中国建筑科学研究院有限公司
China Academy of Building Research

Feasibility Study on Application of Air Collector, Air Source Heat Pump and Energy Storage Compound System in Passive Ultra-low Energy Building in Severe Cold Area

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China Academy of Building Research

contents

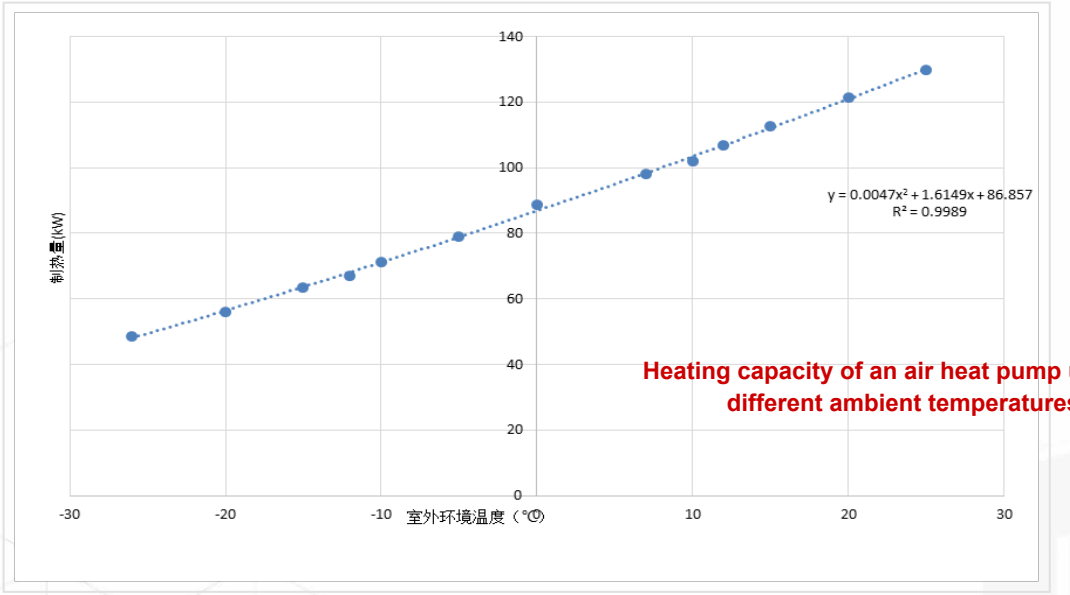
Energy shortage

Environmental pollution

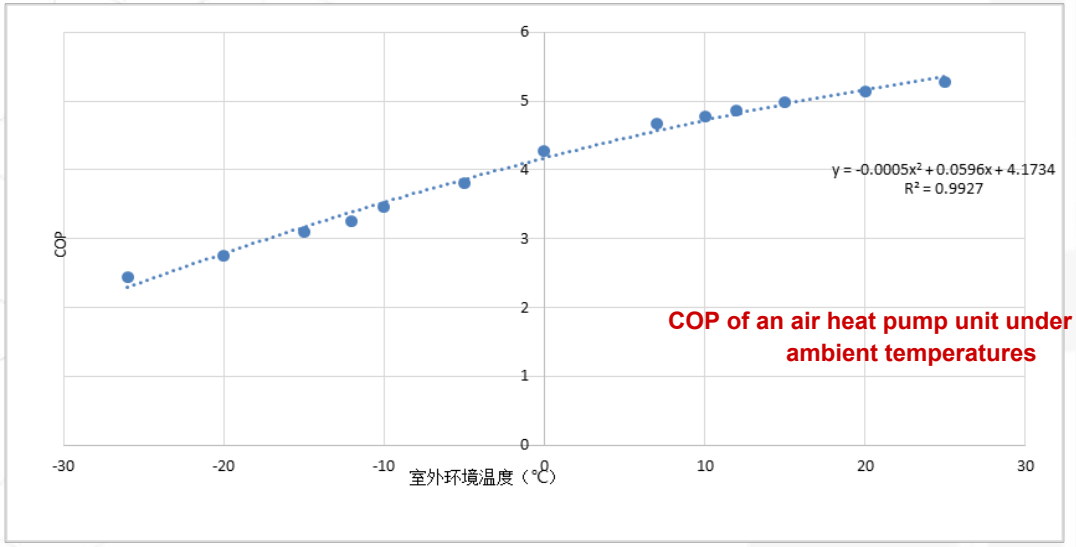
Increase awareness of energy conservation and environmental protection

Energy technology development

Air source heat pump



Heating capacity of an air heat pump unit under different ambient temperatures



COP of an air heat pump unit under different ambient temperatures

From the above figure, it can be seen that comparing the outdoor temperature of -26℃ working conditions and outdoor temperature of 7℃ standard conditions, the unit heat attenuation by 50%, COP decay 47.8%.

the heating capacity under the unit design conditions

$$q_h = Q_h / (K_2 \cdot K_3)$$

K_2 is the dry bulb temperature correction coefficient calculated for outdoor air conditioning in winter

Outside temperature ℃	-15	-10	-8	-4	-2	0	2	4	6	7	8	10	12	18
K_2	0.6232	0.689	0.711	0.763	0.798	0.821	0.880	0.935	0.975	1	1.03	1.088	1.062	1.337

Increase heat pump evaporator temperature

- **Extend the normal working hours of the heat pump**
- **Reduce the number of defrosting**
- **Effectively improve the heating performance of the unit**

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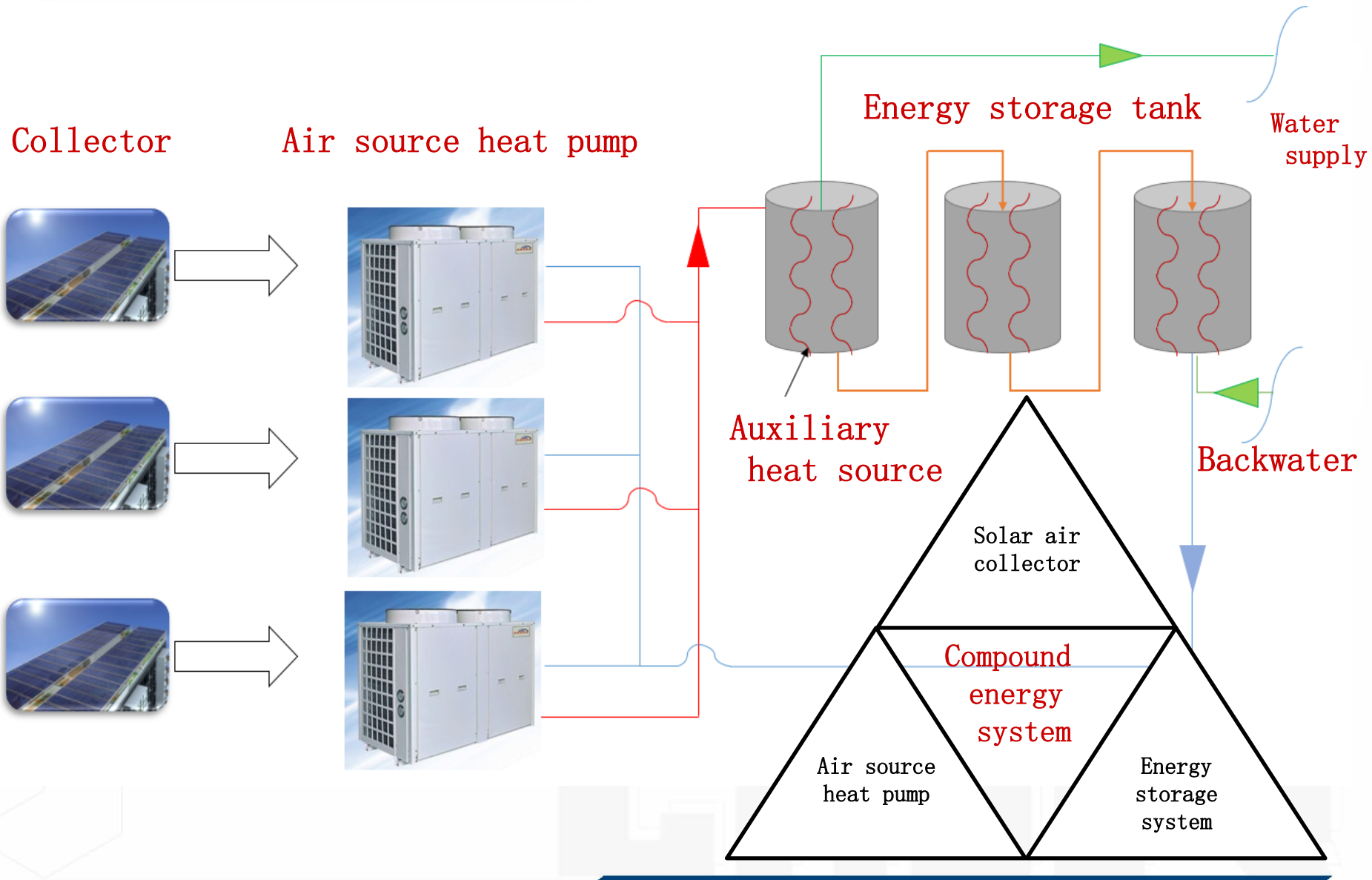
Collector
Air source heat pump
Energy storage tank
Water supply
Auxiliary heat source
Backwater
Solar air collector
Compound energy system
Air source heat pump
Energy storage system

