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Evaluating rural low-carbon communities: A study of Guangdong Province, China

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ABSTRACT

As the Chinese economy has rapidly developed, energy consumption and carbon emissions in China's rural areas have also steadily increased. Rural communities are the most important component of rural areas; as such, developing low-carbon communities will likely promote reductions in rural carbon emissions. As one of the low-carbon pilot provinces, Guangdong Province has gradually constructed low-carbon communities; however, neither the province nor China as a whole has established a system for evaluating different energy-related factors in rural low-carbon communities. Using real-world conditions in Guangdong Province, combined with the general parameters associated with low-carbon communities, this study evaluated six categorical factors: carbon reduction performance, low-carbon planning, energy consumption, low-carbon transportation, environment and resources, and low-carbon management and living. These categories were measured using several suitable indices according to the SMART principle. The baseline value corresponding to each index was determined by two zones: the Pearl River Delta zone and the non-Pearl River Delta zone. Each index weight was calculated using a method that combines a Monte Carlo simulation and an Analytical Hierarchy Process. Ultimately, one typical community was selected for a pilot evaluation. The sensitivity analysis of each index was conducted using the One-At-a-Time (OAT) method. Establishing this system is beneficial for promoting rural low-carbon communities construction in Guangdong Province, and supports system evaluation and adoption in rural low-carbon communities. This study's system can also provide a reference case and experience for the Chinese government, as it establishes a system for evaluating rural low-carbon communities at the national level.

1. Introduction

With the rapid development of the Chinese economy, there have also been sharp increases in China's carbon emissions. Since 2008, China has surpassed the U.S. in carbon emissions and has become the world's largest emitter of carbon. In 2012, China's carbon emissions reached 9.21 billion tons, accounting for 26.7% of the world's total emissions [1]. Carbon emissions sharply increased concurrently with economic development, mainly due to the rapid industrialization and civilization growth [2]. However, when addressing climate issues, China has mainly emphasized urban, transportation, and industrial energy consumption; it has consistently failed to pay adequate attention to the issues of energy consumption and greenhouse gas emissions in its rural areas [3].

With the rapid development of China's rural economy, its total energy consumption and per capita household energy consumption have continuously increased, leading to the gradual increase of rural carbon emissions [4]. Fig. 1 shows the per capita household energy consumption of urban and rural residents in China [5]. The figure shows that the per capita energy consumption by China's rural residents generally increased between 1980 and 2013; consumption by urban residents first showed an increasing trend, following the decrease. The rural per capita energy consumption reached 311 kgce in 2013, up from 60 kgce in 1980; this high level approaches the urban per capita household energy consumption level (357 kgce). The ratio of the rural to urban per capita household energy consumption has also continued to rise, increasing from 18.1% in 1980 to 87.1% in 2013; this reflects a decrease in the gap between rural and urban use.

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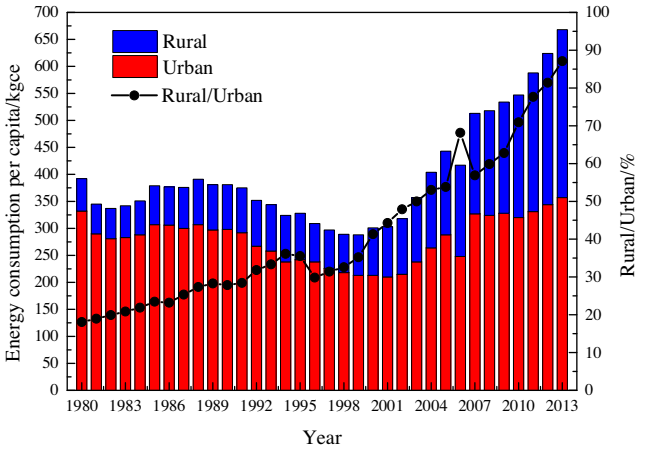

Fig. 1. Rural and urban household energy consumption per capita.

The continuous increase in energy consumption inevitably leads to gradual increases in carbon emissions. As such, rural energy and carbon emission issues should receive closer attention from policy makers, to encourage policy changes that reduce rural energy consumption and carbon emissions. It was in this policy context that the concept of rural low-carbon communities (LCC) emerged. The goal of building rural LCC is to guide energy consumption and carbon emission reductions in China's rural areas.

