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GREEN AND ENERGY-SAVING TECHNOLOGY IN OLD PORT RECONSTRUCTION: CASE STUDY OF SHANGHAI

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ABSTRACT

This paper introduced the green energy-saving technology in the reconstruction of Huangpu River old port area. In order to facilitate the green energy-saving technology of Shanghai International Shipping Service Center (SSC), we studied the application status of green energy-saving technology and listed the green energy-saving measures used in SSC. By evaluating green measures adopted in Huishan block, the good effect of the project was got. Meanwhile, the broad application prospects of green energy-saving technology was found via the preliminary prediction of the demonstration effect of green building, combined with the analysis of the environmental benefits and market demand of the project. Some suggestions on how to study the old port area in the future were put forward.

Keywords: old port area, green energy saving, low carbon, design, SSC

1. Introduction

With the increase of population and the acceleration of energy consumption, various environmental problems have threatened the living environment of human beings. Energy conservation and emission reduction have become a problem that must be faced. Countries around the world started to realize the importance of energy conservation, environmental protection and sustainable development. As one of the main resource consumers and environmental pollutants, building has become the focus of energy-saving and emission-reduction. To creat architecture which is green, low energy consumption and environmental is the current goal of people.

The purpose of building energy-saving is to ensure the quality and comfort of living, the rational use of renewable resources, and the reduction of energy consumption. That means, in the stage of planning, designing, constructing and using, we should implement building energy-saving standards, adopt low-energy-consuming materials, design rational building structures, and improve the operation efficiency of heating, cooling, lighting, drainage, ventilation systems.

Shanghai Port is a century-old port, Huangpu River Port Area is the most important part of Shanghai Port. For a long time, Huangpu River Port Area, especially the public wharf, has played an important role in the economic development, foreign trade and personnel exchange. SSC is located in the core area of Huangpu River in Hongkou District and has about 550,000 square meters construction area. After completion of SSC, multi-functional business communities such as shipping transaction and shipping office will be formed, so as to attract the headquarters of transnational shipping enterprises and promote the convergence of various shipping economic factors such as shipping transaction and shipping finance.

The fast development of SSC green building will play a positive role in promoting the market demand, encouraging all sectors of society to participate, and further expanding the green building popularity rate. On the other hand, because SSC is located in the riverside area of the city, applying the concept of green building to SSC will improve the quality of SSC, show a good city image and play a positive role in demonstrating.

2. Literature Review

Energy consumption is one of the issues widely concerned by the international community in this day and age[1]. Green buildings, as they require the consideration of resources depletion and waste emissions during their whole life cycle, are being widely promoted around the world[11].In the United States, construction and use of buildings consume 39% of the nation's total energy consumption[2]. Statistics show that buildings are recognized as the largest consumer of primary energy; for example, nearly 30% of the energy consumed in China is used by buildings[11], while 40% in the US and Europe[12]. In the 1960s, Paolo Soleri, a famous American architect, put forward the concept of "ecological architecture" by studying the perfect combination of integrated ecosystem and architectural theory. The birth of this concept brought people into the new field of architecture [3]. In the 1970s, there was an energy crisis in which Earth’s resource supply and environmental health became an increasingly serious problem. At that time, people began to rethink the values of the industrial era and re-adopted the green thinking of ancient agricultural civilizations [13].In the 1980s; people shifted their attention to the historical background and regional differences of architecture and designed a space suitable for human existence according to various factors of life and environment. In the 1990s, the United Nations Conference on Environment and Development was held, which further promoted the concept of sustainable development and made green building an important development direction in the field of architecture [4].

Research on green buildings has received significant attention in recent years[9]. Scholars have studied green buildings from different levels. David Gottfried (2004) pointed out from the cost and benefit point of view that green building will not increase too much cost and payback period will not be too long, but the return on investment will increase greatly[5]. Jonatan Pinkse and Marcel Dommi.se (2008) began from the perspective of practical cases, think that the reason restricting the promotion of green building is the slow promotion of energy-saving technology [6]. Lowe. R (2006) argues that the government mostly puts forward corresponding systems and policies for new buildings, but does not pay enough attention to the green renovation of existing buildings [7]. Diana (2007) believes that in order to promote the development of green buildings, the government should focus on the regulation mechanism, market regulation, fiscal incentive policy, information disclosure and other aspects, they should analyze and compare the cost of different policies, and formulate relatively optimized promotion policies[8]. Cook suggested that all products, services or processes that use fewer resources than current standards and generate less pollution to create value can be named green technologies [10].

Generally speaking, China is a country with relatively poor per capita resources. In order to save resources, we should vigorously promote the development and application of green buildings [14]. Green buildings were first introduced to China in the 1990s[15]. In 1993, the Chinese government recognizes the importance of solving the energy crisis, changing the energy structure, and most importantly, advocating favorable measures for energy conservation [16]. In 2002, China fifirst mentioned “strengthening green building technology”, and the term “green building” began to appear in government documents, opening the way to encourage green development [17]. In 2005, the fifirst international green building conference was held in Beijing [18]. With the deepening of its commitment to green development, China will increase its energy savings and reduce its emissions as a national strategic policy [19]. In 2012, the Ministry of Finance, the Ministry of Housing and urban rural construction companies jointly published opinions about accelerating the development of green building in China [20]. In 2013, Chinese government departments jointly issued a”green building action plan", after which the national Chinese green building action officially kicked off [21].

At present, many green building energy-saving projects have been carried out in China. However, most of these projects are aimed at energy-saving renovation and external construction of existing buildings. The design of internal system is few, and especially, the study of building energy saving in old port area is very few.

3. Green Energy-saving Technological Innovation in the Construction of Old Port Area

3.1 Connotation of Technological Innovation

Technological innovation refers to the innovation of production technology, including the development of new technologies or the application of existing technologies. In the process of green building construction, technology innovation involves the green building innovation of the whole life cycle such as project plan, design, construction and operation. Energy-saving measures include enclosure structure, HVAC system, lighting system and rational application of new materials.

3.2 Innovative building energy saving measures

3.2.1 Architecture Development in Harmony with Environment

According to the site location, sunshine conditions, elevation, body shape and other comprehensive factors, a building coordinated with the environment is designed to better achieve the effect of green energy-saving. It can be measured in five ways: (1) Make full use of the convenient bus resources around SSC, install adequate bicycle parking space, so as to minimize carbon dioxide emissions; (2) Set up the underground garage with low-row parking space; (3) Install a large atrium space indoors with good lighting conditions and wide vision, and install natural windows with mixed ventilation to make the indoor environment better; (4) The exterior

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wall has good thermal performance, which can ensure the indoor effect of warm winter and cool summer; (5) Plant green plants on the roof and install leisure greening outdoors, so as to provide a good leisure and entertainment place for people who work hard in the city. See Figure 1 for details.