Daytime：**A solar air collector is used to heat the air to a suitable temperature of the air source heat pump,and then the air source heat pump is turned on to obtain hot water, and part of the hot water is used for heating, the other part of the heat energy is stored in the hot water tank.**

Dighttime：**The hot water in the hot water tank is supplied to the user when the heat is applied.**

Auxiliary heat sources：**Due to the instability of solar energy resources, certain auxiliary heat sources (electric heating or municipal heating) need to be configured.**

The heat pump inlet air is preheated by the solar air collector, which improves the energy efficiency of the heat pump system

- **The system solves the problem of frequent defrosting when the conventional air source heat pump operates in the low temperature working condition, and improves the reliability and economy of the system**
- **The area of use of air source heat pumps has been expanded**
- **The air collector uses a direct current system, not a recirculating air heating system, and the temperature difference between the inside and outside of the collector is small and the application efficiency is high**

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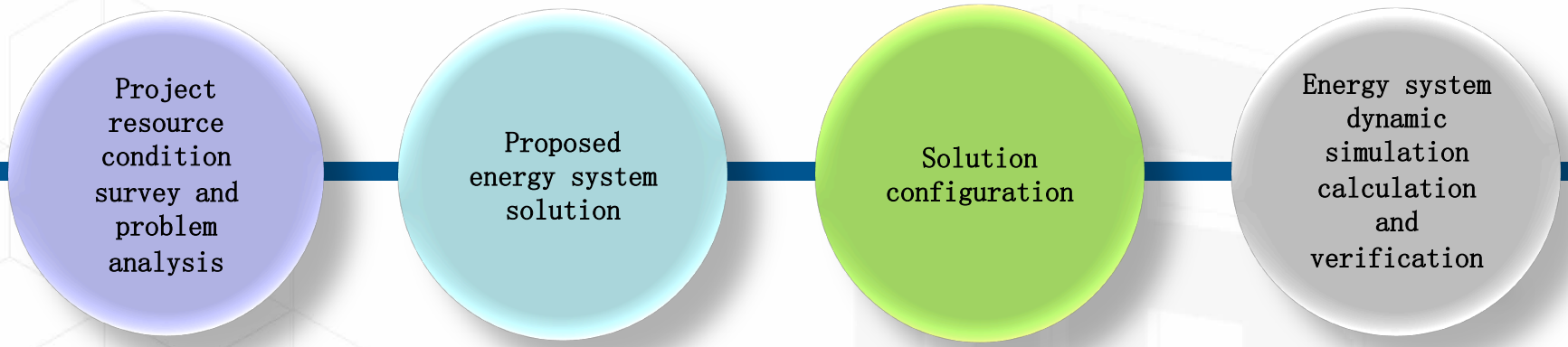
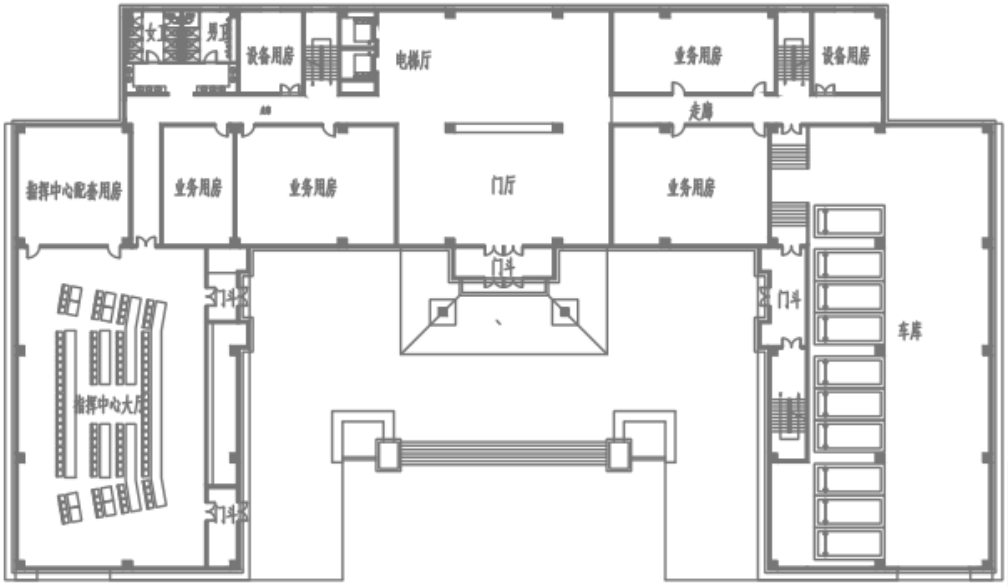
Application route of technology in actual cases



