Analysis and Comparison of Energy Saving for Construction Scheme of a Large Commercial Complex Project

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DOI: 10.32629/aes.v3i3.1046

Abstract: With the development of urbanization, large-scale commercial complex projects emerge as the name cards of cities. The construction of large-scale urban complex projects is large in scale and complex in business form. After completion, energy consumption expenses account for nearly 80% of the entire operation cost. Therefore, it is particularly important to select energy saving schemes for the construction of large commercial complex projects. This paper takes a large commercial complex project in a city as an example, analyzes and compares its energy saving schemes, and calculates the comprehensive energy consumption of the selected schemes, so as to demonstrate whether the energy saving schemes meet the energy consumption policies advocated by the state and provide reference for other similar projects.
***Keywords*:** commercial complex, energy saving, analysis

1. Project construction content

This large-scale commercial complex project has a planned total construction area of 335914.9 square meters, including the above-ground construction area of 221532.62 square meters. Including 34,700.54 square meters of commercial, 185,299.12 square meters of office, 1045.87 square meters of property service room, 129.4 square meters of public toilet, 357.69 square meters of motorized garage, and 114,382.28 square meters of underground construction area. Including commercial 9,877 square meters, the main business form of the project is the construction of 2 commercial office buildings, 1 skirt house, 1 underground motorized garage, commercial and ancillary facilities and 1 non-motorized garage, and the construction of supporting facilities such as road, water supply and drainage, greening and so on. Two commercial office buildings are 45F above ground, including business office and commercial properties, and the building height is 198.9m. The podium is 4F above ground, commercial in nature, with a building height of 23.9m, underground motor garage, commercial and auxiliary facilities 4F underground (part of the mezzanine), non-motor garage 2F underground.