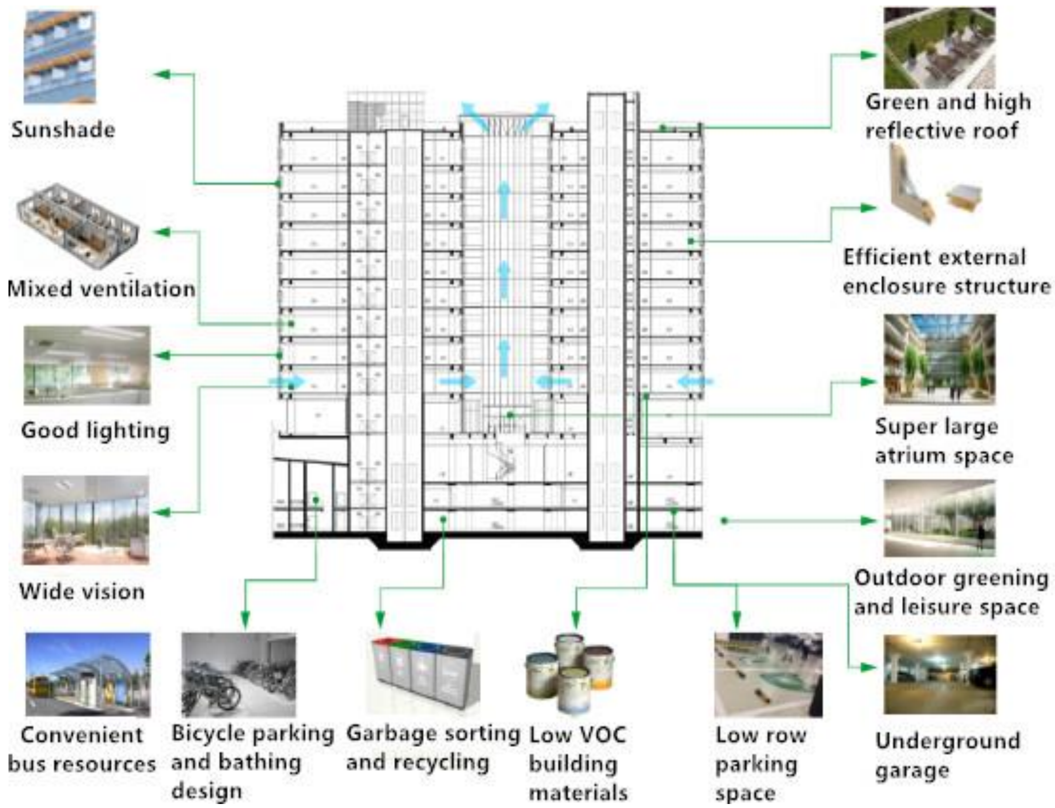

Fig. 1 Architecture Development in Harmony with the Environment

3.2.2 Sustainable Energy System Design

During the process of this project, many optimal designs and innovations of energy systems have been adopted, which can be measured in three aspects: (1) In air conditioning system, VAV air conditioning, CO2 control fresh air, exhaust heat recovery and ice pipe water are adopted. In order to increase the intelligence and adaptive ability of the house, a transition monsoon adjustable system and a fresh air system are designed; (2) In terms of lighting system, SSC mainly adopts efficient lighting controlled by the advanced circuit control system, so as to reduce the waste of energy; (3) Because SSC is close to Huangpu River and water resources are easy to obtain, a river water source heat pump is designed to take heat from river, which greatly reduces power consumption. See Figure 2 for detail.

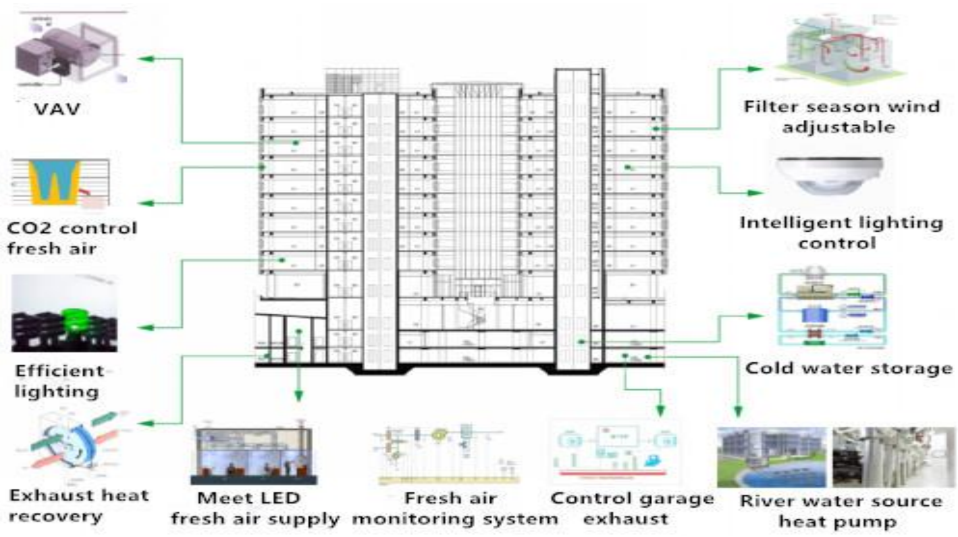

Fig. 2 Design of Sustainable Energy System

3.2.3 Rainfall Flood Control and Water Saving Design

In order to save water, technological innovations have been applied in the project, it can be measured in four ways: (1) Recycle roofing water to supply the yacht harbor basin water source, which can reduce the dependence on Huangpu River; (2) Divert rainwater reasonably, so as to alleviate the impact of rainstorm on city pipelines; (3) Apply permeable ground to reduce the adverse effects of ground hardening, which prevents the form of puddles and pits; (4) Recycle and reuse toilet rainwater, garage washing and irrigation water, so that the waste of water resources can be minimized. As shown in Figure 3.

