A review of the application of renewable energy in the design standard system of public buildings in China

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Abstract. Energy consumption in building sector remains high. Utilizing renewable energy in buildings can help to reduce the consumption of conventional energy. Through the research on the current standard system of public building design and related literature in China, this paper classifies the main standards involved in the common design process of public building. It aims to summarize the characteristics and shortcomings of renewable energy utilization in the field of public buildings in China, and put forward some suggestions. This paper presents the main technical contents and evaluating index system of the renewable energy utilization. It can be concluded that the practical existing problems are the weak connection between renewable energy utilization and architecture design. It is suggested that consideration of renewable energy application in the whole design process should be strengthened, and development suggestions of climate and site resource and energy conditions should be added.

1. Introduction
Nowadays, the building sector has become one of the biggest contributors towards energy consumption. In China, the building sector consumed 899 million tce, accounting for 20.6% of the national overall energy consumption in 2016 [1-5]. The energy consumption per unit building area of domestic public buildings is more than twice higher than residential buildings [6-7]. Renewable energy can help to mitigate the tension between the energy demand and public concerns on environmental pollution with rapid development. As in Figure 1, China ranked the third in the use of renewable energy in the world. However, it’s a very big disparity in the application form of renewable energy. Small hydropower is more frequently used than photovoltaic and wind power, which are more closely integrated to buildings.

Figure 1 World renewable energy distribution [8]
In fact, the application of renewable energy in buildings is mainly limited to solar energy, including photovoltaic and solar thermal, and ground source heat pumps using temperature difference between shallow soil and surface water. Renewable energy application will be an important part and development direction of green building design and evaluation. [9]

Research on renewable energy in building standards is now insufficient in China. This study aims to investigate the situation of renewable energy by analysing the relevant design standards for energy efficiency of public buildings. And then proposing some suggestions to promote the use of renewable energy in the design of public buildings.

2. Current status on green building design standards in China

Standards can be divided into national, trade, local/provincial and enterprise. The standards of public building design, which basically covered architecture design, construction, acceptance, operation, test and energy-saving construction, are the basis of public building design in China.

The main standards and regulations considered in the design process of public buildings will be analysed, including general standards and principles related to specific building functions. It totally includes 5 national standards and 15 industrial standards such as the national standard Design standard for energy efficiency of public buildings and trade standard Code for green design of civil buildings.

The main relevant standard for energy-saving design in public buildings is the Chinese national standard Design Standard for Energy Efficiency of Public Buildings GB50189-2015. In terms of regions, mostly provincial-level regions (including provinces, municipalities, autonomous regions and special administrative regions) already have respective corresponding local standards or specific implementation rules, which are the main standards and specifications for energy conservation design of public buildings in each provincial-level regions.

3. Main contents and features of the selected standards

3.1. Features

The features of current Chinese design standards for public building could be deduced as follows:

(1) Most of the national and trade standards of public building design still focus on basic design principles or functions and streamline design. Only Design standard for energy efficiency of public buildings GB50189-2015, Technical code for the retrofitting of public building on energy efficiency JGJ176-2009 and Code for green design of civil buildings JGJ/T229-2010 are focused on energy saving design of public buildings. However, the last two codes were issued before 2010.

(2) Many of the energy efficiency design standards or implementation rules for local public buildings were issued and implemented earlier than 2010, which has not been updated for many years.

3.2. Correlation and Index system

Figure.2 and Figure.3 show the number and correlation of the provisions of renewable energy in each standard of national and industrial. The provisions in the standard are the specific contents below the chapter catalogue in the standard level (e.g. 5.4.1), and the quantity reflects the consideration of renewable energy utilization in a standard. In the design standards, the correlation of the use of renewable energy is based on the Score. It is whether the three items are related to hot water, cold and hot air conditioning sources, and power generation. 0 points are scored for no mention, 1 point for mention, and 2 points for specific content. Taking the sum of the three scores, it can reflect the relevance between the specific provisions of a standard and the utilization of renewable energy.
It’s concluded that the main relevant national and trade standard is Design standard for energy efficiency of public buildings GB50189-2015, Technical code for the retrofitting of public building on energy efficiency JGJ176-2009 and Code for green design of civil buildings JGJ/T229-2010, which are consistent with the focus of their respective standards. It can be seen that in the current design standard system, other design standards are hardly reflected. This reveals the disconnection between architectural design and the design of energy conservation and renewable energy utilization.
Figure 5 Correlation degree of renewable energy of standards in provincial-level regions

Figure 4 and Figure 5 shows the number and correlation of the provincial-level regions. Although most provincial-level regions have issued local public building energy conservation standards corresponding to the national standards, due to climate, regional conditions, resources, economic development and other factors, various local public building energy conservation standards pay different attention to renewable energy. This reflects the uneven development of renewable energy in different places.

