Research on Green Energy Technology for the Innovation Park of Wuhan National Bioindustry Base

Yu Bo[1], Yu Songtao[2]
1 Wuhan National Bioindustry Base Construction and Management Office, Wuhan, P.R.China, 430079
2 Wuhan Far-Seeker Energy Technology Co. LTD, Wuhan, P.R.China, 430074
(E-mail: yubo0707@sohu.com, yust@fseet.com)

Abstract The Innovation Park is an important part of the Wuhan National Bioindustry Base, which has been planned as a strategic highlight for the biotechnological R&D of Hubei Province or even the entire Central China. With information collected by questionnaires and estimates made by annual energy consumption simulation software, this paper makes scientific analysis on various demands for heating, cooling and steaming supplies of the R&D Incubator, Animal Test Center, Pilot Amplification Platform, Business Center and Living Zone. Innovations are made with respect to green energy modes, and district energy supply technologies and various types of energy saving methods are taken in the Innovation Park with a building area of 650,000 m^2 to realize the targets of energy conservation, emission reduction and sustainable development.
Key words Green energy technology; District energy supply; Sustainable development; Energy saving

1 Introduction

In June 2007, as officially approved by the National Development and Reform Commission (NDRC), Wuhan National Bioindustry Base (the "Biolake") was ready for construction, which is the second national industrial base in Wuhan East Lake High-tech Development Zone following the National Optoelectronic Information Industry Base.

The core area of Wuhan National Bioindustry Base is located in Wuhan East Lake High-tech Development Zone with a planned area of 12 km^2, covering specialized parks for biological innovation, biological pharmacy, biological agriculture, medical appliance, etc. The Jiufeng Innovation Park presently under construction is located to the south of High-tech Avenue and west of the Guanggu No. 3 Road. With a total area of about 1 km^2, the Park is a specialized one for innovative R&D of bioindustry designed to provide favorable software and hardware environment for the R&D and incubation of biological enterprises. The project is to be completed in June 2011. Regional energy supply planning and construction have been carried out according to the concept of building the park into an ecological and environmental one".

Figure 1 The Innovation Park of Wuhan National Bioindustry Base

Compared with traditional distributed central air-conditioning system mode for buildings, which offers only limited spaces for energy conservation, district air conditioning can substantially reduce energy consumption, investment, land occupation and be favorable for environmental purposes. Considering the special requirements on temperatures in biological R&D activities that a great amount of heating/cooling supplies are needed, and after thorough demonstrations, centralized energy saving district energy supply has been determined for the entire Park. The greatest advantages include: (1) An integrated solution from planning, construction, operation to management will be provided by professional AC technology company at the planning stage of the project in consideration of project features;(2). Energy conservation technologies such as distributed energy supply will be applied, which can greatly cut down unit investment in air-conditioning system, reduce energy consumption and emission, etc.

2 Overall Arrangement of the District Energy Supply

The Innovation Park mainly consists of two parts of Bioindustry Zone and Supporting Service Zone. For Bioindustry Zone, energy supplies are required mainly in daytime working hours; while for Supporting Service Zone, 24h supplies are needed. The two areas share different energy consumption demands. Therefore, the energy supply of the entire Innovation Park is divided into two parts of District A and District B; and two concentrated energy stations will be constructed accordingly. Two types of pipes are adopted for the energy supply pipelines, of which the trunks are arranged in circularity and branch trunks are arranged in branched arrangement. The main ring pipeline will be ready in Phase I project, with interface reserved for each plot. And branch pipelines in each plot can be designed by steps as per the progress of construction. Such arrangements have taken into account not only the overall systematic planning and designing, but also the construction arrangement of newly built projects by steps. The service areas of the concentrated energy stations are detailed in the following figure.

