Data Analysis-Based Approach to the Green Retrofit of Existing Public Buildings in Northern China: A Case Study of School Buildings

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Abstract. China's existing public buildings are large in scale and low in energy efficiency. Public institutions with government financial support are the main parts of public buildings. In energy saving and emission reduction, they should be green retrofitted to demonstrate for other types of buildings. Taking school buildings in the North as example, the status of green architectural technologies in existing public buildings are investigated to propose approach to the green retrofit of existing public buildings. The research content includes technologies of saving water, saving land, saving material, and saving energy. According to the results of the survey data analysis, green methods to renovate the existing public buildings in the North are raised, which are strengthening the insulation performance of the envelope structure, paying attention to the application of energy measurement and monitoring technologies, selecting recyclable materials for buildings, attaching importance to the intervention on occupants` water use behaviour, and using underground space according to local conditions. The research results indicate the direction of green transformation of existing public buildings in northern China.

1. Introduction

The main function of public buildings is to serve the public. Most of them are government-funded public institution buildings, such as government office buildings, schools, and hospitals. Building energy consumption accounts for 6.19% of the total energy consumption of the entire society. The construction area of public institutions is several billions square meters. The overall energy efficiency of buildings is low, which hinders the development of green buildings [1]. In the National Action Plan for Green Building, it has been clearly stated that the promotion of green buildings and the requirements for energy-saving reconstruction of existing buildings are required. As the operation costs of public institutions are partly or totally derived from government, the energy and resource conservation are concerned by the entie society. The green retrofit of existing public institution buildings should reasonably control costs, select appropriate technologies to use government

investment efficiently [2]. In order to implement the Green Building Action Plan and create conservation-oriented public institutions, it is of great significance to promote the green retrofit of public institutions.

2. Method

This research is mainly aimed at the existing public buildings' green retrofit needs. By investigating the status quo of the application of green technologies in public institutions, the gap between them and green buildings is analyzed to determine the green transformation methods of existing buildings in public institutions. Focusing on school buildings, technologies for energy conservation in existing buildings, renewable energy applications, water-saving and comprehensive utilization of water resources, green building materials, waste recycling, and environmental quality control are researched to provide basic data for the following studies. China's building climate division includes severe cold regions, cold regions, hot summer and cold winter regions, hot summer and warm winter regions, and temperate regions. The survey area is severe cold regions and cold regions. The thermal division indicators are shown in table 1 and the geographical distribution is shown in figure 1. The survey content includes basic building information, energy-saving technologies for building envelopes, HVAC energy-saving technologies, electricity-saving technologies, water-saving technologies, land-saving technologies, and materials-saving technologies.

Table 1. Thermal division indicators and representative cities in severe cold region and cold region [3]

Thermal division	Major indicators for thermal division	Representative cities
Severely cold region	The average temperature in January ≤ -11°C The average temperature in July 25°≤C	Mohe, Tuoli, Heihe, Nenjiang, etc.
Cold region	The average temperature in January -11～0°C The average temperature in July 18～28°C	Chengde, Zhangjiakou, Taiyuan, Jinzhou, etc.

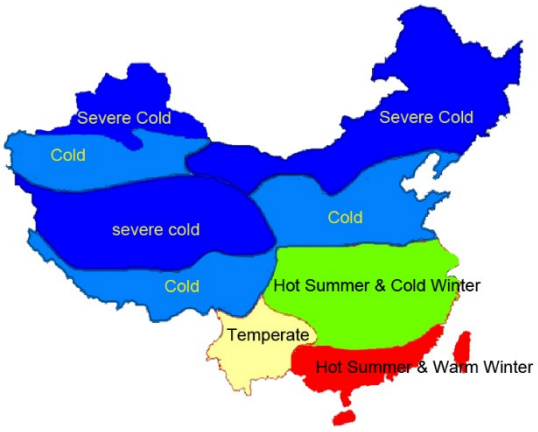

Fig.1. Thermal design division of buildings in China [3]

3. Results and discussion

3.1. Status of green technology of existing public buildings in the North

A total of 72 schools were surveyed. Energy-saving and water-saving technologies are widely used. There is no application of land-saving technology and indoor/outdoor environment improvement technology. The material saving technology is mainly the saving of the office process.