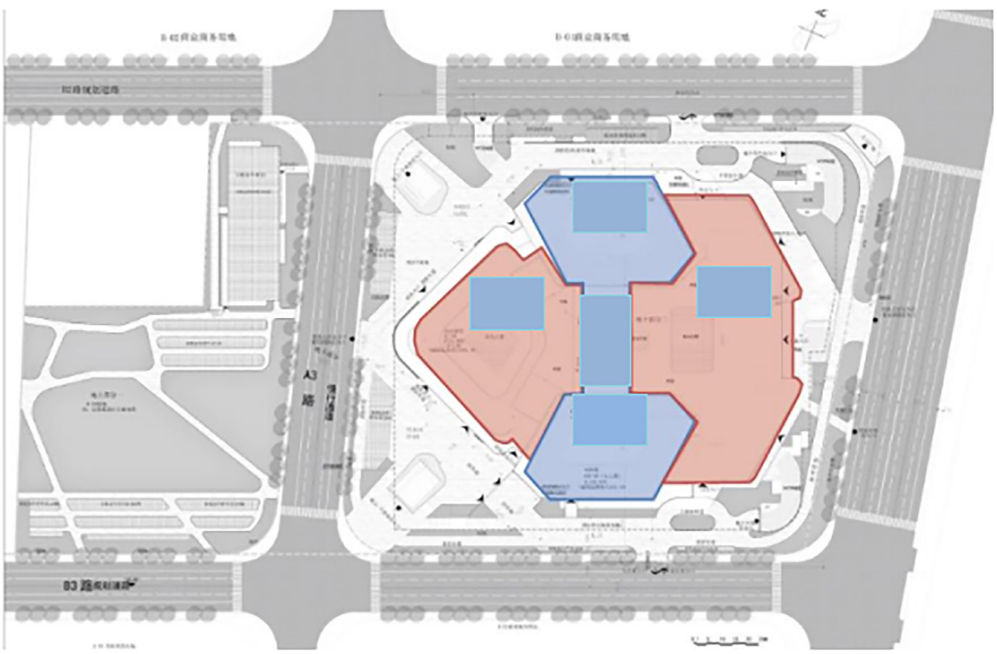

Figure 1. Plan of large commercial complex project

2. Energy saving analysis and comparison

2.1 Structural design form and material selection

According to the local seismic intensity, site conditions and corresponding structural design specifications, the 1#, 2# and 3# podium of the project adopts frame structure, the tower adopts reinforced concrete frame + core tube structure, the tower aerial corridor adopts steel truss structure, the tower adopts raft foundation, and the commercial podium adopts raft + lower reverse column pier. The underground garage, business and auxiliary facilities of lot B-03 adopt frame + shear wall structure, raft + lower reverse column pier, and the non-motorized garage of lot B-04 adopts frame structure with independent foundation. Structure design service life of 50 years, according to the key fortification class (class B) fortification, seismic fortification basic intensity of 7 degrees, the design of the earthquake group three.

According to the requirements of building energy saving materials, steel and concrete materials in line with national energy saving are selected as the main materials. Autoclaved aerated concrete blocks (A5.0) are selected for the outer wall of filling wall, and autoclaved aerated concrete blocks (A3.5) are selected for the inner wall. Autoclaved mortar MU10.0 and M10.0 are selected for the wall under positive or negative zero that contacts the soil.

2.2 Architectural design scheme and material selection

According to the requirements of planning and design, three schemes are tentatively decided in the early stage of the project as follows.

Plan 1

Plan 2

Plan 3

Figure 2. Project construction scheme selection

After several rounds of argumentation, it is analyzed from the angle of energy saving. The structure of scheme 1 is more regular and neat, and the shape coefficient is low. The north and south of the office tower are basically symmetrical in design, and the distribution of energy loads such as water and electricity is even, which is convenient to determine the partition of each energy supply system reasonably and reduce the loss of energy transmission. However, compared with the other two schemes, scheme 1 is equipped with an air corridor, which increases the range of heating and air conditioning.

Figure 3. Renderings of large commercial complex projects

The outer wall of the underground part is waterproof reinforced concrete wall, and the inner wall is 200 thick autoclaved aerated concrete block (300 thick if the height exceeds 6m). The curtain walls of the office lobbies from the first floor to the third floor of the above-ground towers are framed glass curtain walls (low-E hollow ultra-white coated glass); Stainless steel ribbed frame glass curtain wall (low-E hollow laminated super white coated glass) is used as the curtain wall of the irregular position on the northwest side of the podium. The curtain wall of the commercial podium and the standard floor of the tower is made of monolithic glass curtain wall (LOW-E hollow coated glass), and the inner wall is made of concrete beam or galvanized iron sheet coated rock wool board. The exterior wall of the ground is made of 200 thick autoclaved aerated concrete block wall, and the exterior surface is coated with stone imitation paint or imitation metal coating. The southwest skirt of the 1st and 3rd floor of the inner wall adopts 200 thick light steel keel gypsum board partition wall, and the rest adopts 200 thick autoclaved aerated concrete block wall. External wall insulation system and 120 thick rock wool board insulation are adopted. The wall materials such as bricks, blocks, wall panels and insulation materials (systems) must meet the corresponding standards for energy conservation.

The windows and doors adopt broken bridge aluminum alloy window frame and dark gray fluorocarbon spraying. The glass adopts three glass double hollow argon filled high-permeability double silver Low-E glass (TP8+12Ar+TP8+12Ar+TP8 double Silver LOW-E). All doors and windows, the selected glass thickness and frame material should meet the safety strength requirements. Its resistance to wind deformation, rain infiltration, air infiltration, in-plane deformation, heat preservation, sound insulation and impact resistance and other performance indicators are in line with the provisions of the current national product standards. The outer wall is made of metal coating outer wall, glass curtain wall and aluminum alloy metal plate outer wall, in addition to the assembled scope of foreign shop and the initial decoration in the office. Interior decoration materials must be selected non-combustible materials and anti-corrosion, fire treatment, and where the need to choose a class of materials should be strictly executed.