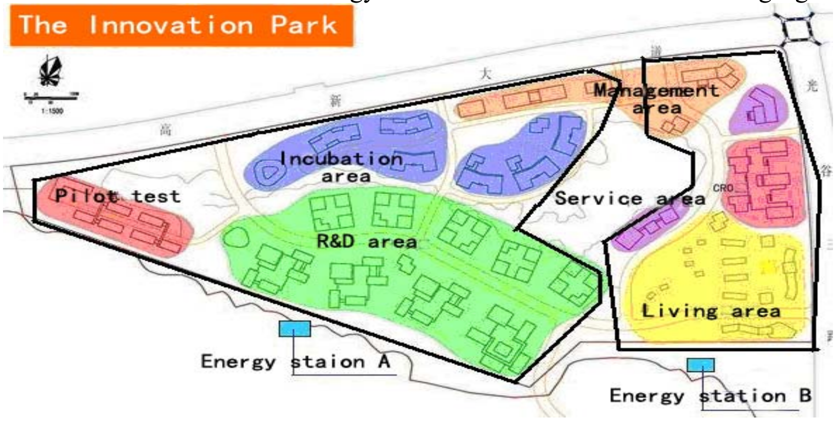

Figure 2 Location Plan for Service Area of Concentrated Energy Stations in Jiufeng Innovation Park

3 Total Heating/Cooling Load of the Park

Annual energy consumption simulation software DeST is applied in the design phase to calculate the annual consumption of the buildings. DeST is large-sized calculation software used to simulate the indoor thermal/humidity environment and dynamic process of the refrigerating system of the heating/ventilation air-conditioning for buildings. By simulating the total hourly cooling consumption of each typical building, the software can calculate proportions of different load rates in the total operation hours, cooling supply amount of each time interval, operation costs, etc., which can provide detailed and accurate data basis for technical solution analysis.

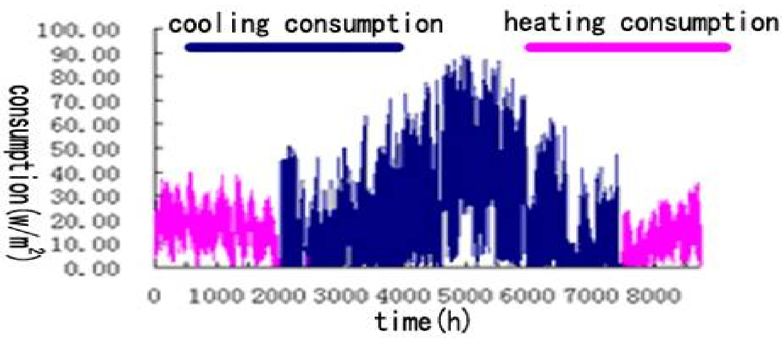

Figure 3 Annual Consumption Curve of Typical Office and R&D Buildings

Check calculations will be made according to the functional areas and load characteristics. Loads of Concentrated Energy Station A and B in summer and winter are detailed respectively in the following tables.

Table 1 Cooling Load Calculation for Concentrated Energy Station in District A

Cooling Load Calculation	Building Area (m^2)	Load Index (W/m^2)	Simultaneous Coefficient	Area Use Coefficient	Total Load (kW)
Pilot Base of Chinese/Western Medicine	36500	100	0.8	1	2920
Innovation Platform	95330	100	0.8	1	7626
Canteen	4000	180	0.2	1	144
Hubei Provincial Institute Co., Ltd. of Pharmaceutical Industry	10900	110	1	1	1199
Animal House	10000	1800	0.8	1	14400
Medical Appliance Park	70620	100	0.9	1	6356
Incubator	17000	110	1	1	1870
R&D Building	113000	100	0.9	1	10170
Institute of Drug Control	24000	110	0.7	1	1848
Subtotal	381350				46533

Table 2 Heating Load Calculation for Concentrated Energy Station in District A

Heating Load Calculation	Building Area (m^2)	Load Index (W/m^2)	Simultaneous Coefficient	Area Use Coefficient	Total Load (kW)
Pilot Base of Chinese/Western Medicine	36500	80	0.8	1	2336
Innovation Platform	95330	75	0.8	1	5720
Canteen	4000	130	0.2	1	104
Hubei Provincial Institute Co., Ltd. of Pharmaceutical Industry	10900	90	1	1	981
Animal House	10000	1500	0.8	1	12000
Medical Appliance Park	70620	80	0.9	1	5085
Incubator	17000	80	1	1	1360
R&D Building	113000	75	0.9	1	7628
Institute of Drug Control	24000	80	0.7	1	1344
Subtotal	381350				36557

Contrastive analysis shows that, cooling load peak hour occurs at 3:00 p.m. in concentrated energy station of District A and heating load peak hour occurs at 8:00 a.m. with great number of staff starting to take daily duties and relatively low outdoor temperatures. The concentrated energy station serves a building area of 381,400 m^2. In summer, the total cooling load is 46.53 MW and the unit average cooling load is 122.02 W/m^2 (86.53W/m^2 for Animal House excluded). In winter, the total heating load is 36.56 MW and the unit average heating load is 95.86 W/m^2 (66.13W/m^2 for Animal House excluded).

