid decline in performance in winter.
- Main factors: surface irradiance, rainy season, shelter, ambient temperature, cleaning…



3.3 Generation performance

- Comparison between crystalline silicon and thin film PV.
- ✓ Crystal silicon PV generate more power per unit area, the part of that with less shielding account to 226.4kWh/m2. The power generation of the thin-film PV on the rooftop reaches 184.0 kWh/m2.

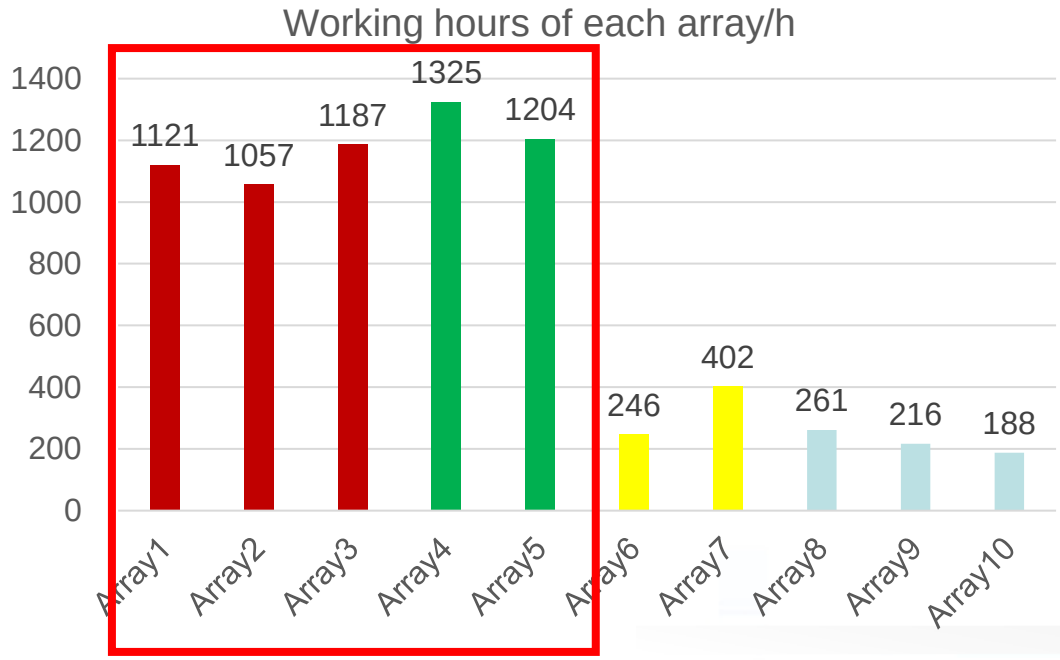


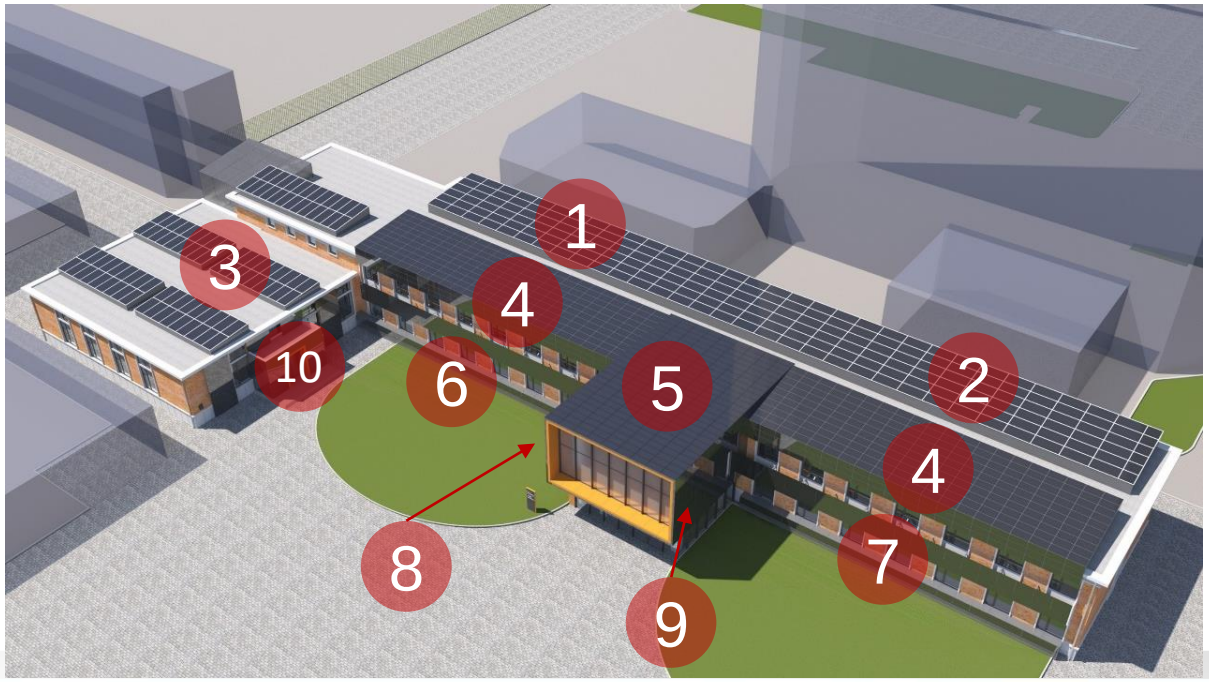




3.4 Working hours

- The PV working hours decrease from west to east shielded by surrounding tower, ranging from 1187h to 1057h.
- The thin-film PV working hours are relatively high, reaching 1325h at the rooftop of main building.
- The performance of the south non-shielded area is 1.5 times longer than that of east and west.
- The west facade has better radiation, with more power generation than the east.







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4 Conclusions

- Zero carbon building requires overall solution of building and energy systems.
- Solar energy is extremely necessary, especially for the reconstructed project. Better integration of buildings is the key to break through the space constraints.
- The balance between energy supply and demand is the key for self-sufficiency rate.
- Surface irradiance, rainy season, shelter, ambient temperature, cleaning, etc. will deeply affect the solar energy utilization, which needs to be carefully considered for design.
- The performance of crystalline silicon and thin film PV in different directions and angles shall be measured and analyzed in detail.

THANK YOU!

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