The results of benchmarking the design parameters of this project with national standards are as follows:

Table 1. Architectural design index table

Project		Standard limit	Project design index	Make sure those goals are met
Body size coefficient S		≦ 0.40	0.10	YES
Window wall than	Facade A	≦ 0.80	0.69	YES
	Facade B	≦ 0.80	0.66	YES
	Facade C	≦ 0.80	0.67	YES
	Facade D	≦ 0.80	0.68	YES
Maintenance of structural parts	Heat transfer coefficient K limit W/$(m^2.k)$		Project practice Heat transfer KW/$(m^2.k)$	/
	S ≦ 0.30	0.30<S ≦ 0.50		
Roof	≦ 0.40	≦ 0.35	0.32	YES
External walls (including non-transparent curtain walls)	≦ 0.50	≦ 0.45	0.43	YES
An elevated or cantilevered floor in contact with outdoor air	≦ 0.50	≦ 0.45	0.38	YES
Floor slabs between HVAC rooms and non-HVAC rooms	≦ 1.0	≦ 1.0	0.89	YES
The wall between the HVAC room and the non-HVAC room	≦ 1.2	≦ 1.2	0.67	YES
Deformation joint (thermal insulation in both walls)	≦ 0.60	≦ 0.60	No content	/
Outer door (including non-transparent and transparent parts)	≦ 3.0	≦ 3.0	2.5	YES
Single facade exterior window (including transparent curtain wall)	Heat transfer coefficient/solar heat gain coefficient			/
0.60<Window wall than ≦ 0.70	≦ 1.70/ ≦ 0.60	≦ 1.60/ ≦ 0.60	1.50/0.30	YES
Roof transparent part (roof transparent part area ≦ 20%)	≦ 2.40/ ≦ 0.44	≦ 2.40/ ≦ 0.35	2.40/0.39	YES
Thermal resistance of surrounding ground	≧ 1.2	≧ 1.2	1.52	YES
Heating and air conditioning basement and soil contact exterior wall thermal resistance	≧ 1.2	≧ 1.2	1.45	YES

In conclusion, the area of the transparent part of the atrium roof of the project accounts for 100% of the total area of the atrium roof, which does not meet the requirements of Article 3.2.5 of "Energy Saving Design Standards for Public Buildings" (DB37/5155-2019) and the proportion is less than 70%. After weighing and judging, The project can meet the relevant requirements of "Energy Saving Design Standard for Public Buildings" (DB37/5155-2019).

2.3 Water supply and drainage design scheme

Water supply system design should make full use of municipal water supply pressure, high-rise building water supply system zoning design, according to the "National civil construction engineering design technical measures for energy conservation — water supply and drainage" commonly used pressurized water supply methods and energy consumption are compared as follows[1].

Table 2. Comparison of common water supply methods

Serial number	Water supply way	Pump operating condition	Energy consumption	Safety and stability of water supply	Eliminate secondary pollution	Investment	The operating cost
1	High tank water supply	All run in high efficiency segment	1	Good	Poor	1	1
2	Air pressure water supply	Worse than 1	>1	Worse than 1	Poorer	<1	Better than 1
3	Frequency control water supply	Part of the time inefficient operation	1—2	Worse than 1	Poorer	<1	>1
4	Pipe network superimposed water supply	Worse than 3	≈1	Poor	Good	<1	≈1

As can be seen from the above table, from the perspective of energy saving and water saving, the superimposed water supply from the high water tank and pipe network is more energy saving. Considering the project's architectural design scheme and municipal conditions, the project decides to adopt water tank + frequency conversion water supply equipment for pressurized water supply.

2.4 HVAC design scheme

According to the project scale and business type and the requirements of the construction unit, the commercial air conditioning system of the project is preliminarily determined from the following system forms.