3.3. The main technical contents

Figure 6 Distribution of relevant chapters of renewable energy

The top three standards with high correlation will be as examples to show the analysis and arrangement process and main statistical contents of the provisions related to renewable energy in the design standards. In addition to the number of relevant provisions and the relevance score, it shows the specific section distribution of renewable energy related content of each standard, that is, where the utilization of renewable energy is considered. Its distribution statistics can be seen in Figure 6.

Although most of the standards include renewable energy in the equipment, hot water and air conditioning sections, the general provisions are less. While only a few standards have a separate section on renewable energy, there are generally more relevant provisions. However, it’s a lack of consideration on the use of renewable energy and site resources in the process of building and site design.
Then, the key contents of renewable energy terms is summarized, as a total of five kinds of situations: Just mentioned should as far as possible or use (Mentioned); As a conditional priority (Priority); Specific to the system of the selection (Selection); Design and construction should be considered and the building integration (Integration); Puts forward the evaluation or calculation index (Index). The distribution of these situations can be seen in Figure 7. Most of the provisions focus on the "Mentioned" and "Selection" types, that means renewable energy can be used (or should be used) when conditions permit, or what kind of equipment or what type of heat and cold source should be selected. However, most of the content of this part focuses on the overview and professional design of HVAC system and water supply system, which is not enough closely related to the architectural design process. The two items that are really closely related to the architectural design process are: Integration, which means appropriate to adopt an integrated system or design synchronously with the building, and Index, which means how or what indexes should be considered in design, but these clauses is relatively less.

Figure 7 Distribution of main contents of renewable energy

It also summarizes the forms of energy concerned with the provisions of the standards, including: heat pump systems, solar thermal utilization, solar photovoltaic power generation, wind power and other energy utilization, as well as the overall overview of renewable energy. The distribution of renewable energy forms can reflect the focus and concerns of the emerging standards system. The distribution can be seen in Figure 8. Most of the provisions focus on the use of heat pump systems and the overview of the application of renewable energy, while insufficient consideration is given to the application of solar photovoltaic, and even less consideration is given to wind and other renewable energy.

Figure 8 Relevant form of renewable energy
4. Problems and proposal

Most of the existing energy-saving designs focus on the thermal insulation design of building envelope and the design of natural lighting and ventilation, so as to achieve the goal of energy saving of 50% or more. However, insufficient consideration has been given to "more resource", ignoring that renewable energy can reduce building energy consumption, and no design process and system has been formed to consider and utilize renewable energy. At the same time, the content closely related to renewable energy is more inclined to system selection or equipment itself, which is not closely related to buildings and design. Last, development is uneven in different regions and different forms of energy. Some proposals are shown:

1. The research and technology on integration of renewable energy in buildings needs to be further developed in China.
2. It needs a complete national standards and industrial standards of related technologies and products, and especially the site resources in the early and middle design process;
3. The building safety system for renewable energy products as well as the service life, effective operation and maintenance are inadequate. The phenomenon of wind and light abandoning occurs;
4. The high initial cost of renewable energy compared to the conventional energy needs to be solved. The equipment imported overseas cost more than those purchased locally. And the lack of effective electricity price, subsidies and other policy support limited the extensive utilization of renewable energy.
5. It is also necessary to supplement specific standards or guidelines in the whole design process based on the climate, environment and resources of different regions in the design, and appropriate forms of renewable energy utilization should be selected according to different regions and building types.

5. Conclusion

Using renewable energy in public buildings is a significant way to reduce consumption of conventional energy. This paper coordinates the current system of public building design standards for the utilization of renewable energy and analyses the related provisions. In the architectural design progress, only three national and trade standards involve a large number of renewable energy application provisions. At the same time, the content of renewable energy also focuses on the selection of cold and heat sources for HVAC equipment and other systems, which is weakly related to buildings and architectural design process. It reveals the disconnection between current architectural design and renewable energy utilization design. However, many local standards for energy conservation have not been updated for many years. Thus, the whole standard system of public building design needs to be sorted out and developed to enhance the application of renewable energy. This paper provides a comprehensive and systematic reference for the building application of renewable energy and the development of public building design process in China.

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