Study on Energy Planning and Energy Saving Analysis of Cooling and Heating Load of a Building Complex

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Abstract: With the rapid development of the construction industry, the demand for energy is also expanding rapidly. The cooling and heating load in the building consumes a lot of energy, which is an important part of the building energy consumption. This paper takes the actual project as an example, under the guidance of the relevant national laws and regulations, analyzes the energy endowment provided by the surrounding environment of the project, and predicts and analyzes the demand of cooling and heating load of the project, so as to further put forward the energy planning scheme of cooling and heating load of the project and analyze its energy saving effect.

1. Introduction
Energy is the lifeblood of the national economy. With the rapid development of China's economy and society, the demand for energy in various industries is also expanding rapidly. Building energy consumption is a key component of the terminal energy consumption. At the same time, the cooling and heating load in the building is an important component of the building energy consumption. Therefore, deeply integrating the cooling and heating load energy planning of buildings with information to carry out the top-level design is an effective guarantee for building energy saving and can promote the development of energy conservation and emission reduction in China.

2. Energy demand analysis and main planning basis of cooling and heating load

2.1. Energy demand analysis of cooling and heating load
The project is located in Nanjing, a teaching building complex, with a building area of about 1.3 million square meters. The project needs cooling in summer and heating in winter. Specifically, it needs to meet the cooling and heating load demand of apartments, offices, gymnasiums, libraries and other buildings in the campus. In addition, students' apartments also need stable supply of domestic hot water. Therefore, there are three types of cooling and heating load demand according to its application: heating load in winter, domestic hot water load and cooling load in summer.

2.2. Main planning basis of cooling and heating load
Energy Conservation Law of the People's Republic of China (Order of the President No. 77)  
Renewable Energy Law of the People's Republic of China  
Design Code of Heating Ventilation and Air Conditioning of Civil Buildings (GB50736-2012)  
Standard for Energy Conservation Design of Public Buildings (GB 50189-2015)  
on Energy Conservation of Civil Buildings (Decree of the State Council No. 530) (2007)  
Regulations on Energy Conservation Management of Civil Buildings (Order of the Ministry of
Construction No. 143) (2007)
Standard for Energy Conservation Design of Public Buildings (GB 50189-2015)

3. Analysis of energy endowment of the project

3.1. Solar energy
Nanjing is an inland city of China, belonging to the mid-latitude region. The average total solar radiation over the years is 4982MJ/(m²·a), which is the third category of solar radiation intensity. According to the statistics over the years, the days with sunshine hours greater than 6 hours in Nanjing are about 197 days. See Table 1 for the estimated solar energy consumption of the project.

| Building Type   | Annual solar radiation kWh/(m²·a) | Roof area (m²) | Roof area utilization | Ratio of solar water collector area to horizontal area | Solar collector volume (m²) | Luminous efficiency | Solar hot water efficiency | Total solar energy (kWh) |
|-----------------|----------------------------------|----------------|----------------------|------------------------------------------------------|-----------------------------|---------------------|--------------------------|--------------------------|
| Office Building | 1178                             | 124440         | 0.5                  | 0.4                                                  | 24888                       | 0.4                 | 0.55                     | 6.45 × 10⁶               |
| Apartment       | 62462                            | 12492          | 3.24 × 10⁶           |                                                      |                             |                     |                          |                          |
| Others          | 13518                            | 2704           | 7×10⁵                |                                                      |                             |                     |                          |                          |
| Total           | —                                | 200420         | —                    |                                                      |                             |                     | —                        | 1.039×10⁷                |

3.2. Shallow geothermal energy
Shallow geothermal energy is an important part of the earth's thermal energy and the main utilization form of geothermal energy at present. The project is close to the Yangtze River and rich in shallow geothermal energy resources. According to the Code for Evaluation of Shallow Geothermal Energy Exploration, the total heat that can be extracted and discharged from rock and soil is calculated as shown in Table 2. In theory, the shallow geothermal energy can solve the cooling and heating load demand of 10.92 million square meters of buildings. See Table 2 for details.

| Season          | Exchangable soil area (m²) | Unit depth heat exchange (W/m) | Buried depth | Drilling spacing of vertical buried pipe (m) | Cooling / heating hours (h) | Heat exchange of buried pipe (kWh) | Heat exchange of buried pipe (kWh) |
|-----------------|---------------------------|-------------------------------|--------------|---------------------------------------------|---------------------------|---------------------------------|---------------------------------|
| Summer          | 1.06×10⁶                 | 60/40 (Summer / Winter)       | 100          | 4.5 (Summer / Winter)                       | 400/320                   | 2.8318×10⁶                     | 1.092×10⁷                     |
| Winter          |                           |                               |              |                                             |                           | 1.2586×10⁶                     |                                 |

4. Prediction of cooling and heating load demand

4.1. Prediction method
According to the unit area index of the building, the cooling and heating load is predicted based on the corresponding building index. When predicting the domestic hot water load, the load of apartment is predicted according to the daily demand of each person, and other buildings are predicted according to the unit area index method.