Table 3. The scheme of air conditioning system is selected

Unit form	Advantages	Disadvantages
Chiller electric refrigeration air conditioning system	Simple system; High efficiency, energy saving; The investment is relatively small.	The quantity and capacity of electric equipment is large, which is not convenient for later operation and maintenance; The electricity consumption is all peak electricity, not enjoy the peak-valley price policy, the operation cost is high; Cooling tower is required.
Ice storage air conditioning system	Less unit capacity; High refrigeration efficiency; Flexible use, transition season can be provided by melting ice, do not open the main machine, conducive to energy saving; The peak-valley price policy can be used to reduce the operating cost.	Large demand space for equipment units; High equipment investment; Can only supply cooling, no heating function.
Air cooled heat pump air conditioning system	Hot and cold integrated, no need to configure additional heat source; The demand room area is small; Use of air cooling, no need to configure cooling tower.	By air cooling, refrigeration efficiency is slightly lower than other air conditioning systems; Large power load; High investment in equipment.

Comprehensive analysis, project for high-rise commercial office complex building, the building forms more types and arrangement of different types of forms is relatively concentrated, project both cold and hot load is bigger, different formats and project with 4 f commercial podium, roofing for cooling tower set, with cold (hot) combined with the project situation, the project construction scheme and construction unit. The project finally decided to use chiller refrigeration air conditioning system as the project cold source. The heat source is municipal central heating.

2.5 Electrical design scheme

According to the estimation of electricity load and quantity, the project adopts 10kV high-voltage power supply, which is distributed to 8 transformer and distribution rooms through radial distribution. In transformer and distribution rooms, the ring network cabinet is used as the load switchgear. The dual 10kV power supply works at the same time and serves as back-up for each other. When one of them interrupts the power supply, the remaining power supply can meet the power supply demand of all secondary and above loads in the building. The project has its own diesel generator set. The emergency bus section and the standby bus section are respectively set in the low-voltage bus section of the transformer and distribution room. The emergency bus section provides emergency power for the especially important load in the primary load, and the standby bus section provides standby power for the primary load. There are two diesel generator rooms, and each diesel generator room is configured according to 1 Cubic meters.

Table 4. Project power consumption scheme.

Name	Location	Capacity of transformer (kVA)	Configuration Quantity (set)	Type of transformer
1# transformer distribution room	-2F, northeast side of building 1#	1250	2	SCBH17 meets the second-level energy efficiency requirements of Limited Value and Grade of Energy Efficiency of Power Transformer (GB20052-2020)
		1000	2	
2# transformer distribution room	-1F, northeast side of Building 2#	1250	4	
3# transformer distribution room	Mezzanine, northeast of Building 1#	1250	2	
		630	2	
4# transformer distribution room	-1F, southeast side of Building 2#	1250	2	
		630	2	
5# transformer distribution room	Refuge floor 11F, Building 1#	1000	2	
6# transformer distribution room	Refuge floor 11F, Building 2#	1000	2	
7# transformer distribution room	Refuge floor 33F, Building 1#	1000	4	
8# transformer distribution room	Refuge floor 33F, Building 2#	1000	4	

A total of 8 transformer distribution rooms are set in the project, including 4 in the underground garage and 4 in the refuge floor of the tower. Each transformer distribution room is set in the power supply load center according to its service scope, and the power supply radius of each transformer is no more than 200m. The transformer capacity of the project is properly configured according to the calculated load. The configured transformer load ratio is between 75% and 85%, which meets the requirements of energy saving, economic and efficient operation of the transformer. Special transformers are used to power the high-power equipment in each refrigerator room, such as chiller, chilled water pump and cooling water pump. Reactive power compensation and harmonic control measures are adopted in the project, including the installation of reactors on the low-voltage side of the transformer to suppress harmonics, the installation of passive filtering devices at the power intake line of the weak current room, and the installation of reactive power automatic compensation screens on the low-voltage bus of the transformer. The project is equipped with emergency power supply, including two diesel generator rooms. The capacity of each diesel generator room is 1600kVA, which is full of the relevant requirements of 6.1.3 in the Standard of Electricity and Gas Design for Civil Use Construction (GB51348-2019). The power supply and distribution system adopts high-efficiency and energy-saving transformer, SCBH17 dry type power transformer is selected, which can meet the energy efficiency requirements of level 2 in the Energy Efficiency Limit Value and Energy Efficiency Grade of Power Transformer (GB 20052-2020)[2].