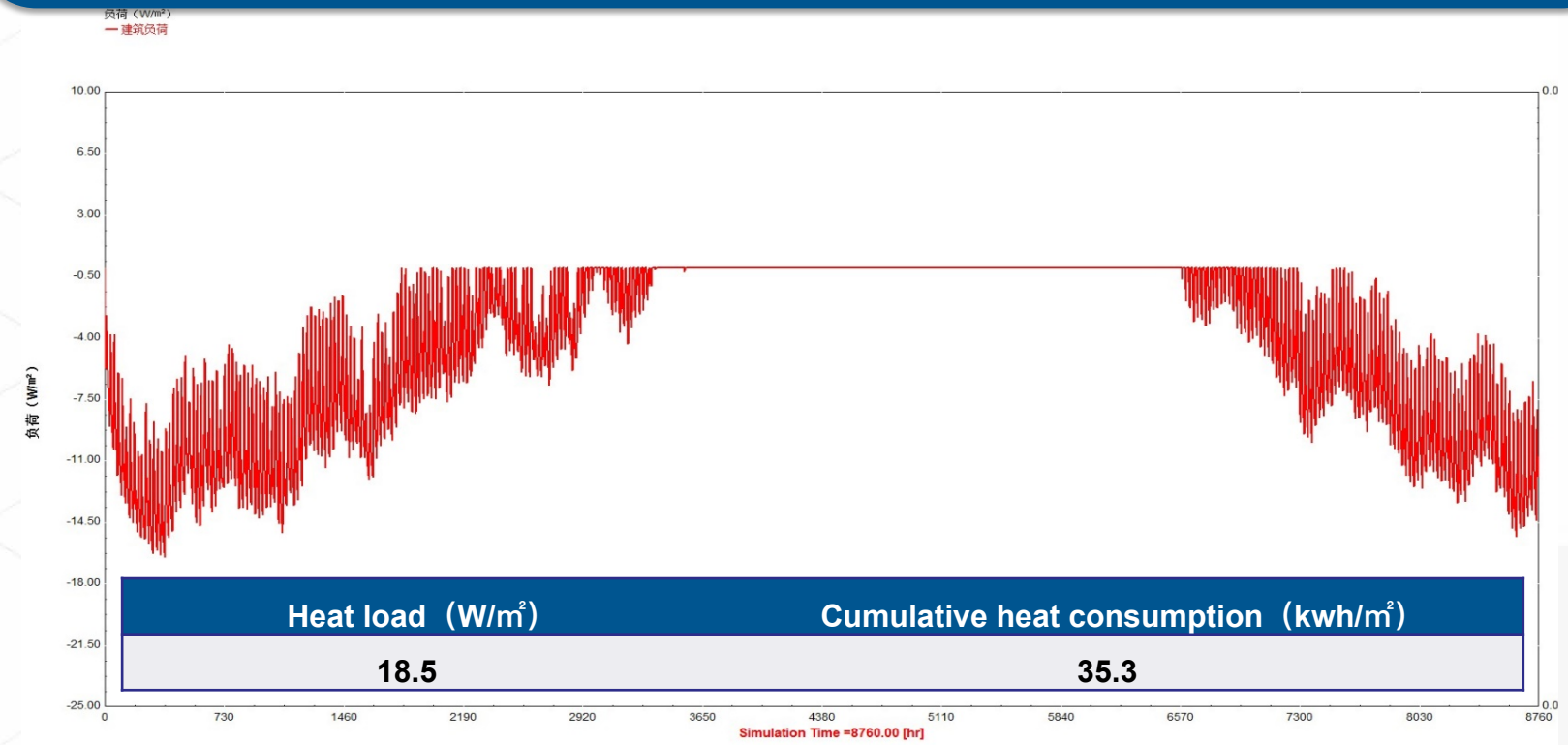


The project is located in Hailaer, which is an extremely cold area. The outdoor heating calculation temperature is -35℃, the heating period is 9 months, and the related resources are scarce. Passive ultra-low energy buildings are difficult to implement. The heating area of this project is 7000m^2.

	Parameter settings
Roofing heat transfer coefficient（W/(m^2·K)）	0.10
Wall heat transfer coefficient（W/(m^2·K)）	0.15
Outside window K value（W/(m^2·K)）	0.8
Outside window g value	0.4
Personnel density (person/m^2)	0.1
Personnel fresh air volume（m^3/person）	30
Heat recovery efficiency	75%
Heat recovery	90%

Enter the analog computing platform:

- Hailar Regional Meteorological Document
- TRNSYS architectural model
- Parameter setting for building personnel, temperature and humidity, equipment, HVAC, schedule, etc.



Heat load（W/m²）	Cumulative heat consumption（kwh/m²）
18.5	35.3

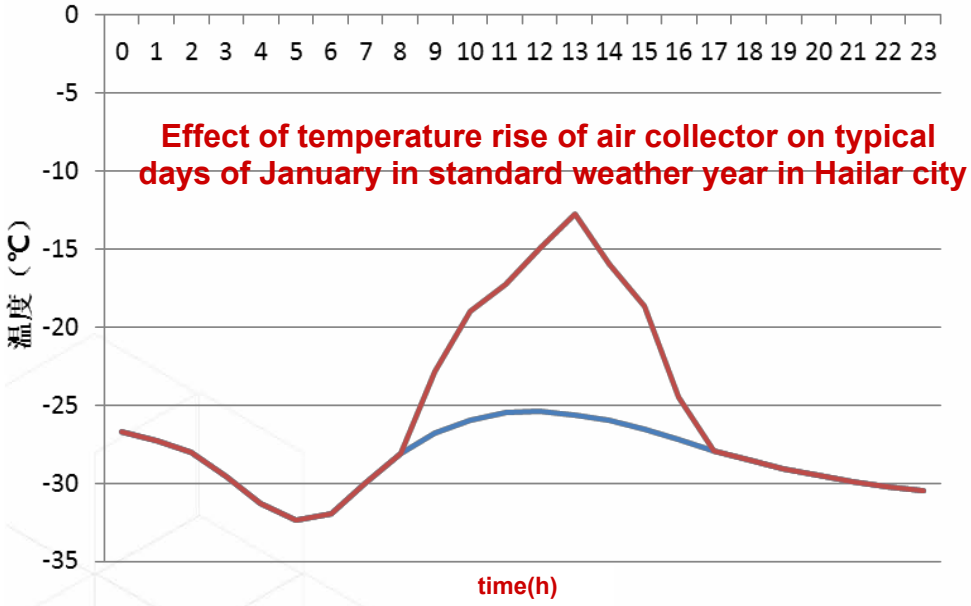
During the analysis of the system plan of this project, due to the poor regional resource conditions, the selection is less and the implementation is more difficult:

1) The extremely low outdoor temperature conditions make it difficult to implement the air source heat pump alone. At present, the domestic air temperature heat pump generally operates at an outdoor temperature of -25℃ and has a low energy efficiency value (about 1.0).

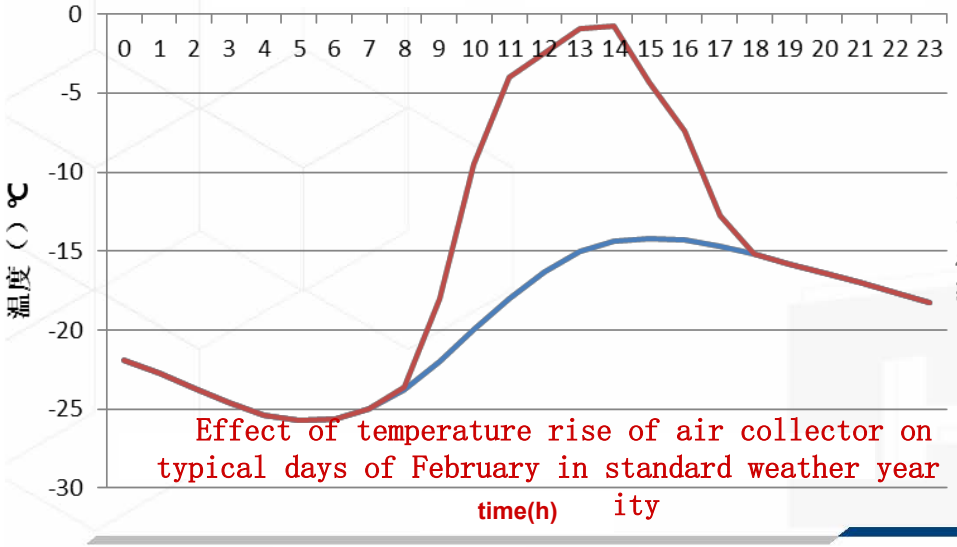
2) The initial temperature of the soil is low (annual average temperature is -1.0℃). It is difficult to implement the underground pipe alone, and the energy efficiency is low. This project has only winter heating load, no air conditioning load in summer, and the cold and heat balance is difficult to meet. The area is located in the Daxinganling mountain range, and the cost of drilling holes in underground pipes is high.

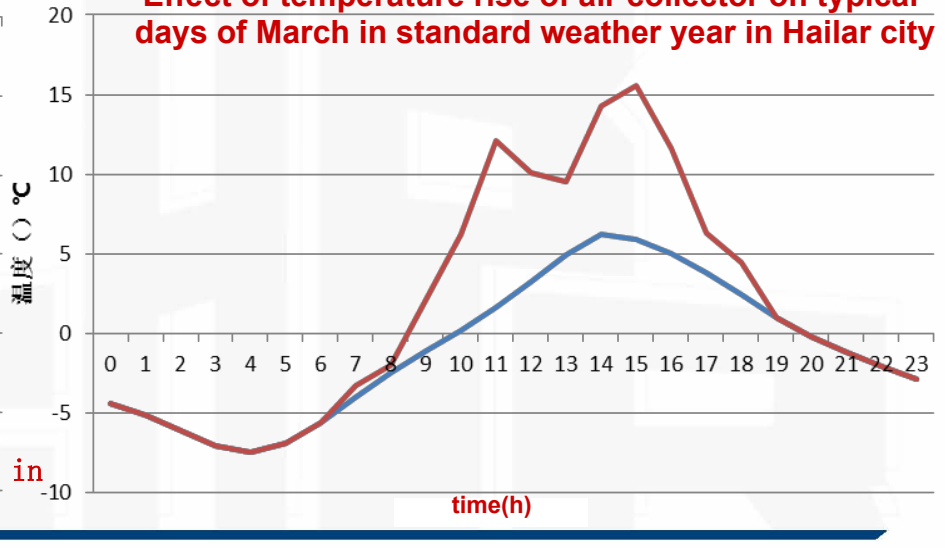
3) The use of solar water heaters in cold regions needs to solve problems such as leakage prevention and anti-freezing. When the temperature is low, the efficiency of solar water heaters is low. The heating cycle of this project is too long, and the seasonal heat storage time available in summer is short.