Some researchers have studied energy consumption and carbon emissions of rural residents in China; these studies have analyzed the major factors influencing carbon emission, and have proposed corresponding measures for reducing energy consumption and carbon emissions [4,6–9]. However, these studies have not attempted to establish a corresponding low-carbon evaluation system based on the realities of China's rural areas. Without a corresponding low-carbon evaluation system, it is impossible to measure the actual effect of energy-savings and low-carbon improvements. In addition, low-carbon construction relates closely to many aspects of rural life, such rural construction, transportation, energy, residential living, and rural management. As such, only quantifying rural carbon emissions is insufficient to draw a complete picture [10].

China's National Development and Reform Commission (NDRC) has published *Guidelines for the Pilot Construction of Low-carbon Communities*, but there is no corresponding evaluation system. As one of the low-carbon pilot provinces in China, Guangdong Province should set an example in this field. Five demonstration LCC have been launched in Guangdong Province; two of these are rural communities. Based on the demand for LCC construction in Guangdong Province, this study developed an evaluation system specifically for rural LCC, based on rural community characteristics in Guangdong province.

Although China does not have a specific evaluation system for LCC in China, other countries do have these kinds of mature evaluation systems. The most widely-applied systems include the British BREEAM-Communities, the U.S. LEED-ND, and the Japanese CASBEE for Urban Development [11–13]. These three systems adopt indices such as site selection, energy resources, water environment, transportation, ecological environment, community planning, and design. The current evaluation systems mainly emphasize indices related to sustainable community development, but rarely introduce indices quantifying the carbon emissions of communities. As a result, their relevance to community carbon emissions is not strong enough to make them capable of measuring carbon emission or leading the movement towards low-carbon development.

In addition, each country's evaluation system considers the local economy, social development, resident lifestyles, and climate conditions. Therefore, to establish an evaluation system for the rural LCC in Guangdong, it is important to consider the impact of local characteristics on the indices that strongly correlate with carbon emissions. Furthermore, establishing a specific low-carbon evaluation index system for Guangdong rural communities will also assist in benchmarking each rural community against the baseline, against the optimal level, and against other communities in the system.

In summary, based on the current development of rural communities in Guangdong Province, this study identified indices correlated with rural LCC and screened the existing indices using SMART criteria. SMART is an acronym constructed from five words, Specific, Measurable, Achievable, Relevant and Trackable. Index weights were calculated using a method that combines a Monte Carlo simulation and an Analytical Hierarchy Process (AHP). At the end, a typical rural community was selected for a pilot evaluation. Further, a sensitivity analysis of each index was conducted using the One-At-a-Time (OAT) method to differentiate the influence of each index on evaluation results. The resulting system can be used as a tool by the Provincial People's Government of Guangdong to evaluate the low-carbon degrees and levels of the rural communities, and may also provide a reference point and experience that can support the Chinese government's development of a national LCC evaluation system.

2. Methods and data for the rural low-carbon communities index system

2.1. Categorization of the index system

LCC, especially rural LCC, are not well defined. Usually, different countries and regions apply different definitions based on local situations, and scholars define them based on their own research perspectives. LCC construction needs to fully account for every aspect of the communities involved, including energy utilization, public service facilities, environmental greening, resources recycling, resident lifestyles, and management modes [14–16].

This study developed a comprehensive concept to describe existing LCC, and proposes that the following features are critical to rural LCC. First, there should be harmonization with the ecological environment. This means that the rural low-carbon construction should protect the rural ecological environment, explore renewable energy resources in rural areas, and also promote rural economic development. Rural low-carbon construction should avoid damaging the natural environment and recycle resources, striving to balance the needs of human beings and the surrounding biological environment.

Second, there should be an efficient and comprehensive utilization of resources. Rural low-carbon construction should be guided by low-carbon development and the goal of reducing energy consumption, to maximize natural resource use, reduce environmental pollution and damage, achieve low resource and energy use, and realize recyclable energy production and waste disposal. The third feature should be community sustainability. The low-carbon construction of the rural communities should encourage self-sufficiency with respect to energy supplies, effectively use the land, reduce energy consumption in buildings, limit damage to the natural environment, and promote sustainable community development.

Fourth, constructing rural LCC should maximize resident living comfort, advocating thrift and simplicity, and elevating the living comfort of the residents. Fifth, when constructing a low-carbon rural community, public participation by community residents throughout construction and use is critical. Sixth, it is important to guide economic development. Rural house building should