The lighting system of the project shall be in strict accordance with the "Architectural Lighting Design Standard" (GB50034-2013) to determine the illumination standard value, power density value and other related design parameters. The project uses energy-efficient lighting fixtures, and all light sources of the project are LED lamps. The lighting system control of the project is reasonably determined according to the function of the building. Natural lighting is used as far as possible in the office, centralized switch control or local induction control is used in the public area, radar induction lamps are used in the underground garage to realize delay control, and automatic control devices are set in various modes such as ordinary times and festivals for outdoor landscape lighting[3].

2.6 Other energy-saving measures

The project requires the application of energy-saving, efficient, suitable, safe and environmentally friendly green lighting fixtures to improve the efficiency of electricity consumption. Water and electricity use centralized meter reading or centralized data collection, which is conducive to energy saving. Set up the start and stop control system in the elevator room, heat exchange station, transformer and distribution room, refrigeration room and other ventilation facilities, automatically stop when not in use, reduce energy consumption.

The project adopts frequency conversion speed regulation and energy saving technology to monitor the working status of the frequency converter and the system operation parameters in real time, to realize the comparison with the target value, and to find the optimal operation matching and speed regulation strategy, so as to achieve the best energy saving effect. Feed pump according to the design of water supply and head, select the high efficiency and energy saving pump, and run in the high efficiency section. Project increase reactive power compensation function and energy consumption monitoring system, project construction energy consumption monitoring system, based on a digital data platform, using real-time data acquisition technology and other advanced technology, real-time data collection, such as water, electricity and gas monitoring terminal, submit a large database induction, sorting, analysis, summary, providing scientific basis for the implementation of target management responsibility system for energy saving and consumption reducing. At the same time, the project has carried out sponge city design and green construction plan according to the corresponding specification requirements, which are energy saving and emission reduction requirements.

3. Comprehensive energy consumption measurement

The building categories of this project are commercial, business office, supermarket, underground garage and equipment room. Electricity consumption estimation is divided into: air conditioning equipment, lighting equipment, indoor socket, public auxiliary equipment, etc.

3.1 Power consumption

The construction area of the project is 335,100 square meters, and the air conditioning area is about 167,500 square meters. The cooling and heat load of air conditioning is estimated by the index method of building area cold and heat load. Detailed calculation is shown in the table below.

Table 5. Air conditioning cooling and heating load estimation

Serial number	Building name	Construction area (h ㎡)	Air conditioning service area (h ㎡)	Cooling load index (W/ ㎡)	Cooling load (kW)	Heat load index (W/ ㎡)	Heat load (kW)
1	1# Business office building	9.78	6.96	125	8718	68	4749
2	2# Business office building	9.71	6.96	120	8406	66	4620
3	Podium business	2.87	2.82	149	4227	92	2591
4	Underground garage and equipment room	11.15	-	-	-	-	-
	Total	33.51	16.74	394	21351	226	11960

A total of 8 transformer and distribution rooms are set in this project. The electricity consumption within the service scope of each transformer and distribution room is as follows.

Table 6. Air conditioning cooling and heating load estimation

Variable transformer room	Service scope	Annual electricity consumption (kWh)
1# transformer distribution room	North of podium and garage	4638027.22
2# transformer distribution room	South of podium and garage	5395661.395
3# transformer distribution room	The 10th floor and below of Building 1#	2390892.54
4# transformer distribution room	Offices on the 10th floor of Building 2 and below	1937791.74
5# transformer distribution room	The 1 # floor 11 ~ 22 layers	1538305.64
6# transformer distribution room	The 2 # floor 11 ~ 22 layers	1533377.99
7# transformer distribution room	23rd floor and above Building 1#	3047187.06
8# transformer distribution room	Building 2# 23rd floor and above	2982337.29
Total	/	23463580.88

In summary, the total annual electricity consumption of this project is 23463580.88kwh

3.2 New water consumption

The new water consumption of this project mainly includes office water, catering water, commercial water, supermarket water, fresh air humidification water, cooling tower water, refrigeration unit water, underground heat exchange station water, 22nd floor heat exchange station water and unforeseeable water.