4) The month with the weakest solar radiation is also the month with the lowest temperature, and it is also the season with the largest heating load for buildings, which brings difficulties to solar energy applications.

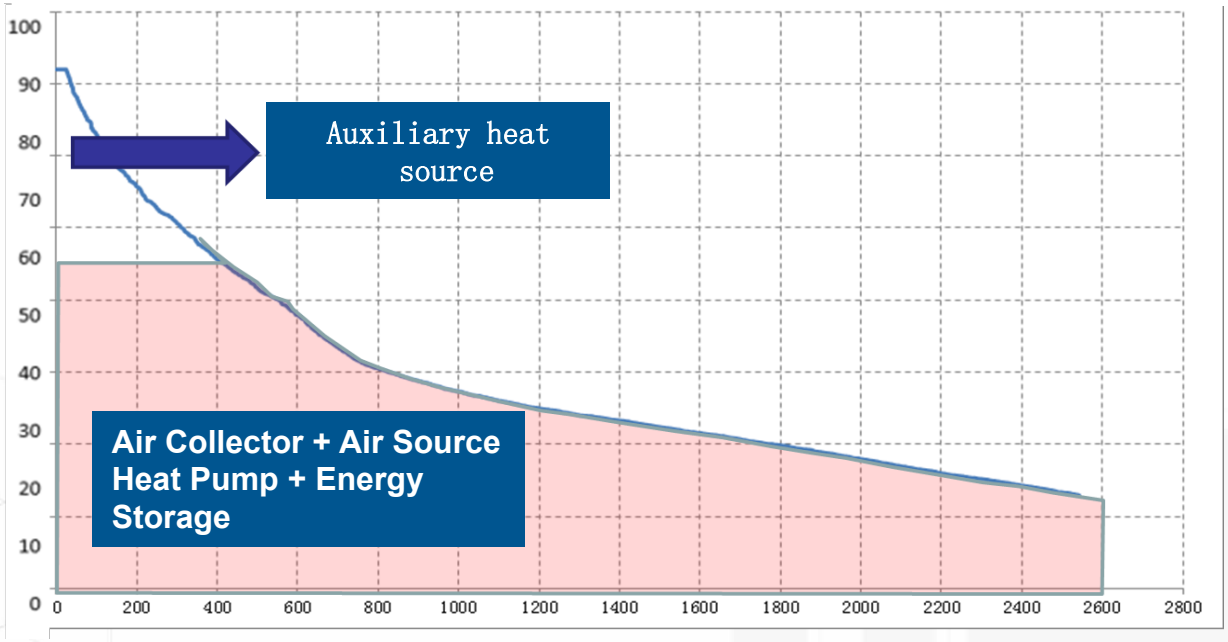


- During the winter, the solar air collector heats the air above -25℃, and the air source heat pump can operate normally.
- Floor heating system at the end of the building, operating temperature 36/28℃.

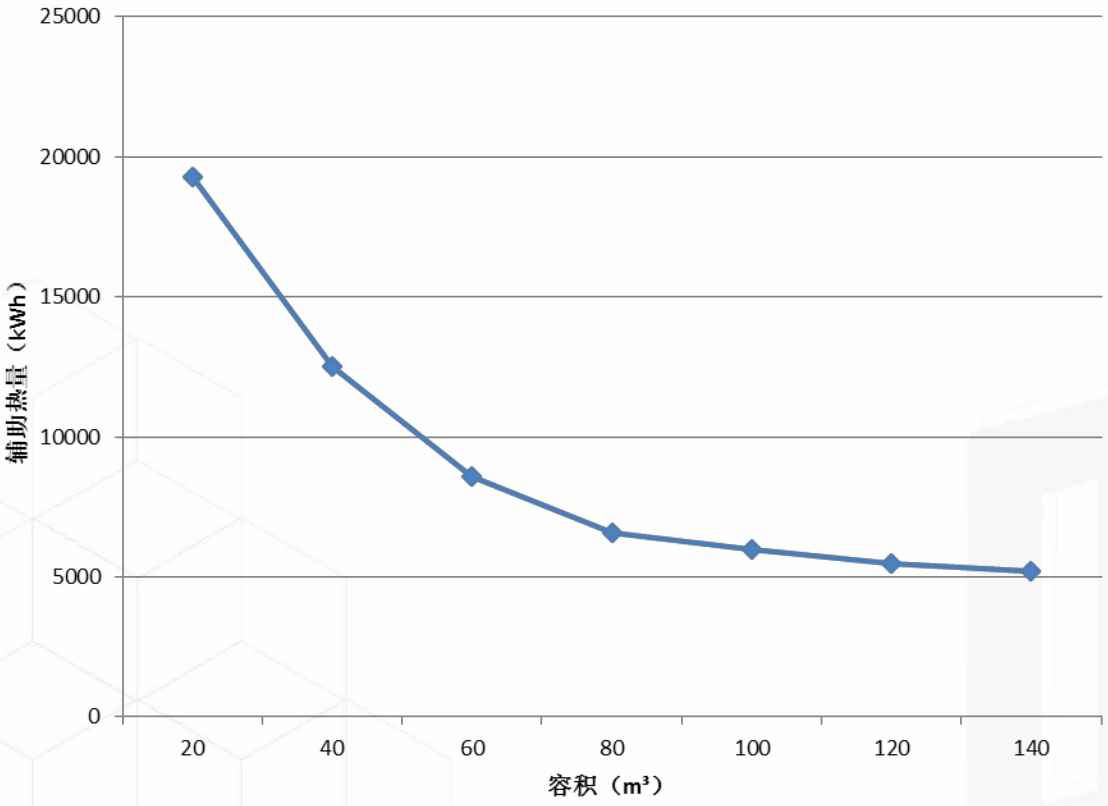




Energy system configuration principle



- The solar collector is arranged at a height of 25°, and the collector area is about 1400 m^2. The air volume per square meter corresponds to 100m^3/h, and the equipment selects three air source heat pumps with rated heat capacity of 127KW and rated air volume of 47000m^3/h. Since the end of the building is floor heating, the air source heat pump load side working condition is 36/28 ° C, and the lower end grade requirements can ensure the efficient operation of the equipment. The unit can run smoothly above -25℃.
- During the winter, the solar air collector heats the air to above -25℃, the air source heat pump is turned on, the hot water is prepared, and the hot water is stored in the hot water tank. The three storage tanks are connected in series to ensure that the temperature of the first tank is always the highest and the third tank is always the lowest.
- The electric auxiliary heat source is set in the compound system, and the proportion of the solar energy and air source heat pump in the heat load should be fully ensured during the operation, and the auxiliary heat source should be opened as little as possible.



Auxiliary heat source of system under different tank volumes

In this project, the energy storage tank is set to 60m^3, three in series to ensure that the temperature of the first storage tank is always the highest, and the third storage tank is always the lowest, making full use of energy storage.

