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Energy Planning Analysis of an Agritourism Complex Based on Energy Demand Simulation: A Case Study of Wuxi Yangshan Agritourism Complex

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***Abstract*—**China is experiencing the rural development process, with the agritourism complex becoming one of the significant modes. Therefore, it is imperative to understand the energy performance of agritourism complex. This study focuses on a typical case of the agritourism complex and simulates the energy consumption performance on condition of the regular energy system. It was found that HVAC took 90% of the whole energy demand range. In order to optimize the energy supply structure, the hierarchical analysis was carried out on the level of architecture with three main factors such as construction situation, building types and energy demand types. Finally, the energy planning suggestion of the agritourism complex was put forward and the relevant results were obtained.

***Keywords*—**Agritourism complex, energy planning, energy demand simulation, hierarchical structure model.

I. Introduction

IN recent years, the economy and environment in rural areas in China during the urbanization process are lagging behind and are therefore facing problems such as population loss, land reduction, environmental pollution and so on. At the same time, during 2011-2015, the lifestyle of urban people changed as the "5+2" life mode and the "2.5 day" vacation mode had been promoted in all parts of China. The advent of this national leisure time has stimulated the innovation of the rural leisure mode. Rural areas seized the opportunity to explore the sustainable development mode with the theme of rural scenery appreciation and agricultural leisure experience.

To promote the development of rural areas, China's "Central No. 1 Document 2017" was released to support the pilot demonstration of agritourism complex, which will go through comprehensive agricultural development. After that, China issued the policy to carry out the pilot program for rural complex, and established 26 national rural comprehensive pilot projects.

People have different understanding of agritourism, and the research on its definition involves different aspects. Thomas Streifeneder proposed the understanding of the real meaning of agricultural tourism by analyzing its key suppliers and demand-side characteristics [1]. The study by [2] discussed the contents and definition of agritourism in many countries and suggested that agritourism in Malaysia should have some main factors in its definition. In this paper, the agritourism complex means to integrate recycling agriculture, innovative agriculture and agricultural experience into an idyllic complex in rural areas, allowing farmers to fully participate and benefit. The agritourism complex is able to stimulate comprehensive agricultural development and link urban and rural space organically as well.

In the aspect of the development and factors of agritourism practice, [3] pointed out that long-term and effective financial, as well as technical support were necessary for the stable development of agritourism. Nair analyzed and affirmed the roles of enterprise and the cooperation of them especially those with innovation in improving the competitiveness of a rural tourism destination [4]. The Italian example was studied by [5] to analyze some key elements such as structure, society and economy which contributed to the success of the agritourism business model [5]. Meanwhile, [6] suggested that landscape and environment variables have an important influence on agricultural tourism which means that some rural regions are more suitable to develop agritourism. Similarly, [7] found that rural areas in Croatia have the prerequisites to develop rural tourism and suggested guidelines for the sustainable development of rural tourism there [7].

Some have studied the evaluation of agritourism, [8] adopted the Delphi method to establish the appropriate evaluation criteria for farm accommodation and carried out the case application [8]. The study of [9] analyzed the use of the product category rule (PCR) on accommodation in a case farm and gave some recommendations of how to develop better implementation of the PCR in agritourism. As to the future development trend, [10] summarized the principles and tendency of sustainable tourism and agroecology, thus pointed out the agroecological tourism, which is the model of ecological agritourism.

II. Background

Energy planning generally is accepted as the process aimed at developing long-term policies for supporting the development, implementation and management of local, national, regional or even global energy systems [11]. But it can give more than this, energy planning links low carbon building design and the regional energy utilization program, thus stimulating environmental friendly building projects and scientific energy planning methods. Summed into one sentence,

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energy planning will play an important role in a region's low carbon development and energy reform.

Energy in a region is usually classified into such two forms: broad sense and narrow sense. Broad sense refers to all the energy consumed by the region, including industrial energy and traffic energy, while narrow sense refers to energy directly related to buildings, and mainly to the electricity, heat and cold for buildings. In this paper, the narrow form of regional energy is studied.