4.2. Load prediction

| Project name                        | Building area (m²) | Cooling load index (W/m²) | Cooling load (kW) | Heat load index (W/m²) | Heat load (kW) |
|-------------------------------------|--------------------|---------------------------|-------------------|------------------------|---------------|
| Institute of Technology             | 12304              | 80                        | 984               | 60                     | 738           |
| College of Life and Environment     | 60636              | 80                        | 5836              | 60                     | 3638          |
| College of Food Science and technology | 12375             | 80                        | 990               | 60                     | 743           |
Table 4 Calculation results of domestic hot water load prediction

| Project name                        | Water consumption standard | Quantity | Maximum daily water consumption (m³/d) | Water consumption time (h) | Time varying coefficient (Kh) | Maximum hourly water consumption (m³/h) |
|-------------------------------------|----------------------------|----------|----------------------------------------|---------------------------|------------------------------|----------------------------------------|
| Student Apartment                   | 70L/ P·d                   | 25000    | 1750                                   | 24                        | 3.0                          | 218.75                                 |
| PhD Apartment                       | 80L/ P·d                   | 3000     | 240                                    | 24                        | 2.5                          | 25                                     |
| Teachers' Apartment                 | 100L/ P·d                  | 15000    | 1500                                   | 24                        | 2.5                          | 156.25                                 |
| Canteen                             | 7L/ P·t                    | 7000     | 490                                    | 12                        | 1.5                          | 61.25                                  |
| Gymnasium                           | 20L/ P·t                   | 100      | 2                                      | 4                         | 3.0                          | 1.5                                    |
| Subtotal                            |                            |          |                                        |                           |                              |                                        |
|                                    |                            |          |                                        |                           |                              |                                        |
| Unforeseen 10%                      |                            |          |                                        |                           |                              |                                        |
|                                    |                            |          |                                        |                           |                              |                                        |
| Total                               |                            |          |                                        |                           |                              |                                        |

5. Energy planning scheme of cooling and heating load

5.1. Principle of scheme
According to the overall planning of the project, the cooling and heating energy supply system is constructed on the principle of "advanced concept, mature technology, energy saving and environmental protection, economic practicability and easy expansion".

5.2. Content of scheme
① According to the renewable energy situation of the project and the evaluation requirements of green buildings, a centralized cooling and heating energy station is planned, the main technical form of which is the ground-source heat pump air conditioning system, which mainly meets the cooling and heating needs of public buildings such as the library and the university student activity center; the buildings such as the school department and the student apartment mainly adopt the split-type air conditioning, air-source heat pump, VRF air conditioning and other air conditioning forms to meet the personalized cooling and heating load demand.

② According to the needs of hot water used in the building, the "solar energy + air source heat pump" hot water supply system is adopted. It is planned to install solar collector, air source heat pump unit, heat preservation water tank and other equipment on the roof of students' dormitory in the new campus to produce hot water to meet the daily use demand of teachers and students and maximize the use of renewable energy. Domestic hot water is preferentially provided by solar thermal system. When the hot water supply by solar thermal system is not enough to meet the demand, the heat recovery unit will be used as a supplement to ensure that the supply of domestic hot water at the end can meet the demand.
6. Energy saving benefits of planning
According to the demand of hot water used in the building, the “solar energy + air source heat pump” hot water supply system is adopted. Combined with the analysis results of domestic hot water demand, the heating demand of hot water of dormitory area is 6.132*10^7 kcal. The local available solar energy resources and hot water production are as follows: the daily average hot water production is 468.32 m³/d, which cannot meet the actual demand, so the rest of the demand is met by producing hot water by the auxiliary heat source. The gap of hot water demand is 10^64.68 m³/d, with a heat demand of 1.75*10^8 kJ, equivalent to about 48617.74 kWh. The air source heat pump hot water unit is used to produce hot water at night. According to COP = 2.8, the daily average power consumption is 17363.48 kWh. Compared with the electric boiler and other types, its daily average power saving is 31254.26 kWh. The average daily electricity saving of solar energy for hot water production is 21385.45 kWh, and the total electricity saving of the two is 52639.71 kWh, with an average daily electricity saving of 28335.96 yuan.

7. Conclusion
On the basis of in-depth investigation of surrounding resources and energy demand, the plan selects the energy utilization mode of fully utilizing shallow geothermal energy and solar energy, with concentrated energy and distributed energy connecting and complementing with each other, and adjusts the energy consumption structure. On the premise of ensuring the safety and reliability of energy supply, the plan comprehensively realizes the purpose of energy conservation.

References
[1] Li JiaNan. Energy consumption analysis and strategy of public buildings in Shandong University of Architecture [D]. Shandong University of architecture, 2015
[2] Hu Xuanang. Evaluation index and analysis of energy consumption of a university building in Zhejiang Province [D]. Zhejiang University, 2014
[3] Han Lei. Analysis and Research on energy consumption characteristics of major universities in Shanghai [J]. Building thermal ventilation and air conditioning, 2012,04:40-42
[4] Wang Wei, Dong Chunqiao. Energy consumption simulation and energy saving measures of university teaching buildings [J]. Building energy saving, 2013 (08): 58-60
[5] Lin Bolong, Li Ziwei. Optimization method of building energy conservation for the early stage of design [J]. Science Bulletin, 2016, 61 (01): 113-115
[6] Chen zhe. Analysis of adjustment potential and evaluation of adjustment value of existing public buildings [J]. HVAC, 2019, 49 (9): 29-36
[7] Cao Yong, Liu Gang, Liu Hui. Research progress and current situation of building adjustment technology at home and abroad [J]. HVAC, 2013, 43 (4): 18-29
[8] Long Weiding. Thinking about building energy saving 2.0 [J]. HVAC, 2016, 46 (8): 1-12