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TRNSYS Energy System Simulation Computing Platform

TRNSYS 17

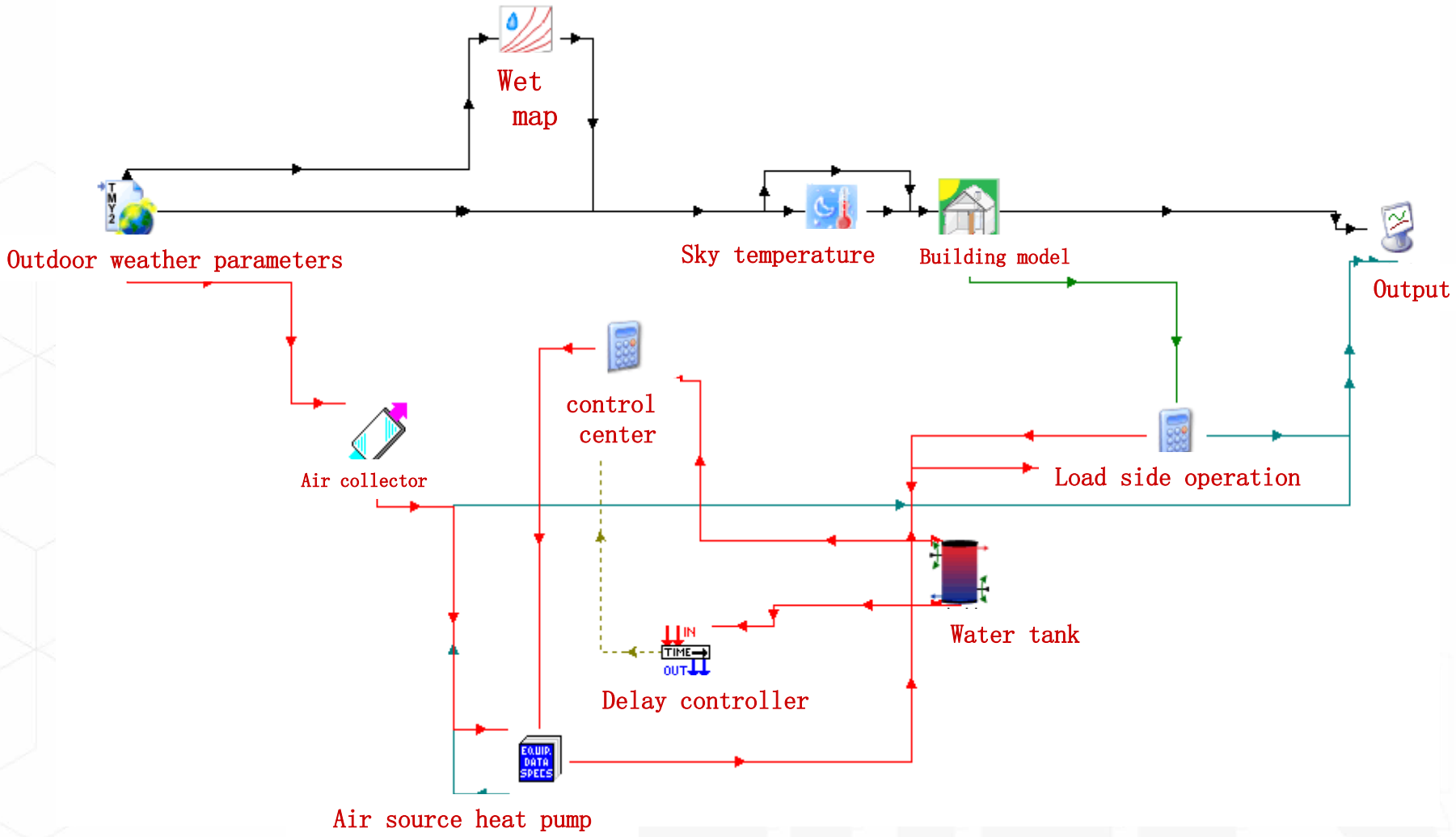
Running strategy:

Heat pump system → Auxiliary cold heat source

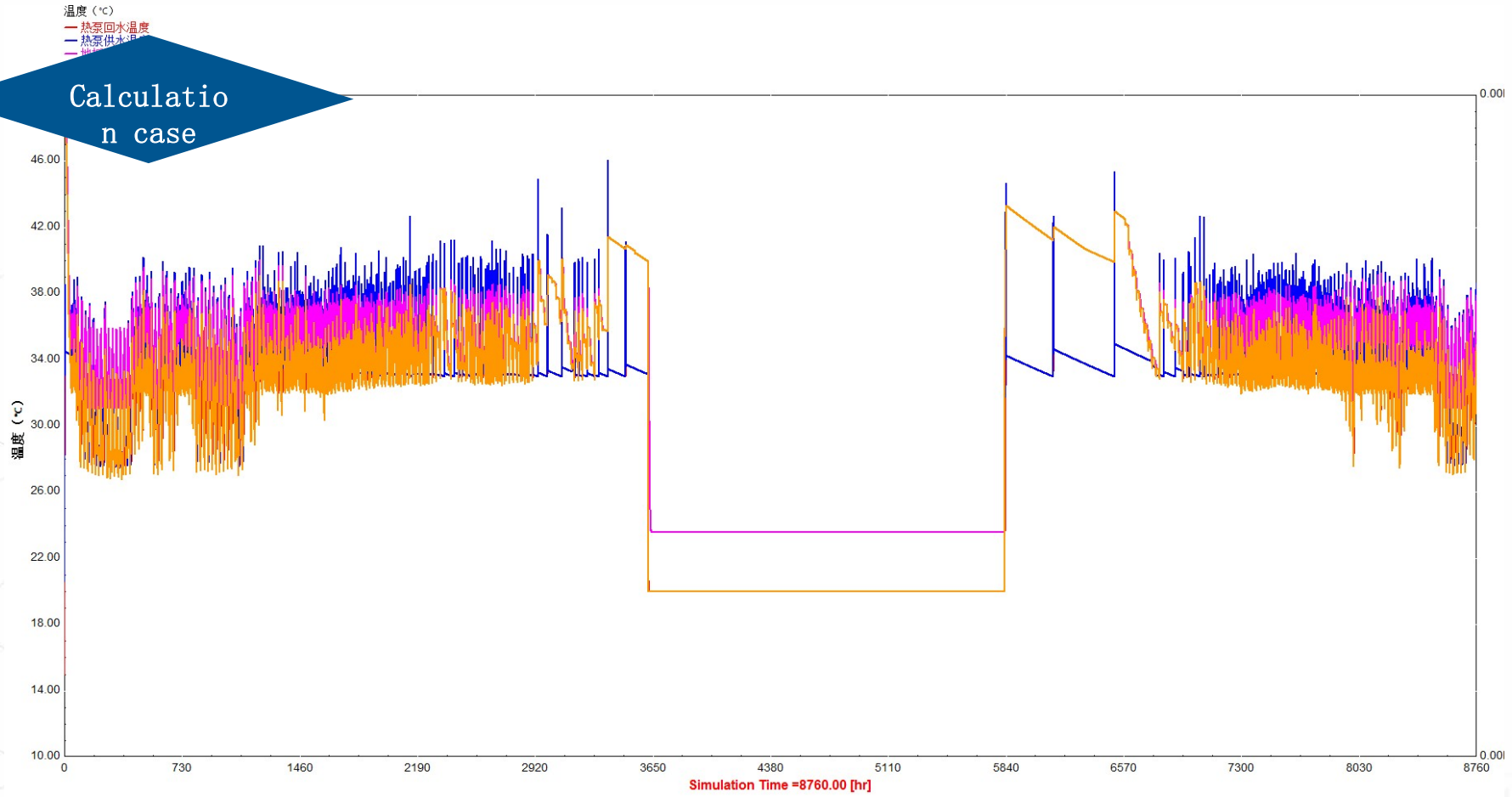
Application mode:

➢ Heat pump bears the main load

The annual energy-saving simulation platform of the energy system of the project

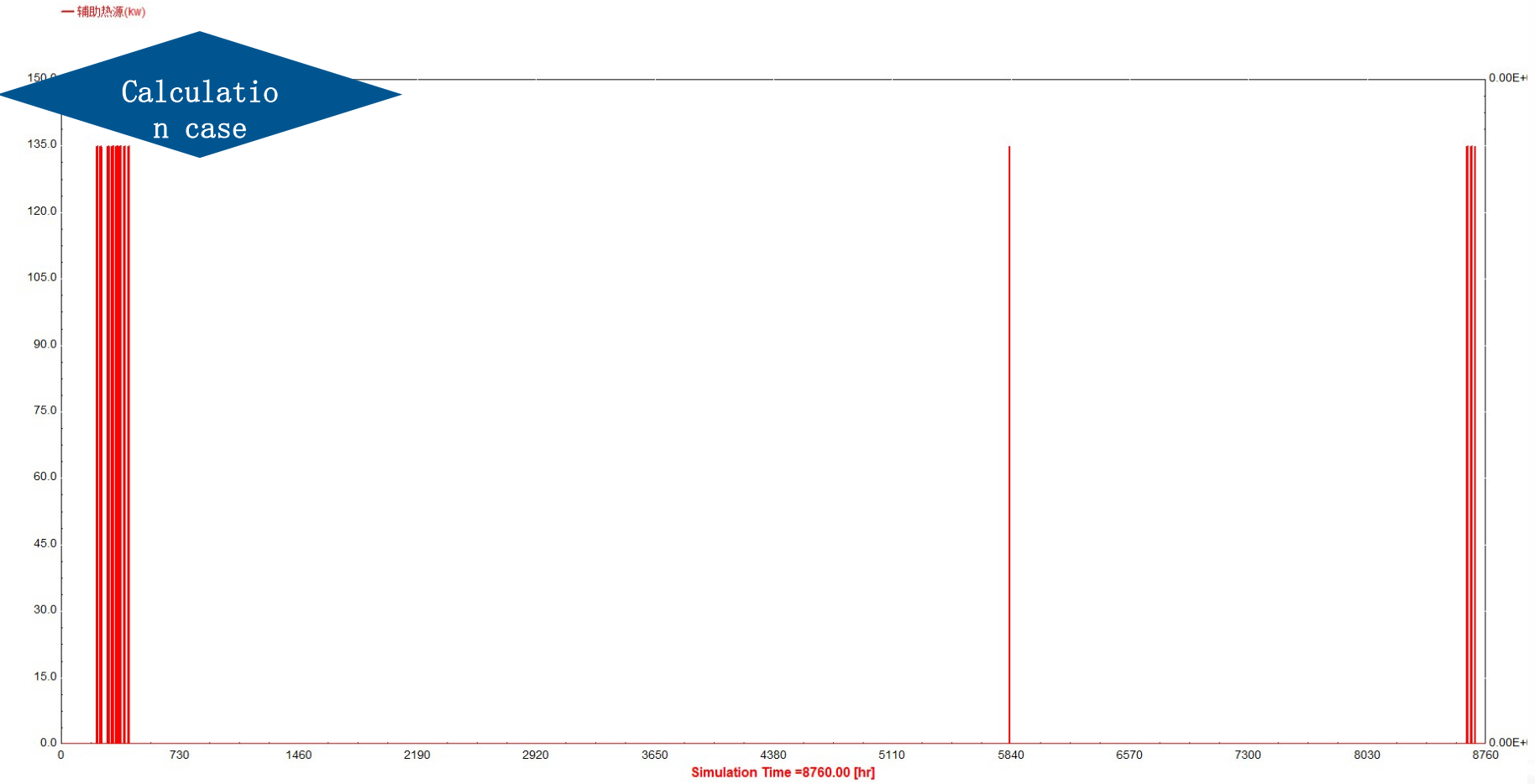


Calculation case

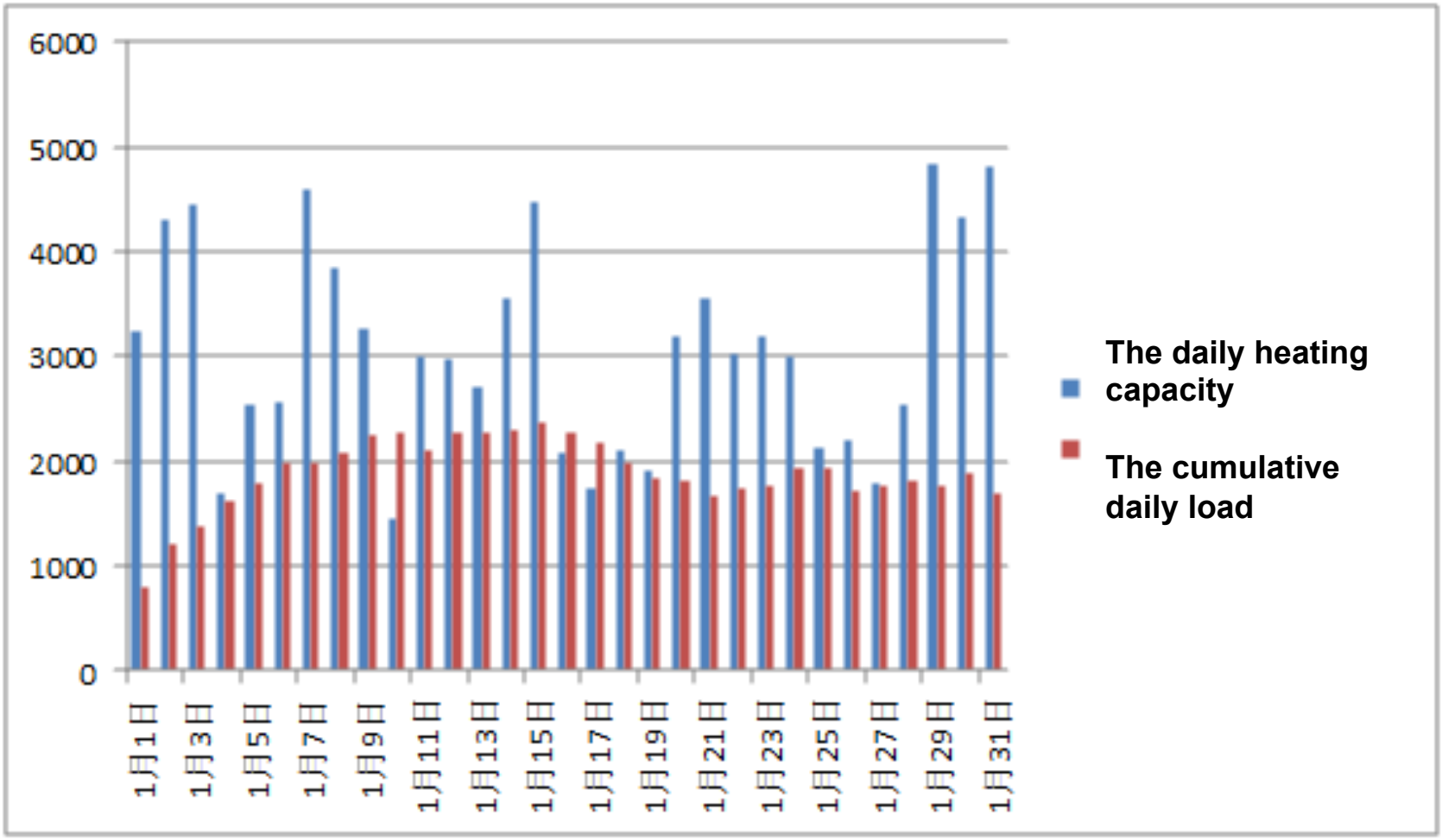