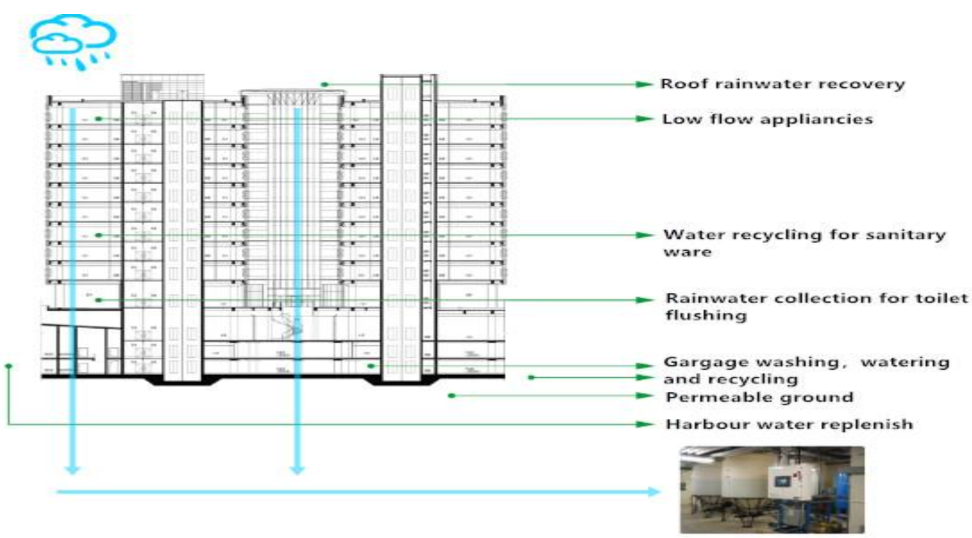

Fig. 3 Flood Control and Water Saving Design

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3.2.4 Indoor environment optimization

Indoor environment mainly includes light, thermal and sound environment. For example, indoor lighting environment means using the lighting artistic language or natural lighting to depict the indoor environment, which creates a harmonious atmosphere. Indoor thermal environment refers to the environmental factors that affect the human body's cold-hot sensation. These factors include air temperature, air humidity, air velocity and radiation heat transfer.

As for exterior decoration of the building, a clay plate glass curtain wall is adopted to enhance the performance against bad weather. The design of strip hollow not only reduces the weight of the ceramic plate, but also improves the air permeability and thermal insulation performance. In addition, the use of virescence and water can reduce site noise. See Figure 4 for details.

(a) Clay Plate Exterior Wall Decoration (b) Virescence and water noise reduction

Fig. 4 Regulation of Microclimate Environment

4. Application of Energy-saving Technology in Huishan Block

4.1 Project Overview

The SSC Huishan Block was originally the third loading and unloading area of Shanghai Port Area, it was built in December 1952, and then rebuilt into Shanghai Port Huishan loading and unloading Company. Over the years, Huishan Handling Company has handled and transported groceries, steel, mining materials and bags, and also transported a certain number of passengers. From 2003, the wharf was no longer in operation and gradually demolished, by the beginning of 2009, it was leveled into open space. This project includes five commercial office buildings, building 13~17. The ichnography is shown in Figure 5.

Fig. 5 Ichnography of Huishan Block

4.2 Energy Conservation and Utilization

4.2.1 Regional Centralized Energy Center Based on River Water Source Heat Pump and Ice Storage

SSC has wide area and multi-functional architectures, and the Huangpu River water is a renewable energy source, so a regional cooling mode combining river water source heat pump and ice storage is adopted.

Because the site is close to Huangpu River, therefore the heating system adopts 12 water source heat pump mainframes with 1750kW heat production, the heat exchanger separates the heat pump evaporator from the river water, meanwhile, adding ethylene glycol non-freezing liquid in evaporator water circle to ensure safety. Air conditioning chilled and hot water are supplied by Jiangshui water chiller and Jiangshui heat pump. The performance parameters of chilled water and hot water chiller are shown in Table 1.

Table 1 Performance Coefficient of Cold and Heat Source Units

Number	Device Type	Rated Cooling Capacity （kW）	Performance Parameter（W/W）	
			Real Device	Standard Requirements
1	Two-mode centrifugal chillers (air conditioning) (4 units)	6330	6.2	5.1
2	Two-mode centrifugal chillers (air conditioning) (1 unit)	3165	6.5	5.1
3	Screw chillers (3 units)	1400	5.1	4.6
4	Screw heat pump (12 units)	1750	5.1	-

According to the analysis and estimation of air conditioning load, meanwhile considering the usability of each functional area, SSC adopts ice storage system. Comparing the hourly energy consumption between ice storage and conventional system in design day, we got Figure 6.

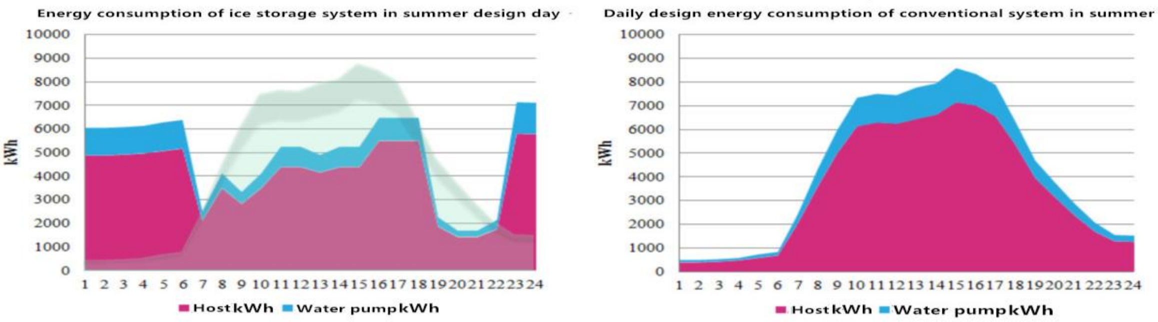

Fig. 6 The Contrast of Design Day Hourly Energy Consumption Between Conventional System and Ice Storage System

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Ice storage operation strategy includes three parts: (1) Store ice in the valley of electricity price; (2) Melt ice to provide cooling firstly at the peak of electricity price; (3) Supply cold air by dual-mode cooler and base host when it is insufficient. The total western, middle and eastern building area of the project is estimated to be about 527720 square meters, so the maximum air conditioning load required for all buildings is calculated to be about 36435kW (10360 cold tons). Because most of the refrigeration unit is in the stage of efficient operation, we assume that the ice storage system provides 30% of the maximum load, therefore the total ice storage capacity is 37800 cold tons. See Figure 7 for details.