3.1.1 Application status of water-saving technology. Most of the buildings has installed the water-saving appliances and adopted water-saving irrigation methods. Most of the buildings adopted rainwater collection and utilization measures, and some of them installed middle water recycle system. The application of various types of technology is shown in table 2.

Table 2. Water-saving technology

Technology	Sample amount
Water-saving appliance replacement	46
Green irrigation	30
Water-saving operation management	3
Non-traditional water use	35

3.1.2.Application status of materials-saving technology. At present, school material-saving technologies are mainly focused on the collection and disposal of used materials, office-materials-conserving, paperless office and the reduction of the use of disposable products.

3.1.3.Application status of energy-saving technology. Energy-saving technologies in school reconstruction mainly include energy-saving technology of envelope, energy saving of HVAC systems, power distribution and Lighting renovation, measurement and monitoring, and renewable energy utilization. In addition, there are energy-saving office equipment, canteen stoves and exhaust system conservation, energy saving of electric water heater, vehicle fuel economy and vehicles fuel efficiency. The proportion of each type of technology is shown in table 3.

Table 3. Electricity-saving technology application ratios

Technology	Ratio
Energy saving technology of building envelope	17%
HVAC energy-saving technology	19%
Lighting energy-saving technology	38%
Renewable energy technology	15%
Energy measurement and monitoring technology	11%

3.1.3.1 Energy-saving technology of envelope. Energy-saving technology of envelope, roof insulation, replacement with energy-saving external windows. Some buildings fixed shade. The proportion of each type of technology is shown in table 4.

Table 4. Energy-saving technology of envelope

Technology	Sample amount
External wall insulation	20
Roof insulation	12
External window replacement	18
Shade	4

3.1.3.2 Energy-saving in HVAC system. Energy-saving technologies for heating and air-conditioning systems are mainly energy-saving retrofit of cold and heat sources (Coal replacement by gas, frequency conversion of chiller units, boiler heating climate compensation, time-sharing control and zoning control etc.), energy-saving operation management, and energy-saving renovation of bathrooms. In addition, there are heating pipeline replacement and insulation, air conditioning and cooling equipment replacement, heating metering and other measures. Some schools have carried out split-air-conditioning control transformations. The percentage of each type of technology is shown in table 5.

Table 5. Energy-saving technology of envelope

Technology	Sample amount
Coal replacement by gas	11
Frequency conversion of chiller units	6
Split-air-conditioning control transformations.	2
Frequency conversion of pump and fan	5
Heating pipeline replacement and insulation	6
Energy-saving renovation of bathrooms	8
Cooling and heating metering	6
Air conditioning and cooling equipment replacement	6
Energy-saving operation management	11

3.1.3.3 Power distribution and lighting. The surveyed objects generally carried out lighting energy-saving reforms, for example using energy-saving lamps and transformation of public area lighting control systems. Some buildings also install lighting energy savers. Smart power system is used for student dormitories and office electricity to control in a time-sharing manner. Some buildings replaced transformer, retrofitted power distribution systems, replaced elevator or adopted energy-saving operation measures. The percentage of each type of technology is shown in table 6.

Table 6. Energy-saving technology of power distribution and lighting

Technology	Sample amount
Energy-saving lamps	57
Intelligent Lighting Control	50
Lighting energy savers	3
Transformer replacement	2
Power distribution systems energy conservation control	1
Elevator energy conservation	5
Intelligent power system	4

3.1.3.4 Renewable energy use. Solar and heat pump in schools are used in combination with hot water system. The second largest quantity is solar street lights. Solar photovoltaic power generation and

ground source heat pump technology are also used. The proportion of each type of technology is shown in table 7.

