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IMPROVING THE ENERGY EFFICIENCY OF LOW-RISE BUILDINGS IN RURAL CHINA

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Abstract

Approaches to the formation of energy-saving (passive) houses in rural areas of China are considered. Practical recommendations for the realization of such houses are offered.

Keywords: passive house, energy saving, insulation

Introduction

With the continuous advancement of the country's poverty alleviation and rural revitalization, the rural economic income has continued to increase, and the living standards of farmers have continued to improve. Because rural houses are usually single-family buildings, the surroundings are exposed to the air environment, the existing buildings and new buildings have poor thermal insulation performance, backward heating facilities, extremely low thermal efficiency, and huge energy consumption and carbon dioxide emissions of individual buildings. Environmental pollution has caused huge pressure. According to statistics and forecasts [1], in 2020, about 560 million people will live in rural areas, and the rural construction area will reach 25.1 billion m^2. The total annual coal consumption is 178 million tons. At present, China proposes to achieve a carbon peak by 2030 and carbon neutrality by 2060. Therefore, how to make good use of clean energy, reduce the energy consumption of rural dwellings, reduce carbon dioxide emissions, improving people's living comfort is an important way to achieve carbon peaking and rural revitalization.

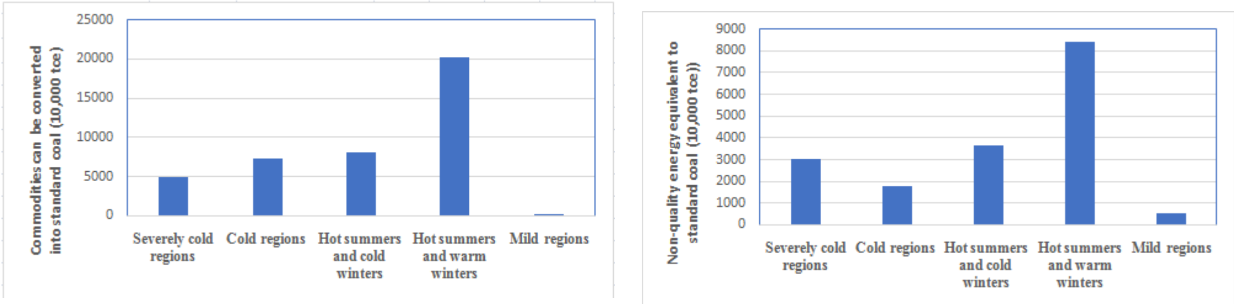
Results of the study

1. The world's energy consumption and carbon dioxide emissions continue to increase and decrease

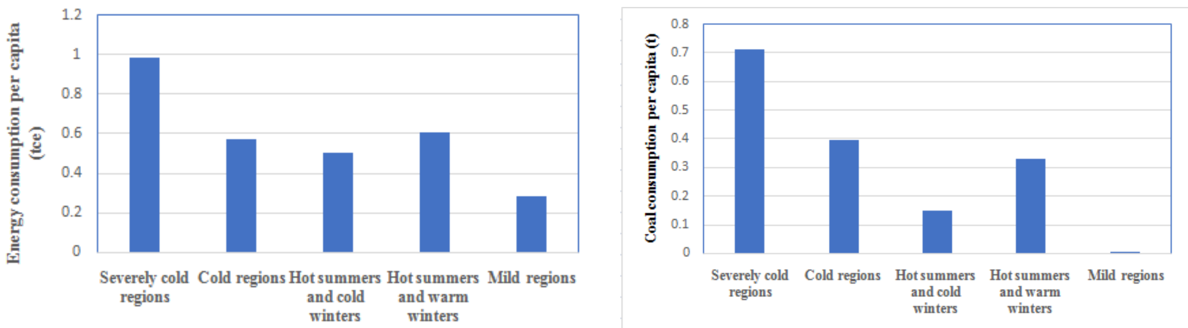
With the rapid development of science and technology in the world and the improvement of the economic level of various countries, human beings' demand for energy continues to increase, especially the rapid growth of fossil energy has led to a rapid increase in carbon dioxide emissions, and the greenhouse effect has had a huge impact on human economy and ecology. Statistics show that in 2020, the total global energy consumption will reach 199.2tce, and oil still accounts for the largest share (31.2%) in the energy structure. Coal is the second-largest fuel in 2020, accounting for 27.2% of the total primary energy consumption, with a carbon dioxide emission of 100t. In China, the total primary energy consumption is 146.46EJ, and coal accounts for 57%. Emissions continued to grow for the fourth consecutive year, with an increase of 0.6%, while carbon emission intensity decreased by 1% [2].