The water consumption is selected according to the "Standard for Urban Domestic Water Consumption of Shandong Province". The unforeseen water consumption is calculated as 10% of the above water consumption. The estimated annual water consumption of the project is 247,171.7m³.

Table 7. Summary of new water consumption in years

Serial number	Project	Daily amount of fresh water (m^3/d)	Annual water use days (d)	Annual fresh water consumption (m^3/y)
1	Office	456	250	114000
2	General store	14.3	365	5219.5
3	Catering shops	206.9	365	75518.5
4	Supermarket	8.1	365	2956.5
5	Fresh air humidification	30	365	10950
6	Cooling tower water refill	148.2	85	12597
7	Water replenishment of refrigeration unit	22	85	1870
8	Water replenishment at underground heat exchange stations	3	120	360
9	Water refill at 22F heat exchange station	6	205	1230
10	Unanticipated water volume	Estimated at 10% above	22470.2	
11	Total	/	247171.7	

3.3 Steam consumption

According to the requirements in Table 4.1.4 of the Food Building Design Standard (JGJ64-2017), the average ratio of the total area of the kitchen area and food warehouse to the area of the dining area is 1:2. The commercial building area of the project with gas kitchen is 3982.39m², and the dining area of the restaurant requiring gas is about 2654.93m². The average working area of each dining area is 1.5m², and the working area/building area is estimated to be 0.6, so the number of dining seats in the project is about 1,062.

The annual natural gas consumption of catering business in the project is about: $Q = S \cdot Q_C \cdot t / H_L$, where S is the number of seats (each); Q_C is the gas consumption indicator, 8300MJ/(block for commercial buildings•year); t is the annual gas consumption time, year; H_L is the low calorific value of natural gas, MJ/Nm³, which is 35.544MJ/Nm³; Q=1062 *8300MJ/(block • year) * year /35.544MJ/N.m³=247991m³, then the project catering commercial annual natural gas consumption is about 247991m³.

3.4 New water consumption

According to the national main energy conversion index coefficient, the actual consumption of primary energy, secondary energy and energy consuming working quality of the project will be converted. The specific folding coefficient is shown in the following table.

Table 8. Energy conversion standard coal coefficient

Name of the energy	Unit	Fold the coefficient
Electric power	kgce/kWh	0.1229
Natural gas	kgce/ m^3	1.2143
Thermal	kgce/MJ	0.03412
Diesel	kgce/kg	1.4571
Fresh water	kgce/ m^3	0.2571

The main energy used in this project is electricity, steam, new water and natural gas. The energy is converted into standard coal, and the energy consumption is shown in the following table.

Table 9. Comprehensive energy consumption

Name of the energy	Project	In consumption	Fold the coefficient	Energy consumption	Note
1	Electric power	23463600kWh	0.1229kgce/kWh(Equivalent value) 0.3055kgce/kWh (Indifference value)	2883.67(Indifference value) 7168.12 (Equivalent value)	65.1% (Equivalent value)
2	Thermal	36415500MJ	0.03412kgce/MJ	1242.5	28%
3	Natural gas	248000m^3	1.2143kgce/ m^3	301.14	6.8%
4	Diesel	3840kg	1.4571kgce/kg	5.6	0.1%
Comprehensive energy consumption				4432.91 (Equivalent value)	
5	Fresh water	24.72m^3	0.2571kgce/m^3	63.55	

As can be seen from the above table, in the whole energy consumption link, electricity and steam play a dominant role, which conforms to the energy consumption policy advocated by the state.

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