The project's whole year hourly energy system temperature conditions

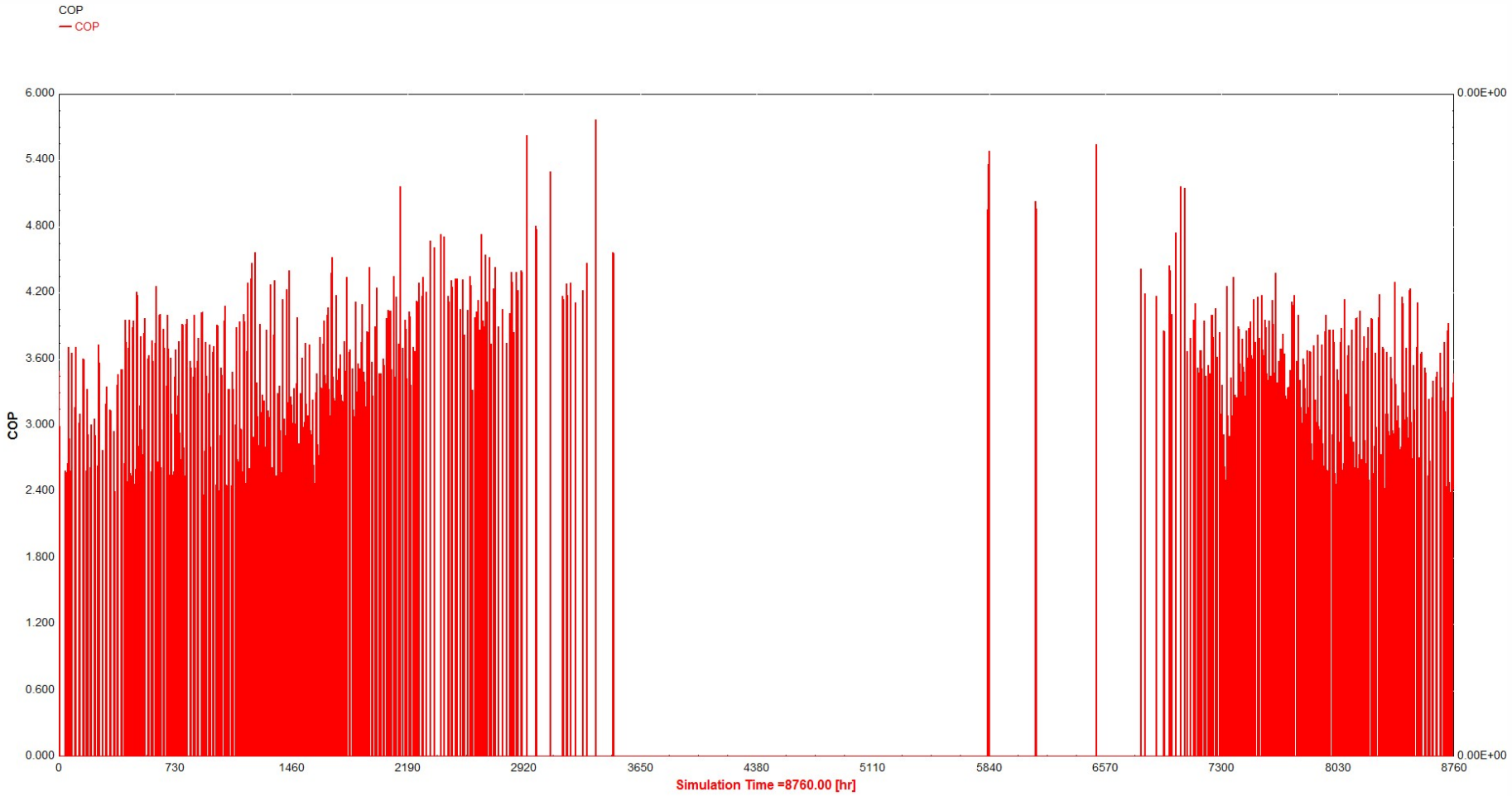
Calculation case



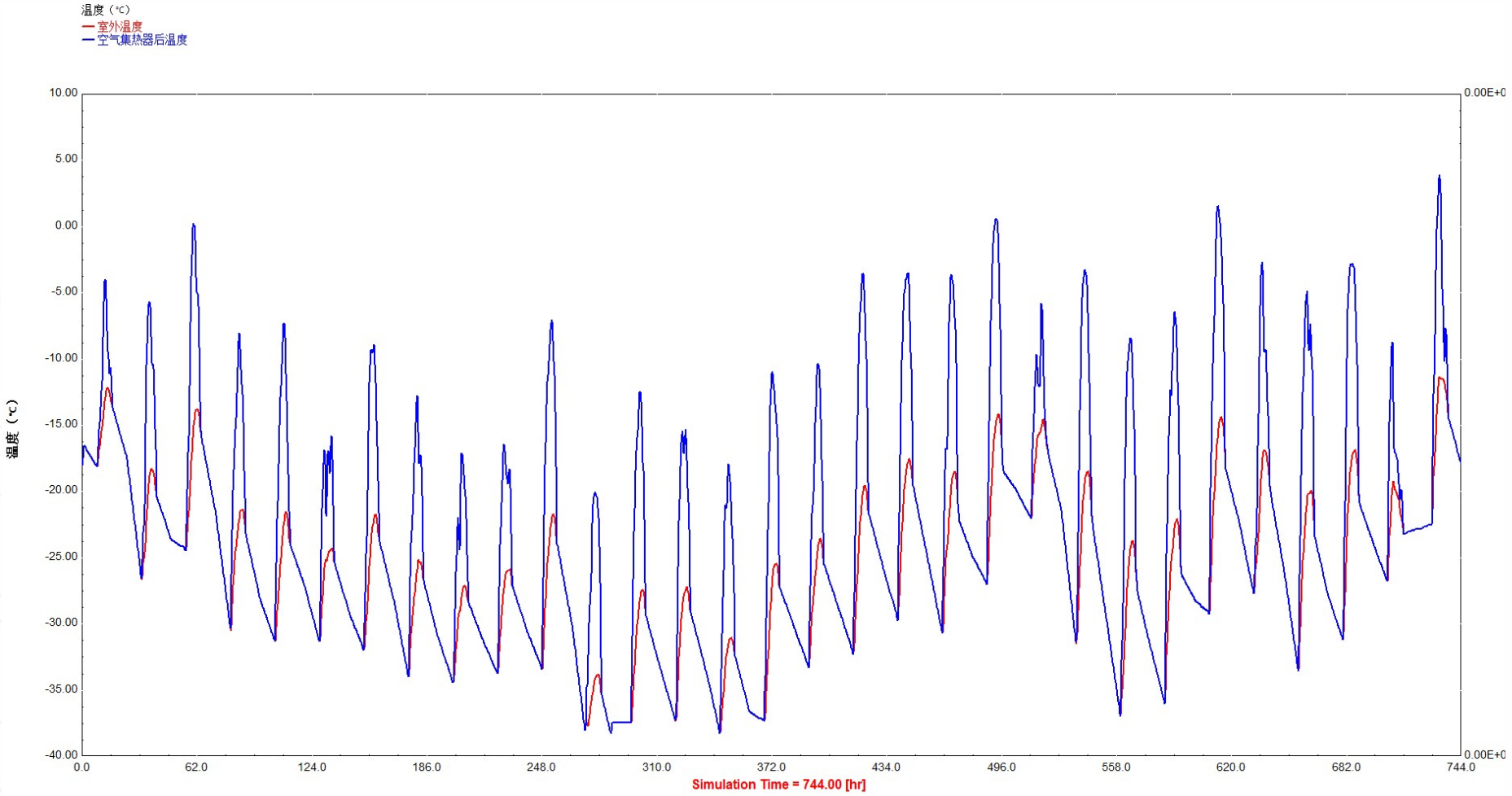
The energy system auxiliary heat source opening of the project