Table 3 Cooling Load Calculation for Concentrated Energy Station in District B

Cooling Load Calculation	Building Area (m^2)	Load Index (W/ m^2)	Simultaneous Coefficient	Area Use Coefficient	Total Load (kW)
Comprehensive office building	35000	100	0.4	1	1400
Hotel	53000	110	0.9	1	5247
Business Center	4100	110	0.9	1	406
0CR Center	58200	100	0.5	1	2910
Canteen	3600	180	1	1	648
Commercial Center	1200	130	1	1	156
Subtotal	155100				10767

Concentrated energy station of District B mainly serves the supporting facilities in the Park as well as OCR Center (Service Outsourcing) and Comprehensive Office Building. Cooling load peak hour occurs at 9:00 p.m. in concentrated energy station of District B and heating load peak hour occurs at

5:00 a.m. The concentrated energy station serves a building area of 208,300 m^2. In summer, the total cooling load is 10.78MW and the unit average cooling load is 59.53W/m^2. In winter, the total heating load is 10.69 MW and the unit average heating load is 43.58 W/m^2 (For Youth Apartment and Specialist Apartment, concentrated AC cooling is excluded and only concentrated AC heating in winter is included for temporary considerations).

Concentrated district heating/cooling solutions are applied. According to related calculations, after heating/cooling solutions of district concentrated energy station are taken, the unit average cooling load of energy station in District A and B is reduced by 14.02% and 40.16% respectively. Wuhan is located in the area with hot summers and cold winters; and the loads in summer are greater than those in winter. If only machine room investment is considered, the investment cost will be cut down by about 25% with heating/cooling provided by district concentrated energy stations compared with the traditional distributed air conditioning systems.

Table 4 Heating Load Calculation for Concentrated Energy Station in District B

Heating Load Calculation	Building Area (m^2)	Load Index (W/m^2)	Simultaneous Coefficient	Area Use Coefficient	Total Load (KW)
Comprehensive office building	35000	70	0.4	1	980
Hotel	53000	80	0.9	1	3816
Business Center	4100	80	0.9	1	295
OCR Center	58200	70	0.5	1	2037
Canteen	3600	130	1	1	468
Youth Apartment	50000	70	0.8	1	2800
Commercial Center	1200	75	1	1	90
Specialist Apartment	3150	80	0.8	1	202
Subtotal	208250				10688

4 Green Energy Technology

With comprehensive comparisons made among various technologies, innovations are made in respect to type selection of major equipment. A combination of centrifuge and gas fired boiler is applied as the major heating/cooling source for the cooling project in this district. In addition, technologies such as ice cooling storage, non-electric refrigeration, ground source heat pump, large temperature difference variable flow transmission, etc. are applied to providing district energy for the building complex of Jiufeng Innovation Park.

With comprehensive comparisons made among various technologies, centrifuge is applied as the major cooling means for the project in summer, supported by other means such as ice cooling storage, ground source heat pump, lithium bromide absorption, etc. A combination of gas fired boiler and ground source heat pump is applied as major heating means for the project in winter, supported by district energy supply means such as large temperature difference variable flow transmission etc. Meanwhile, renewable energy resource technologies such as solar energy heating, generation, etc. will be applied as much as possible in the Park, to achieve the purpose of conserving energy, water, land, environmental protection, etc. and to accord with the national policy on energy conservation and emission reduction.

4.1 Introduction to ground source heat pump (GSHP) technology

Ground source heat pump (GSHP) technology refers to a highly effective, energy saving and environmental friendly system to make heating/cooling supply by utilizing geothermal energy on superficial layer of the earth. To be simple, in winter it “takes” out the heat in geothermal energy and supplies to indoor environment after the temperature rises, and in summer, the heat indoors will be “taken” out and “discharged” into underground. Generally, the consumers will be returned with about 4 kW of heat or cold by consuming 1 kW heat of the heat pump.