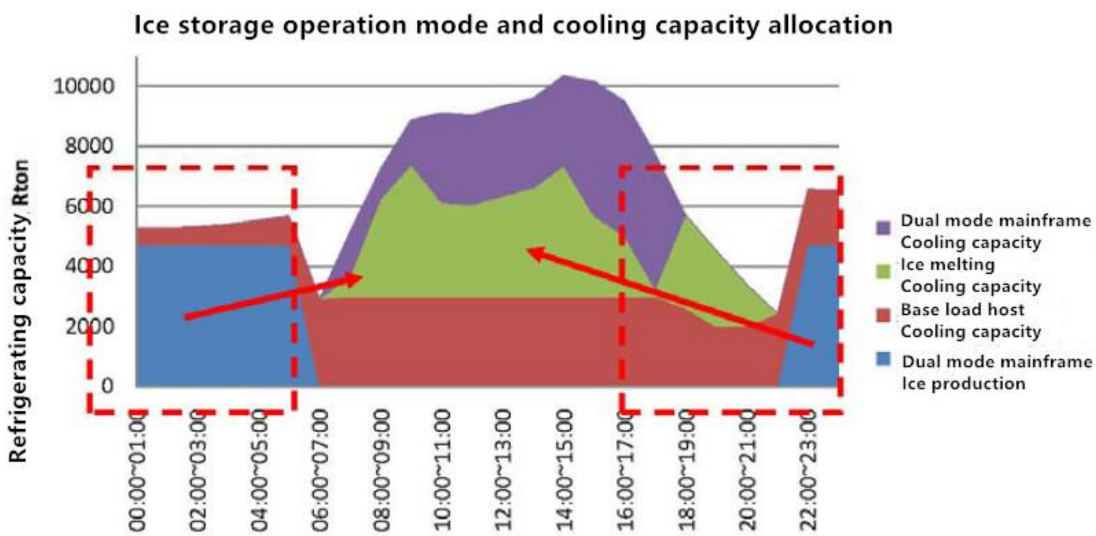


Fig. 7 Hourly Cooling Capacity Distribution of Ice Storage System in Design Day

4.2.2 Energy-saving strategy for air-conditioning terminal

The main building function areas, such as office, conference and commerce all adopt variable air volume system (VAV), which can regulate air volume according to indoor cooling and heating loads. The air handling unit (AHU) is installed in the air- conditioning room of each floor, the fresh air is provided by unit after centralized processing, and the distribution of fresh air is completed through the CAV box which is located at the fresh air entrance of each AHU.

In order to avoid the waste of floor area, in transition seasons (outdoor fresh air temperature is lower than 24°C), CAV valves in fresh air pipe well are fully open and adopting the maximum fresh air running mode. The control strategy is shown in Figure 8.

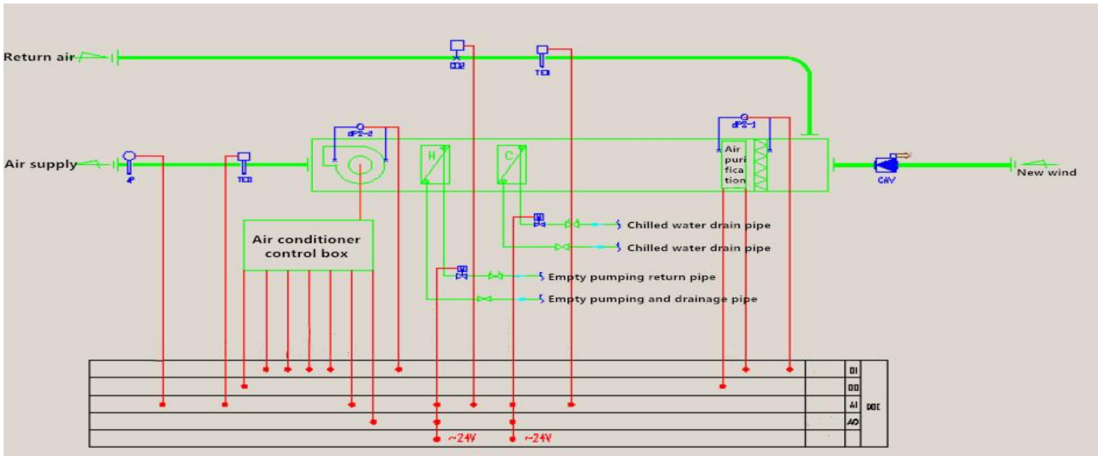
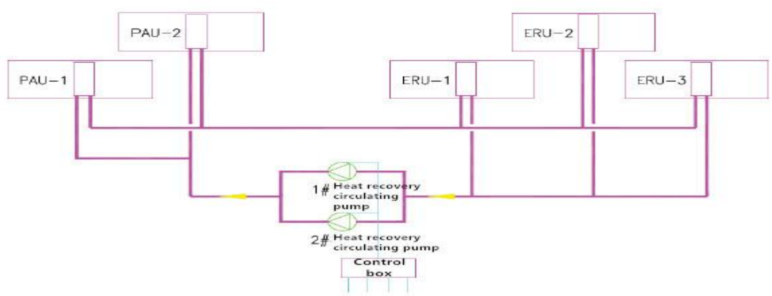


Fig. 8 Control Principle Diagram of Air Conditioning Box

Each building is equipped with exhaust heat recovery system, and considering the distance between fresh airbox and exhaust air outlet, the liquid circulating heat recovery device is adopted (ethylene glycol solution is used to prevent freezing). At the same time, in order to improve the economy of the heat recovery device, the ethylene glycol solution pump is controlled by temperature difference between fresh air and exhaust air.

When the fresh air temperature exceeds exhaust air temperature by 2°C during cooling time, or when the exhaust air temperature exceeds fresh air temperature by 3°C during heating time, the heat recovery solution pump will be turned on. However, in transition season and free cooling season, the heat recovery solution pump will stop running. According to the estimation, the heat recovery device can save 1.5%~2.5% energy. The operation principle of the heat recovery device is shown in Fig. 9.



Serial number	Device name	Service area
1	RP−13A−R−1	New exhaust heat recovery circulating water pump in main building
2	RP−13A−R−2	New exhaust heat recovery circulating water pump in main building
3	PAU−13A−R−1	Office District fresh air
4	ERU−13A−R−1	Office District fresh air
5	ERU−13A−R−2	Toilet exhaust

Fig. 9 Operating Principle Diagram of Heat Recovery Unit (take building 13 as an example)

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4.3 Water Saving and Water Resources Utilization

4.3.1 Water-saving Irrigation System of Virescence

As for roof greening and concentrated green ground, high efficient irrigation systems such as micro-sprinkler irrigation and drip irrigation are adopted, the rainwater is used as irrigation water source.