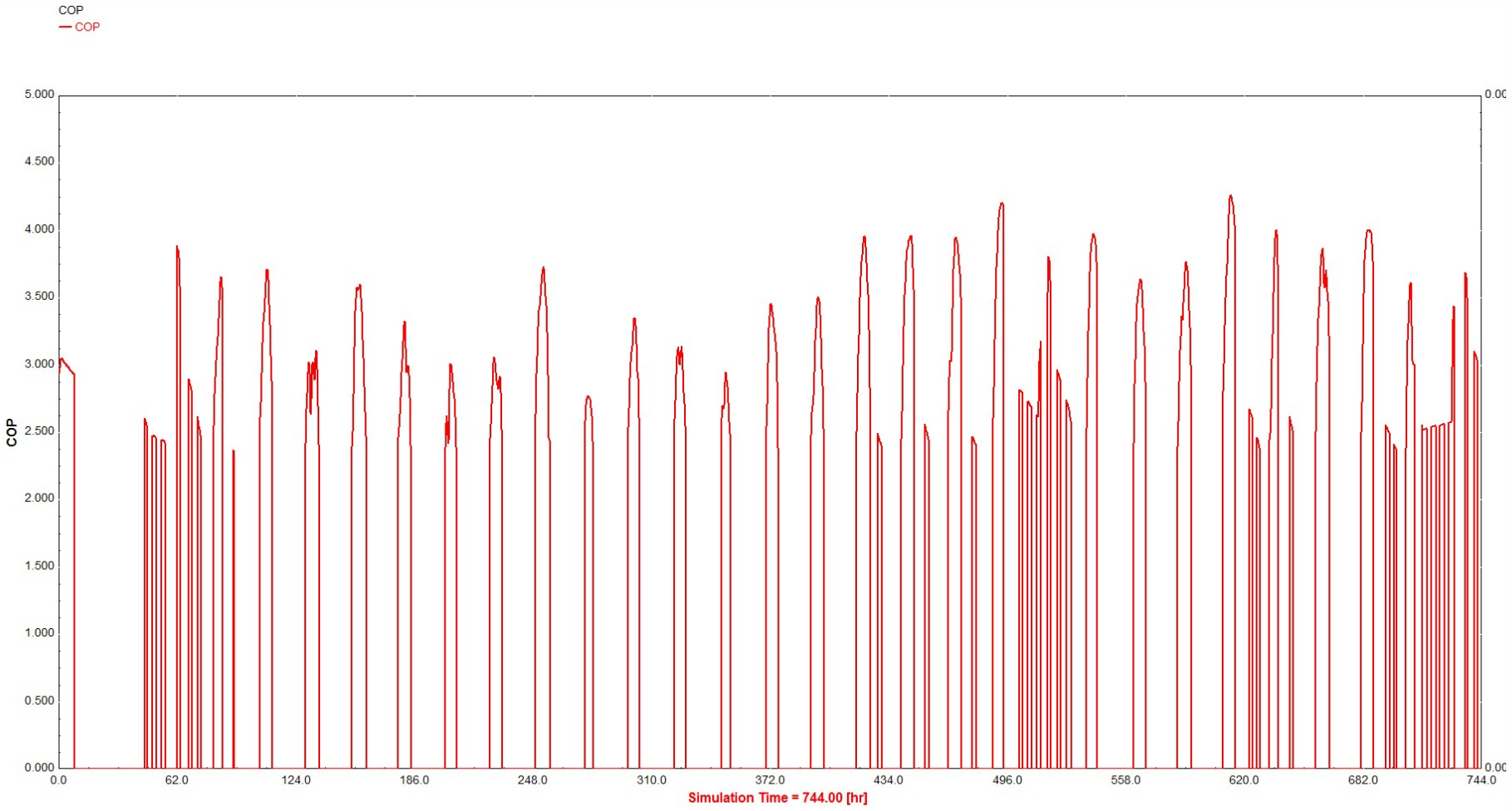
The daily heating capacity of the air source heat pump and the cumulative daily load of the building in this project



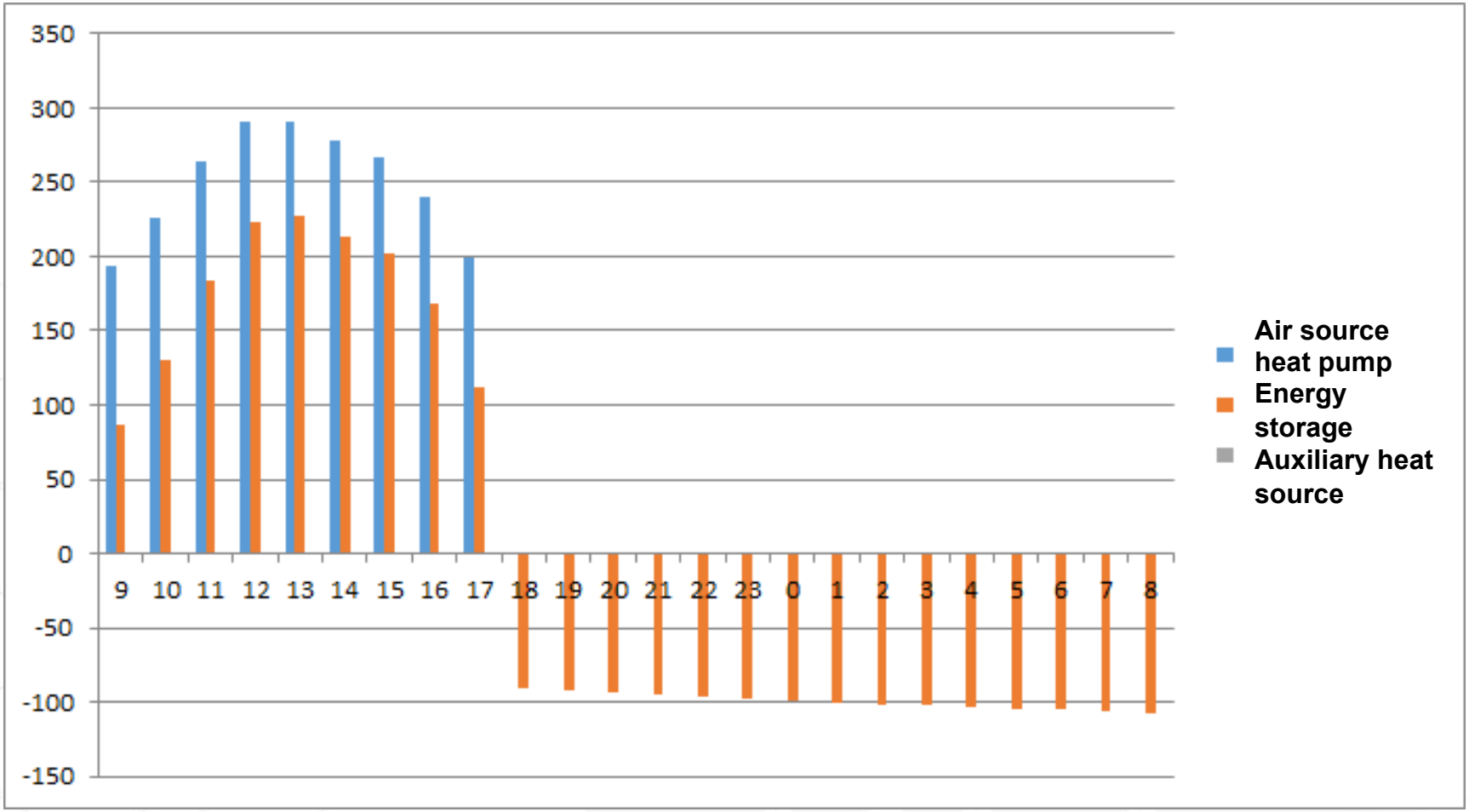
Air-source heat pump hourly COP of this project



After the air passes through the collector in January, the temperature rises in time



Air source heat pump hourly COP for this project in January



The design day's hourly operating mode when the collector area is adequate

When the electricity price of this case is taken as 0.5 yuan/kWh, the annual power consumption of the air source heat pump is 74612.4 kWh according to the previous analysis. If the auxiliary heat source is electricity, the heat energy cost of the heat source is 37,300 yuan/ year, which translates into an area of 5.32 yuan/m^2/year for the construction unit, and the heating cost for similar buildings in the region is generally about 40 yuan/m^2/year. Compared with ordinary air source heat pump systems, this system has only an increase of air collectors and water storage devices, and the cost of the two parts is relatively low. Therefore, the system has a good economy .

The project uses a compound energy system of “air collector + air source heat pump + energy storage” in passive ultra-low energy buildings in the Hailer region. The air source heat pump source side peak temperature increase effect of this system is not lower than 10℃, the system COP is expected to be higher than 3.0, and the energy saving effect is obvious.

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- In the severe cold regions of northern China, the climate conditions are extremely poor, and renewable and energy-saving energy projects are difficult to implement. It is feasible to use solar energy and air energy resources for clean energy heating. Moreover, the energy solution is highly efficient and stable, and can be used as an important pilot energy system for passive ultra-low energy buildings to be promoted in the climate zone.
- The technical solution proposed in this paper effectively broadens the temperature range of the air source heat pump, improves the heat and energy efficiency of the air source heat pump, reduces the installed capacity of the equipment, solves the problem of frequent frosting in the cryogenic working conditions of conventional air source heat pump systems, and shows its good application effect in the severe cold northern regions.
- Air collectors, air source heat pumps, and energy storage combined systems are effective in passive ultra-low energy buildings, the COP of the energy system in the case is expected to be greater than 3.0, the annual operating cost is low, and it has high technical and economic feasibility.
- The air collector, air source heat pump and energy storage compound system proposed in this paper can be highly applied in the Hailer region where the outdoor heating calculation temperature is lower than -30°C and the solar energy resources are normal, and it can significantly improve the economical efficiency and energy saving of energy systems, give full play to the advantages of renewable energy, and has a broad application prospect.

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