4.2 Ice cooling storage technology

Ice cooling storage air conditioning refers to the technology that, in nighttime slack hours (also when the load of AC system is quite low), the main refrigeration machine makes refrigeration with the generated cold stored by cooling storage devices in form of sensible heat and latent heat. And in the daytime, such energy stored will be released in peak hours (also when the load of AC system is quite high) to meet the load requirements or production cooling demands in peak hours.

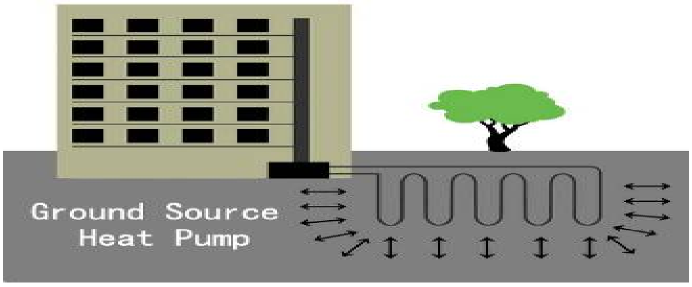

Figure 4　The Picture of Ground Source Heat Pump

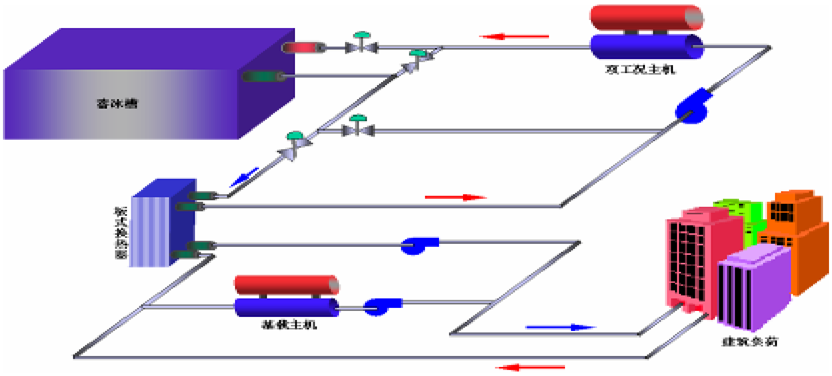

Figure 5　Cooling Storage Technology

4.4 Large temperature difference variable flow transmission technology

Generally, in large-scale central air-conditioning system, power consumption of water pump occupies as high as about 30% of the total power consumption. The large temperature difference variable flow transmission technology mainly refers to the process to increase the temperature difference between water supply/water return to about 9℃ or higher, which can cut the circulating water amount by half and further reduce the power consumption of the water pump by at least 50%.

Figure 6　Large Temperature Difference Variable Flow Transmission

4.5 Non-electric refrigeration technology

Lithium-bromide absorption-type refrigerating machine takes heat energy as power, water as refrigerant and lithium bromide solution as absorbent to prepare chilled water of over 0℃. It can be applied as cold resources for air conditioning system and in production process. Such technology is featured by power conservation, energy saving and stable performance. Meanwhile, it produces low noise and relatively smaller public nuisance.

4.6 Solar utilization technology

Solar energy collectors are planned on the roofs of the project as the preheating resources for domestic hot water, which can fully make use of solar energy and further reduce energy consumption of domestic hot water. As estimated, 1 m^2 solar water heater can save coal equivalent of about 150 kg or power of 450 kWh. The following figure is the photo of roof solar energy collectors.

5 Energy Center Construction

5.1 Design scheme for concentrated energy station (power unit) in District A

Concentrated energy station in District A serves a building area of 381,350 m^2. The building energy demands consist of air conditioning, heating and steaming. The energy supply of host machine is shown in following figure.