Automatic control devices such as rain sensor or humidity sensor are used to minimize irrigation water consumption. See Fig. 10 for details.

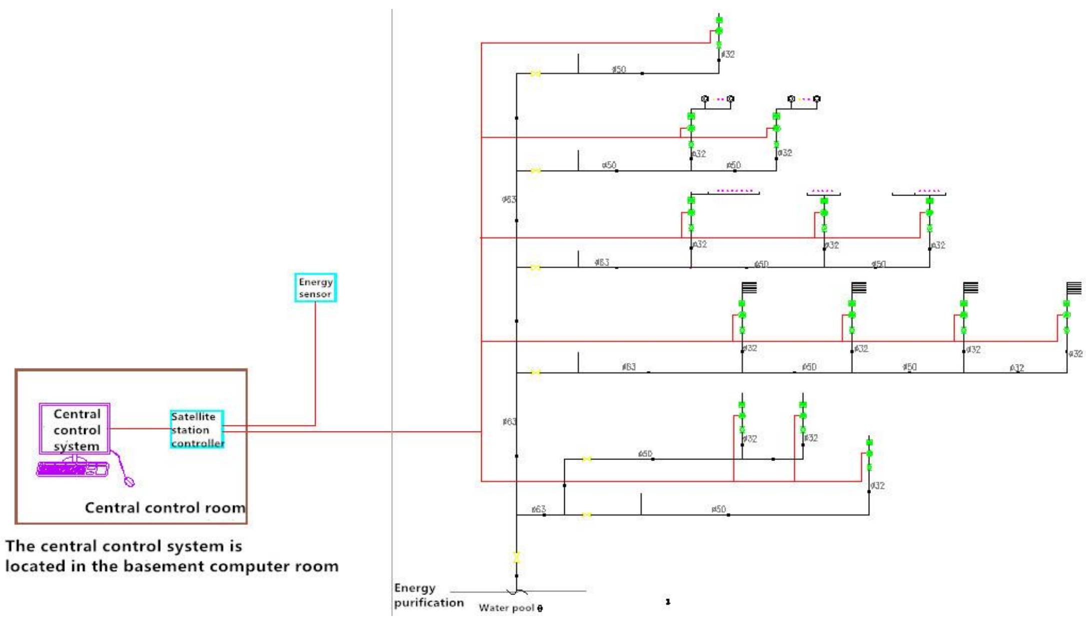

Fig. 10 Principle of Greening Drip Irrigation System

4.3.2 Non-traditional Water Source Utilization System Combining Rainwater, Medium Water and Harbour Pool Water

Reclaimed water system collects, stores and treats various raw water as miscellaneous water (such as toilet flushing, green irrigation, parking garage pavement water and road sprinkling).

The source of reclaimed water mainly come from toilet wastewater and port pool replenishment. Toilet wastewater, port pool replenishment and roof rainwater are firstly recovered to two separate regulating ponds and sedimentation ponds for further treatment, and then they are collected to the same clear water pond.

Rainwater system recover roof rainwater. Roof rainwater is cleaner, so it can be recovered by simple precipitation, filtration and disinfection. The quality of road rainwater is poor and the handling cost is high, so it is not considered in rainwater collection system.

After carrying out water consumption calculation and water balance, the utilization rate of non-traditional water source in the project is 62.9%.

(1) Rainwater collection system
The system collects roof rainwater and harbor basin rainwater as sources. Initially, the site rainwater was abandoned delivered to the stainless steel rainwater collection pond through rainwater collection pipe. Then, the initially abandoned rainwater flow is 5 mm, and the second rainwater within 24-28 hours is not abandoned, it is transported to the clear water tank by the rainwater membrane treatment device. Disinfectant is 10% sodium hypochlorite solution, dosage is 7 mg/L.

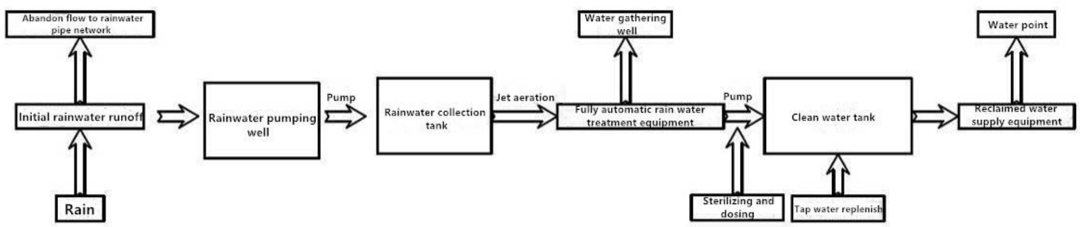

Fig. 11 Diagrammatic Sketch of Rainwater Collection

(2) Reclaimed water recycling system

Firstly, large-particle impurities in harbour pool water or high-quality miscellaneous drainage are filtered by grille, and then delivered to the stainless steel regulating pool which mainly balances water quality and quantity. Secondly, the reclaimed water of regulating pool is lifted into the biological aeration pool by water pump. After a while, the reclaimed water is transported to the MBR membrane treatment device by the jet aeration pump. Finally, after being treated by MBR and disinfected by adding medicine, the reclaimed water can be sent to the stainless steel water tank for use. Disinfectant is 10% sodium hypochlorite solution, dosage is 7 mg/L.

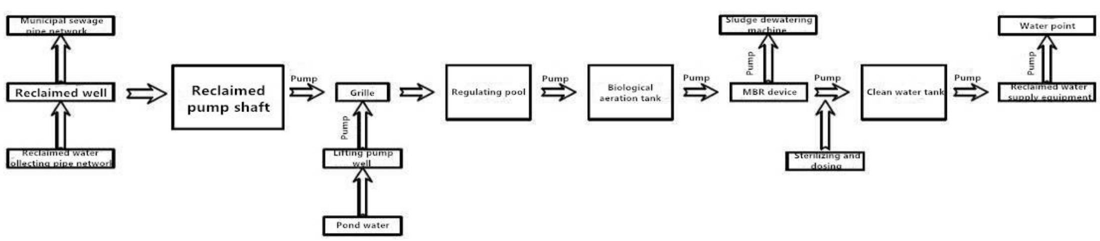

Fig. 12 Diagram of Reclaimed Water Reuse

4.4 Material Saving and Resource Utilization

4.4.1 Optimization of Steel Structure System
SSC is composed of five office buildings. Each office floor is 4.5 meters high, the column spacing is 8.4-9.5 meters.