2. China's rural energy consumption is huge

According to the basic data provided by the "China Statistical Yearbook 2020", the total domestic energy consumption in China's rural areas in 2019 is about 311 million. The energy consumption is mainly used for heating, air conditioning, cooking, and daily electricity consumption. Commodity energy such as energy, electricity, and non-commercial energy such as wood and straw, combined with the statistical data of the China Building Energy Conservation Annual Development Research Report [3], Figure 1-1 shows the consumption of different energy types in rural areas in severe cold regions, cold regions, regions with hot summers and cold winters, regions with hot summers and warm winters, and mild regions.



(a) Rural commodity energy consumption by climate zone (b) Rural non-commodity energy consumption by climate zone



(c) Energy consumption per capita by climate zone (d) Coal consumption per capita by climate zone

Figure 1-1 Diagram of energy consumption by different types of energy in rural areas of various provinces and cities in China

From Figure 1-1, the energy consumption of each climate zone shows that the total energy consumption in the economically developed and densely populated areas in the south is relatively large, and electricity accounts for the largest proportion of energy consumption. The per capita energy consumption and per capita coal consumption in the severe and cold northern areas The consumption of commercial energy is mainly coal consumption for heating in winter, so it is of great significance to solve the problems of energy saving and energy-free heating in northern rural dwellings in the context of carbon peaking and rural revitalization.

3. The task of energy saving of existing buildings in rural areas is arduous

According to the International Energy Agency's statistics on energy use and emissions in the global field, the construction and operation energy of the construction industry accounted for 41% of the global energy consumption in 2018. and operation energy accounts for 36% of the total social energy consumption. In 2018, the total life-cycle carbon emissions of buildings nationwide were 4.93 billion tCO_2, accounting for 51.2% of the national energy carbon emissions. The carbon emission in the building operation stage is 2.11 billion t CO_2, accounting for 42.8% of the carbon emission in the whole life cycle of the building, accounting for 21.9% of the national energy carbon emission, of which: the energy consumption of rural residential buildings is 237 million tce, accounting for 21.9% 23.7%, and the carbon emission of rural residential buildings is 437 million t CO_2, accounting for 20.7% [3]. In the rural areas of northern China, the existing single-family buildings have poor thermal insulation performance, and the heating method in winter is mainly coal-fired.

4. Passive houses are the foundation of nearly zero energy building

30 years ago, the concept of the passive house was first proposed. European countries used various passive energy-saving technical means to build a passive house. It was built in Darmstadt, Germany in 1991. Building energy-saving 90% [4]. In China, many researchers have explored and practiced the engineering application of passive houses [5-9]. At present, there are only a handful of engineering examples in the renovation of passive houses in my country, especially the renovation of office buildings [10-14]. Since 2017, China has started to pilot clean energy for heating in winter in the northern region. The government subsidizes about 80 billion yuan to promote the use of clean energy[15]. Coal to electric heating, coal to the heat pump, coal to biomass, and solar energy can complement each other. Various alternatives to clean energy have played a good role in reducing carbon dioxide emissions and environmental pollution, but two key problems have not been solved. Second, most of the models are inconsistent with rural living habits and energy use status to varying degrees, and the problem of large-scale promotion has not been solved.