In Wuhan, the load of AC system in summer is relatively high. On condition that the outdoor temperature remains extreme high for several days, power restriction will probably be made by switch-off of power grid; while natural gas consumption in summer is relatively low and the gas supply will not easily fall short. To ensure building air conditioning requirement of the key unit of Animal House, a set of large-sized direct-fired lithium bromide absorption type hot/cold water machine unit (with a refrigerating capacity of 5,230 KW), (2 sets) of ice cooling storage systems (with a refrigerating capacity of 4,747 KW), (4 sets) of three-stage compressed large temperature difference centrifugal chiller units (with a refrigerating capacity of 4,220 KW), (4 sets) of screw type chiller units (with a refrigerating capacity of 2,588 KW) and three sets of gas steam boiler (two for 20 t and one for 10 t) are arranged to ensure the steam supply for industrial use throughout the year. The range of accommodation of the steam boiler is 25%~100%, to meet the demands of winter heating loads and steam consumptions.

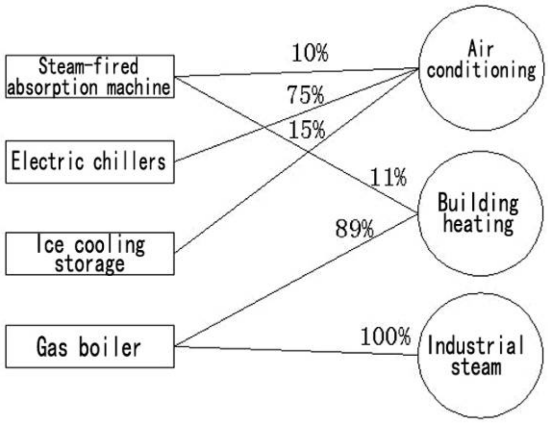

Figure 7 Energy Supply Arrangement for District A Machine of Concentrated Energy Station in District A

5.2 Design scheme for energy station in District B

Concentrated energy station in District A serves a building area of 208,250 m^2. The building energy demands consist of air conditioning, heating and domestic hot water. The energy supply of host machine is shown in the following figure.

Renewable energy resource, i.e. ground source heat pump, accounts for 40% of the total energy supply in District B and 10% of the total Park. A 53,000 m^2 hotel is accommodated in District B, which requires a 24h energy supply, including domestic hot water. To increase the proportion of the renewable energy resource in the total energy system and fully exert the advantage of cost-free hot water provided along with the ground source heat pump under refrigeration mode; a ground source heat pump system is applied in the design of the concentrated energy station in District B, which can guarantee domestic hot water demand of the hotel and provide high quality energy to other buildings in the Park.

Gas shortage will probably occur during the peak hours of natural gas consumption in winter in Wuhan. Ground source heat pump is applied for heating and hot water supplies, which can fully meet heating load demands of the residential area and the hotel as well as guarantee the stable operation of system. The system scheme is designed as follows:

1 set of full heat recovery screw type ground source heat pump unit; 1 set of high temperature screw type ground source heat pump unit; 1 set of three-stage compressed large temperature difference centrifugal chiller unit; 2 sets of screw type chiller units.

As there are no industrial steam demands in District B, heating load in winder will be undertaken by gas fired boilers. In winter, the maximum supply of the boiler is 10.69 t/h. 1 set of 11t hot water boiler is applied.

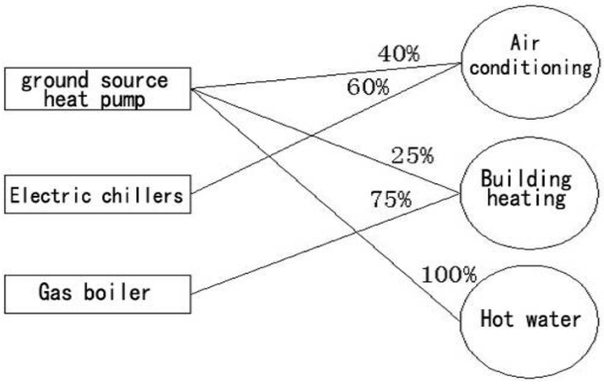

Figure 8 Energy Supply Arrangement for District B

6 Results

6.1 Energy conservation measures

Equipment with relatively high COP value is selected for ground source heat pump and chiller units. Meanwhile, fine partial load performance is required.

Highly effective water pumps are selected. Frequency conversion adjustment technology is applied to two-stage pumps to reduce the energy consumption of the water pump by adjusting the flow according to terminal load requirements.

Advanced automatic control system is applied to make adequate analysis on the load changing rules and conditions of the consumers. The rational number of chiller units for operation will be adjusted automatically according to the annual dynamic and systematic energy consumption analysis.