Four of the office buildings adopt reinforced concrete slab-beam system, the beam is 600 mm high and the slab is 120 mm thick, and a frame-shear wall system is adopted as the lateral load-bearing system. Because of the existence of large-span cantilever, the rest one commercial building adopts the steel-concrete mixed system.

According to the principle of saving material, the final construction drawing design of the tower are compared with many similar projects, it is found that the concrete consumption per square meter can be saved by about 24%, the template consumption can be saved by about 10%, and the steel consumption can be saved by 15%.

A large number of secondary structures (such as partition walls) outside the office building all adopt heavy solid concrete blocks (volume-weight is greater than 18 KN/m). At the same time, considering heat preservation and weight, light sand and concrete blocks are adopted as main wall masonry materials.

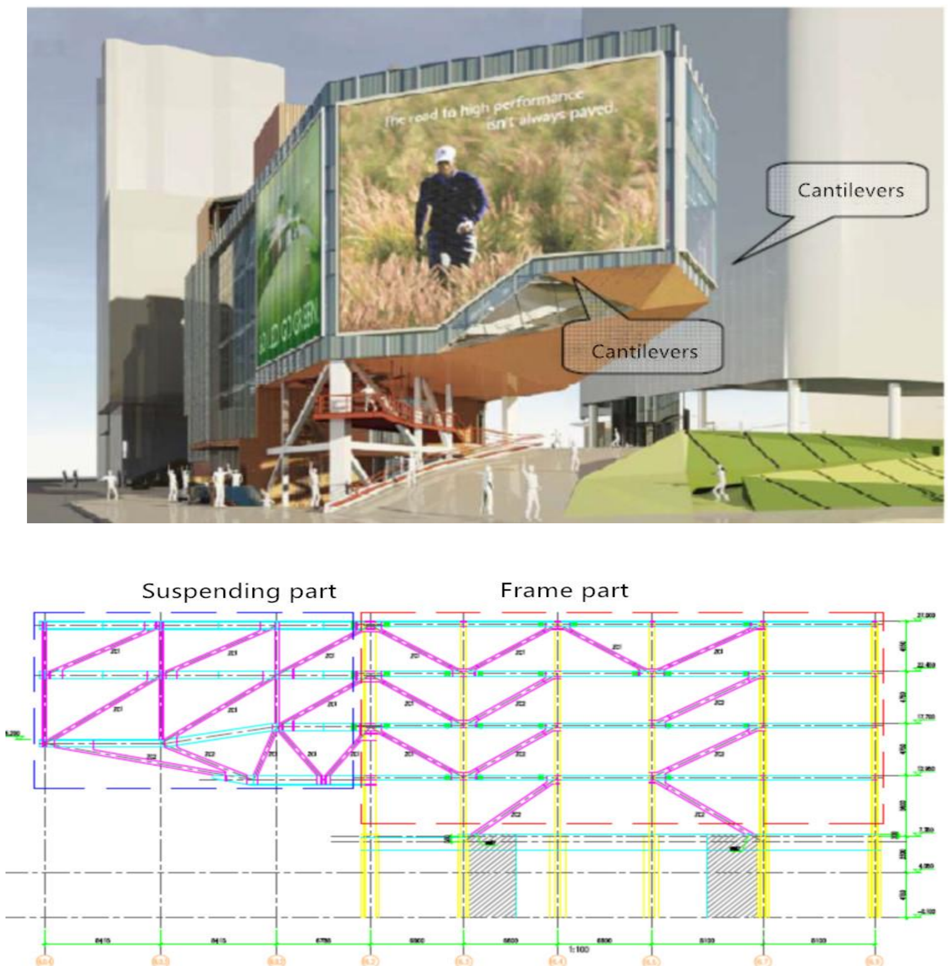

Fig. 13 Effect Diagram of Steel Structure and Stereoscopic Diagram (Building 16)

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4.4.2 Flexible Separation of Indoor Space

Flexible partition is adopted in interior plane, each standard floor of tower building are mainly open office area. As for partition wall of commercial unit, light steel keel gypsum board with segmented removable nodes should be used, in order to facilitate recycling after tenant change.

4.5 Indoor Environment Design

4.5.1 Indoor Natural Ventilation

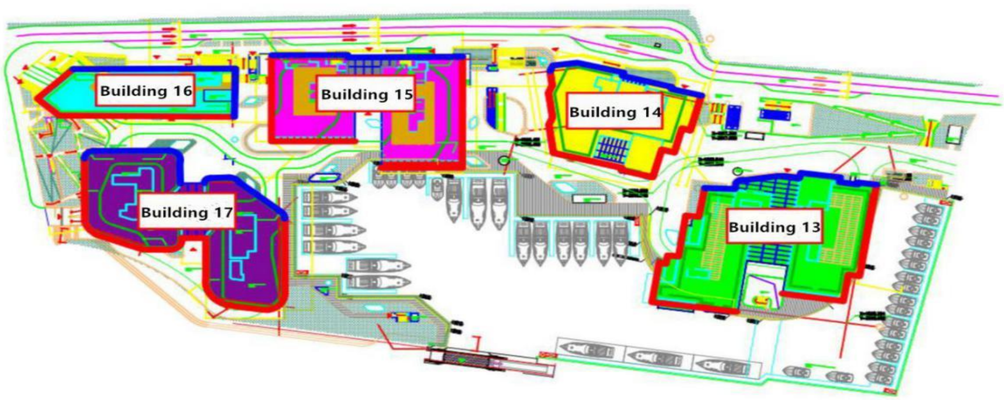
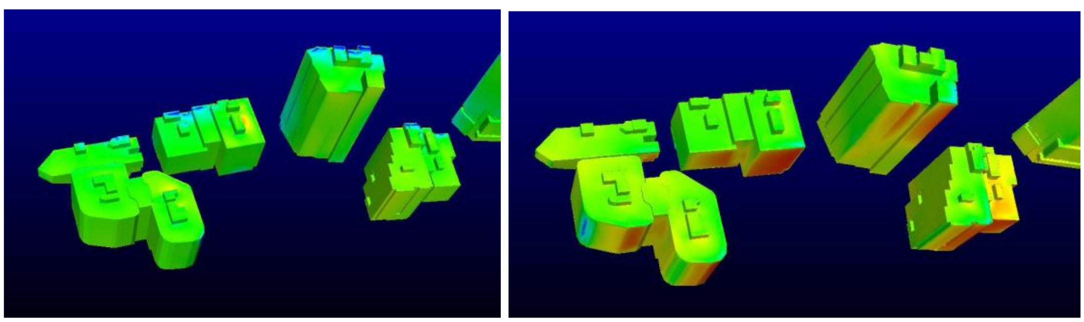


Fig. 14 Location Picture for Each Building

SSC is located on the north bank of Huangpu River, in summer and transitional season, the leading wind direction is southeast. So, apart from building 16, the other four buildings are directly facing the leading wind direction.