5. Energy saving is still the theme of nearly zero energy building realization

After 2015, the Ministry of Housing and Urban-Rural Development promulgated the "Technical Guidelines for Passive Ultra-Low Energy Green Buildings (Trial)", "Design Standards for Energy Conservation of Residential Buildings in Severe Cold and Cold Regions" JGJ 26-2018 "Technical Standards for nearly zero energy building " Energy-saving standard systems such as GB/T 51350-2019 and "Near-Zero Energy Building Testing and Evaluation Standards" (T/CECS 740-2020) provide specific practices and methods for passive house design, construction, quality control, and testing and evaluation. It is of great significance to guide the practical implementation of passive house technology, but there is very little research and practice on the passive energy-saving renovation of active buildings, especially in the vast rural areas, and no corresponding standards have been formed. At present, China is in the process of rural revitalization, and the government will invest a lot of money in rural areas, which makes the energy-saving renovation of rural dwellings a financial guarantee and policy feasibility.

6. Realization path of nearly zero energy building in active service in rural areas

Nearly zero energy building refer to adapting to climatic characteristics and site conditions, maximizing the reduction of building heating, air-conditioning, and lighting needs through passive building design, maximizing the efficiency of energy equipment and systems through active technical measures, making full use of renewable energy, and minimizing energy consumption. The energy consumption of the building provides a comfortable indoor environment, and the energy consumption level of the building should be reduced by more than 60%-75% compared with the original national standard [15]. The key technical points for the construction and renovation of near-zero energy buildings mainly include seven aspects: thermal insulation measures, energy saving of doors and windows, airtightness measures, no thermal bridge treatment, heat recovery fresh air system, renewable energy utilization, and other innovative measures. Years of research and practice have proved that the energy-saving renovation and carbon dioxide emission control of rural dwellings cannot follow the "urban route". Building energy-saving strategies and the development of energy-saving technologies must be formulated in combination with people's living habits and natural conditions. Referring to the "Technical Standards for Nearly Zero Energy Building " GB/T 51350-2019, the realization of nearly zero energy building in rural areas is shown in Table 1.

Table 1

The realization path of nearly zero energy building concerning nearly zero energy building technical standards

parameter		technical standard	Realize
Heat transfer coefficient of exterior walls / [W/（m²·K）]	severe cold area	0.10～0.15	Choose different materials such as GEPS、XPS、 PUR and other materials to carry out thermal insulation transformation of walls and roof envelopes. The selection of the type and thickness of thermal insulation materials can be obtained through energy consumption simulation according to the current state of the constructed buildings.
	cold regions	0.15～0.20	
	Hot in summer and cold in winter	0.15～0.40	
	Hot in summer and warm in winter	0.30～0.80	
	mild regions	0.20～0.80	
Heat transfer coefficient of external windows / [W/（m²·K）]	severe cold area	≤1.0	According to the climate characteristics and energy consumption simulation analysis, choose 6 mm white glass + 12 mm air + 6 mm white glass, 6 mm Low-E glass + 12 mm air + 6 mm white glass, 4 mm ultra-clear glass + 13.5 mm air condensation Plastic + 4 mm white glass, aerogel glass (shading type) and other glass for exterior window renovation.
	cold regions	≤1.2	
	Hot in summer and cold in winter	≤2.0	
	Hot in summer and warm in winter	≤2.5	
	mild regions	≤2.0	
Air tightness/(times/h)		$n_{50} \leq 0.6$ or 1.0	Improve the construction progress of the exterior wall envelope and the renovation of doors and windows, and add transitional halls and curtains.
Annual heating energy consumption /[kWh/（m²·a）]	severe cold area	≤18	The heating equipment has the function of zoning (living room, bedroom, kitchen, bathroom, etc.) adjustment and on-demand function, and independent control of different rooms to meet intermittent heating requirements.
	cold regions	≤15	
	Hot in summer and cold in winter	≤8	
	Hot in summer and warm in winter	≤5	
	mild regions	≤8	
Annual cooling energy consumption /[kWh/（m²·a）]		$\leq 3.5+1.5\times WDH_{20} +2\times DDH_{28}$	Realized by the building envelope, door and window renovation, and renewable energy utilization.
total annual energy consumption /[kWh/（m²·a）]		≤ 55	Using DesignBuilder software for simulation analysis, the energy-saving of the retrofitted building can reach 85%.
Renewable Energy		Utilization≥ 10%	According to the climatic conditions of different regions, the clean energy of biomass, air-source heat pump, solar air heating technology, photovoltaic power generation, and solar thermal heating are adopted to replace the use of existing petrochemical energy.

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