Capacities, numbers of the chiller units are selected rationally. Methods such as combination of large- and small-sized equipment, etc. are applied to meet the load changes throughout the year.

Heat insulating materials with low thermal conductivity, low water absorption and high wet resistance factor are selected. In addition, proper waterproofing materials are applied to the heat insulating materials to ensure the long-term and stable operation of the heat insulating structures and reduce energy loss caused in the transmission and distribution of cold water.

Improve the quality of managerial staff; reduce management level as possible; maintain professional and capable managerial staff; improve economic performance by favorable management.

Establish rational prices for cooling supply. Take effective measure to prevent or reduce unnecessary waste by the consumers.

Try to improve the hydraulic stability and rationality of the pipeline and reduce energy consumption caused by valve regulation in calculations of cold water distribution network.

6.2 Overall benefits of energy conservation

Ground source heat pump is applied as part of heating/cooling source of the AC system, which is of certain demonstration significance on renewable energy resource. Concentrated energy station is applied to reduce the total consumption of fuel gas and reduce the total distribution capacity of AC system in the Park.

Conventional refrigerating machine room in individual building is removed. The building area of the Energy Center is far smaller than that of distributed machine room, which has cut down the building area and brought economic benefits for the Owner.

According to calculations on initial investment and operation expenses of concentrated energy station in District A and B and comparison with conventional VRV AC system, conclusions have been made that:

(1) The installed capacity of the chiller has been reduced by 19,968 kW (27.58%);

(2) The installed capacity of the gas fired boiler has been reduced by 16,701 kW (28.13%);

(3) The annual electric energy consumption has been reduced by 11.14×106 kWh (25.2%);

(4) The annual operation expense has been reduced by RMB 12.7397 million;

(5) The annual natural gas consumption has been reduced by 0.21×106 kg;

(6) The annual peak load transfer of the power network has been 5.86×106 kWh;

(7) Energy consumption calculation in coal equivalent

Power consumption calculation in coal equivalent: 0.33kg/kWh×44.2×106kWh=14,586 tons of standard coal

(8) Calculation of CO_2 emission:

Wuhan is located in the power grid in South China, with an emission factor of 0.7794 tCO_2/MWh

CO_2 emission for power consumption: 0.7794 tCO_2/MWh×44.2×106 kWh=34,449 tCO_2;

According to the proportion of energy conservation, a coal equivalent of 3,676 tons will be saved in primary energy consumption of the project, which can cut down the emissions of CO_2 by 8,683 tons, SO_2 by 236 and nitrogen oxides by 118 tons.

7 Conclusions

The district energy solution of Jiufeng Innovation Park of Wuhan National Bioindustry Base to offer heating, steaming as well as domestic hot water by a combination method of centrifuge, ice cooling storage, gas fired boiler and ground resource heat pump is provided with favorable social, economic and environmental benefits. Under such planning design, the following targets can be obtained: energy saving, emission reduction, water conservation, land conservation. Various types of energy conservation technologies are applied in the total design to make full use of renewable natural energy resources (ground source, solar energy, etc.), cheap power in slack hours, etc. It is feasible technologically and rational economically. In addition, it is in accordance with the national policies on energy conservation and emission reduction and is the technology vigorously generalized by the state with promising futures. Meanwhile, development of such operations is in line with the development objectives and current conditions of Wuhan or even the entire Hubei Province. Therefore, it is provided with necessity to be popularized in similar industrial parks.

References

[1] R.F. Babus'Haq, S.D. Probert, M.J. Shilston. Optimal Configuration for Horizontal Double-pipe District Heating/cooling Distribution Net-works[J]. Ashrae Transaction, 1987, (93): 160-175

[2] F.W.H. Yik, J. Burnett, I. Prescott. Predicting Air-conditioning Energy Consumption of a Group of Buildings Using Different Heat Rejection Methods[J]. Energy and Buildings, 2001, (30):151-166

[3] J.A. Clarke. Energy Simulation in Building Design[M]. Oxford: Butterworth Heinemann, 2001

[4] Yao Runming, Li Baizhan, Koen Steemers. Energy Policy and Standard for Built Environment in China[J]. Renewable Energy, 2005, 30(13): 1973-1988