Table 7. Renewable energy technology

Technology	Sample amount
Solar photovoltaic power generation	5
Solar heating water	11
Breeze power	1
Ground source heat pump	5
Solar street lights	8

3.2. Green retrofit way of existing public building in the North

The green retrofit of existing buildings should follow the principle of adapting to local conditions [4], [5], emphasize the effectiveness of technology applications and select green building technologies that are suitable for local climate characteristics and architectural features. Through investigation, it is found that the school with good sense of green ecology, has some achievements on the green renovation of the building, but there are also some deficiencies. According to the results of the survey data analysis, the following green update approaches are proposed.

3.2.1. Strengthen the insulation performance of building envelope. As the northern part of the winter heating energy consumption accounts for a large proportion, external walls, roofs, doors and windows insulation measurements reduce the building heat consumption index greatly. It is a significant effect of green energy-saving technology.

3.2.2.Pay attention to the application of energy metering and monitoring technology. Due to the lack of refined energy data, it is impossible to clarify the effect of individual energy-saving measures according to the survey. What's more important is that the application effect of building energy-saving technologies is affected by the operation and management. Furthermore, the appropriate operation mode ensures the realization of the desired goals of these technologies.

3.2.3.Select reusable materials for building renovation. Existing buildings have limited in saving materials. It is suitable to choose recyclable materials during the renovation process. The quantity of garbage of construction in China every year is huge. Therefore, the disassembled parts should be recycled fully in order to reduce the environmental impact of construction waste.

3.2.4.Pay attention to the intervention on water use behaviour of occupants` in building. Water consumption in buildings is affected not only by the use of water equipment, but also by the people water use behaviour. Schools themselves are responsible for educating people. They should cultivate students' awareness of saving, establish a correct energy resource consumption concept, and advocate a green lifestyle.

3.2.5.Utilize underground space according to local conditions. Existing buildings are limited in terms of land conservation, and there are few applicable technologies. What needs to be emphasized is that underground space couldn`t be exploited forcibly just only to satisfy the land-saving indicator requirements of green building. It need to evaluate the feasibility and suitability of the program, combining various factors

4. Conclusion

Through the investigation of the existing school buildings in the north, the application of green energy-saving technologies is concluded. The sample is outstanding in the application of energy-saving technologies. All the surveyed subjects have applied energy-saving technologies. Water-saving technologies are widely used. Material-saving technologies are concentrated in the field of office supplies. Land-saving item need to be improved. According to the results of the survey data analysis, green methods to renovate the existing public buildings in the North are strengthening the insulation performance of the envelope structure, paying attention to the application of energy measurement and monitoring technology, selecting recyclable materials for building renovation, attaching importance to the intervention on occupants` water use behaviour in the building and using underground space according to local conditions. The research results would provide positive suggestions for the green renovation of existing public buildings in future.

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References

[1] Deng Q Q, Song B and Hu Y B 2016 Green reconstruction technology of typical public institution building and the development of optimization tool *J. Building Energy Efficiency.* **44** 84-7+91

[2] Wang J, Li X P and Li H F 2017 Policies, standards, typical cases and development trends of comprehensive reconstruction of public buildings *J. Construction Science and Technology.* (11) 12-15

[3] Ministry of housing and urban-rural development of the People`s Republic of China 2005 *Code for design of civil buildings GB 50352-2005* (China architecture & building press) 5

[4] Feng G H, Wang Y H and Yu S 2015 Green retrofit survey and analysis of public institution building in Liaoning province *J. Journal of Shenyang Jianzhu University.* **6** 541-46

[5] Salvalai G, Malighetti L E, Luchini L and Girola S 2017 Analysis of different energy conservation strategies on existing school buildings in a pre-alpine region *J. Energy and Buildings.* **145** 92-106