The open area ratio of curtain wall is nearly 10%, thus can effectively use the outdoor wind pressure for natural ventilation. At the same time, in building 13, 15, 17, there is a large atrium, it is connected to the surrounding office by open windows, air outlets are installed at the top of the atrium.

The setting of atrium, together with the heat of lamplight, personnel and equipment in the office area, are all contributing to natural ventilation, in the transitional season, it can improve indoor environment and reduce air conditioning load. See Fig. 15 for details.



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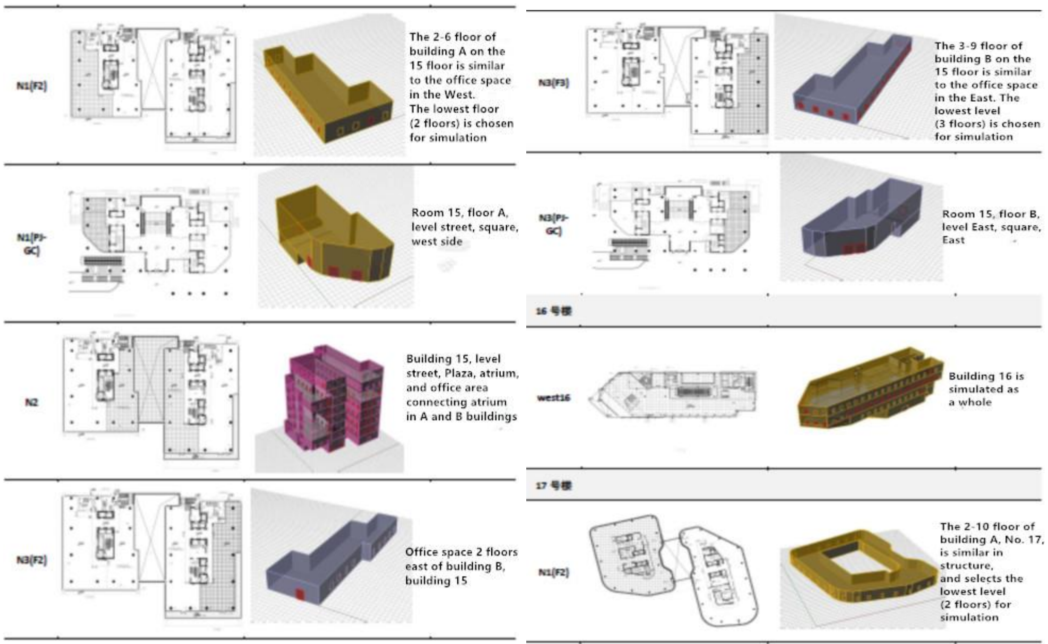

Fig. 15 Simulation of Indoor Natural Ventilation

4.5.2 Natural Daylighting of Underground Space

In order to improve the daylighting of underground space, many measures such as the sunken square, sunken courtyard and daylighting skylight are put to use.

In building 13, 15 and 16, three sunken squares are installed near the commercial retail area. In building 13 and 14, two sunken squares are set near the report hall. In building 17, a sunken courtyard are designed near the report hall. In addition, over the main functional areas (such as commercial retail area, office area and corridor), twenty-four daylighting skylights are installed. See Fig. 16 for details.

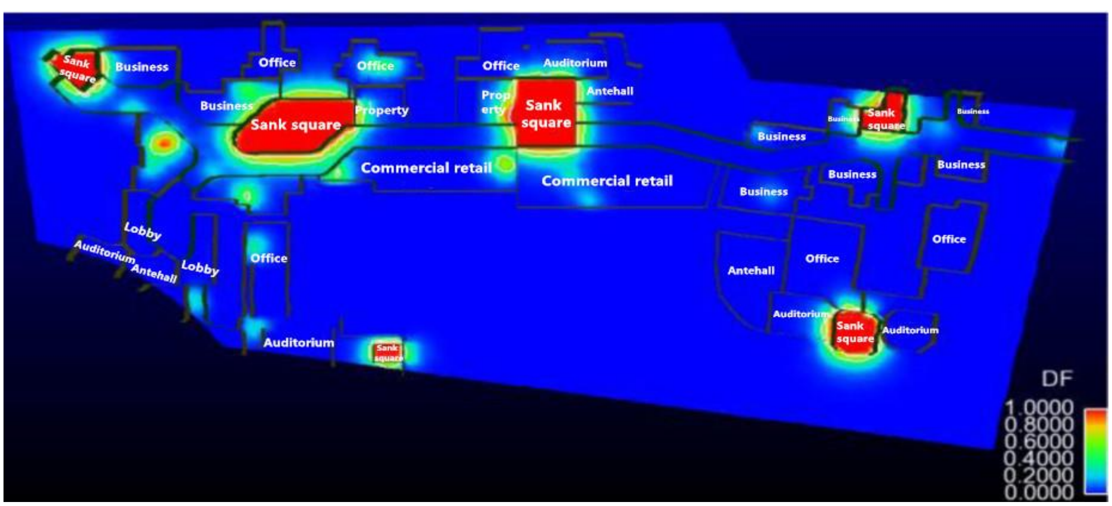

Fig. 16 underground lighting simulation analysis chart

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4.6 Design of Operation Management

4.6.1 Full Energy Chain Real-time Monitoring and Management System for Building Groups

As for water, electricity, gas and other energy loads, a full energy chain real-time energy consumption management system is established. The system includes one main station and four operation substations, so as to achieve the monitoring, management, statistics and control of the energy efficiency of buildings.

This system integrates four parts: (1) Energy consumption management and measurement platform; (2) Energy efficiency monitoring platform; (3) Energy consumption statistics platform; (4) Equipment operation and maintenance platform. So it is helpful to improve the operational effectiveness of buildings.

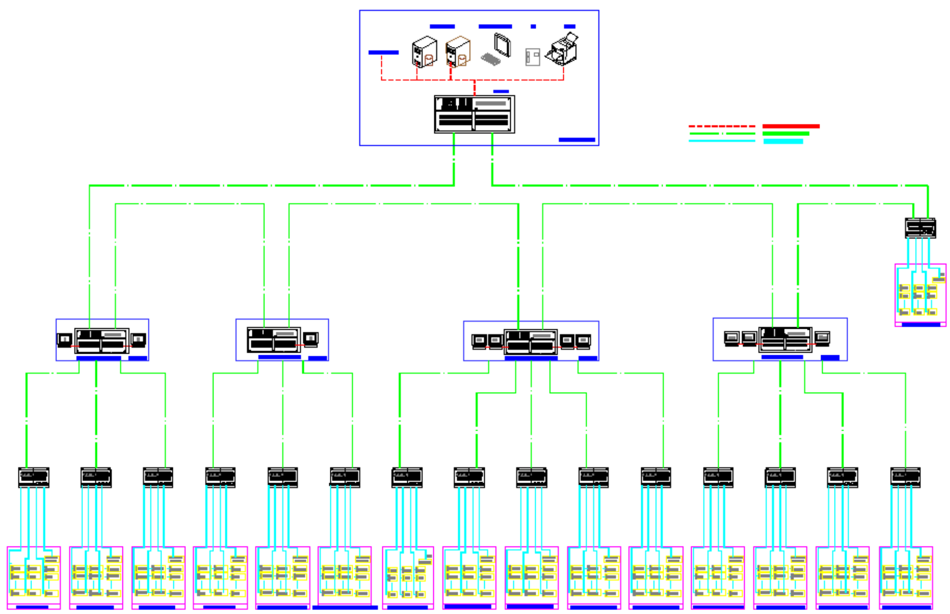

Fig. 17 Topology Diagram of Energy Management System

4.6.2 Building Intelligentialize and BA System

The intelligent building system integrates real-time monitoring system, centralized management system and distributed control system, it supports multiple communication interfaces and protocols, and can integrate all kinds of systems and equipment directly.

It is necessary to set up a centralized BA system, which includes air-conditioning automatic control, water supply-drainage automatic control, power monitoring, intelligent lighting, boiler room, generator set, energy consumption detection system.

The elevator monitoring host has communication interface and can provide access to the automatic control system, which provides convenience for later operation and management.

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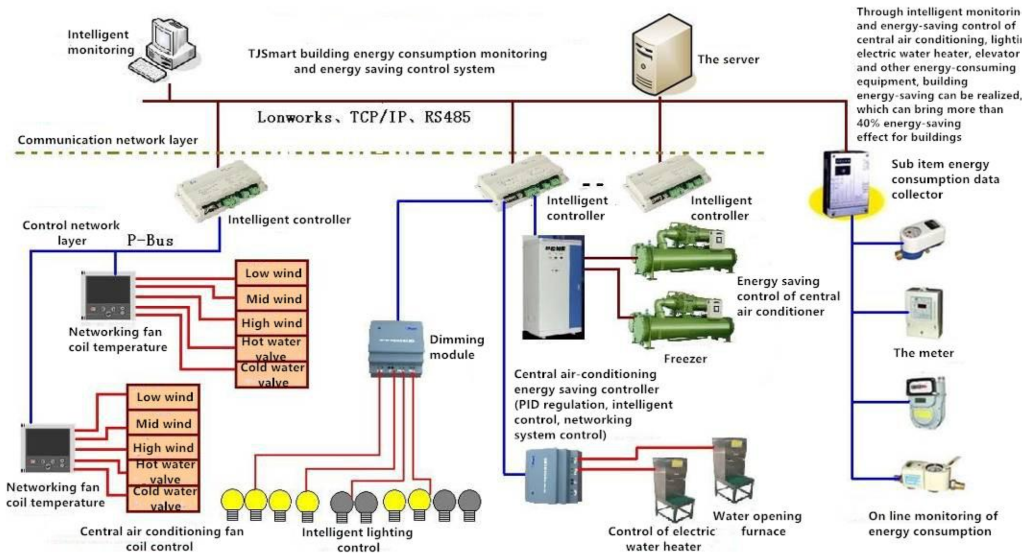

Fig. 18 Diagrammatic Sketch of BMS System Framework

4.7 Effect and Promotion of Green Building

SSC is committed to transforming, upgrading and reconstructing old industrial zones and storage terminals in urban centers, it has explored an ecological and environmental protection way in the transformation and development of old city, which has strong exemplary significance. The green ecological design concept of the project is consistent with China's internationalization orientation and future development trend. The project startes from the demand of green building market and finally returning to the market, so it will provide technical reserve and necessary industry radiation effect for the construction of the whole international shipping center in China.

This project of SSC synthetically applies advanced green building technology, and through some measures (such as the technical design of land-saving, energy-saving, water-saving, material-saving and comfortable environment; the whole process control from construction to operation), it realizes the overall development goal of green building. At the same time, the project guides a new way for new buildings in Shanghai to reduce energy consumption, alleviate resources-environment pressure and achieve low-carbon development.

5. Conclusion

This paper discussed the process of making green transformation and reforming a building into a new core landscape complex in the old port area. The main conclusions are as follows: (1) Through technological innovation, the goal of energy saving, water saving, land saving and material saving was achieved, the due contributions to energy saving and emission reduction has been made; (2) According to local conditions and local materials, energy-saving technological innovations were developed; (3) Taking the Huishan block as an example, firstly the energy-saving effect of green buildings was tested, then the innovation of technology was effectively applied to SSC, thus playing an active role in creating building landmarks and setting up a good model of energy conservation ; (4) By forecasting the demonstration effect of green building, and analysing environmental benefits and market demand, it is pointed out that green energy-saving technology has a wide application prospect.

Further research can be extended and focus on the following aspects: (1) A quantitative comparative study should be conducted through the benefit analysis of energy-saving transformation; (2) Improve the informatization level in the process of green construction so as to carry out dynamic adjustments and guide the transformation work, thus can improve the quality and efficiency; (3) New materials, technology and technics are changing with each passing day. The adoption of more advanced, forward-looking and suitable technology requires more certification and practice.

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