During the process of regional building energy planning, it is always considered that the integration of the ecological concept of combining the natural environment and human values into regional construction or development, and to formulate a planning strategy for the energy demand and energy supply of the buildings studied. Specifically, the following steps should be included during energy planning:

Step1. Have an expectation of the type, quantity, grade, characteristics of building the energy demand side in the planning area;

Step2. Analyze local building energy supply methods, including the various energy resources such as primary fossil energy, secondary conversion energy, renewable energy, and the quantity, availability of these energy resources in the planned area.

Step3. Make the technical analysis as well as the influence on the surroundings in the region of the energy planning system.

Agritourism complex is the new exploration of rural areas in China; it is necessary to plan and design the agritourism complex for energy conservation, of which, energy planning is an important measure. Therefore, carrying out reasonable energy planning within agritourism complex in the countryside is of great significance [12]. However, there is very little research conducted on the energy planning of the agritourism complex. Therefore, this study will take the typical agritourism complex case in China, analyze its temporary building planning and energy consumption phenomenon, and put forward an energy planning project based on this.

First of all, the benchmark building energy demand is obtained by energy consumption simulation.

Afterwards, energy source choice and the optimization of energy systems on the whole architecture level is considered, thus using the hierarchical analysis method to group the regional building energy systems.

Finally, the optimized energy planning project of Yangshan Agritourism Complex will be put forward based on structure hierarchical analysis.

III. Energy Demand Simulation

A. Brief Introduction of the Case Study

Yangshan Tianyuan Dongfang, Wuxi is regarded as a typical exploration of a Chinese urban and rural integration mode that project combines the living and working space with the cultural industry in an ancient village. The original project planning was put forward on the basis of village cultural protection so that its appearance reconciles with the surrounding environment.

Inside the case area, the demonstration region has been completed, which is the main study area including nine buildings. These buildings in the planned region, which are of different functions: home stay, work, retail, exhibition, education and so on. During the initial planning procedure, designers make good use of the buildings already located there for a long time and give rebirth to them, including the academy, home stay and café which are reformed from the old buildings on site. At the same time, the rural life pavilion, the restaurant and Huafude School are completely new, while the village shop and bakery are an overall rehabilitation of the original building materials on the house demolition site. The appearance of these nine buildings is in the form of gray-tiled roofs and white walls, reflecting the traditional local architectural culture. The selection of this project will help to understand the energy performance of the agritourism complex and formulate corresponding optimization strategies.

B. Energy Demand Simulation and Results

In order to have the overall understanding of the energy consumption demand of all the case buildings, energy consumption and load simulation was carried out. The simulation was carried out with EnergyPlus program developed by the US Department of Energy [13]. In order to make the simulation convenient, some simplifications are made prior, these include removal of decorative components or details on the architectural appearance and grille, and the appropriate merging of some functional partition. At the same time, the buildings around the site environment are not taken into account in the simulation. The output effect of the building models in EnergyPlus is shown as Fig. 1.

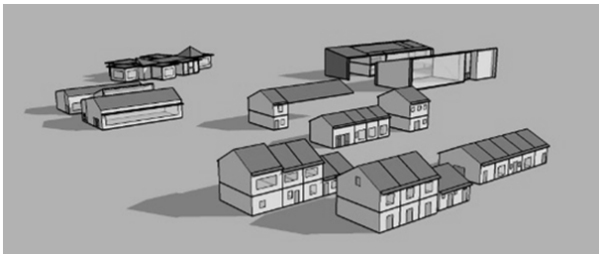

Fig. 1 Building models of the Yangshan Agritourism Complex

On the geography and weather part, Wuxi is in Jiangsu province, which is located in the hot-summer and cold-winter zone of China, where the cooling demand of buildings is brought to the forefront while the heating demand does not get enough attention as the severe cold regions. The annual 99.6% dry bulb temperature for designing heating systems is -3°C in Wuxi, while the 1.0% cooling dry bulb temperature is 32°C [14]. By statistics, the range of orientation of the buildings in the case and the range of the building scale are listed below.

On the part of the parameter setting details, it is assumed that the public buildings in this study meet the design standard for the energy efficiency of public buildings in China released in 2015 [15]. The home stays meet the design standards of thermal-environment and energy conservation for residential buildings in Jiangsu province [16] and the code for the design

of hotel buildings [17]. The main parameters and detailed schedules for lighting, people and electric equipment are derived from the empirical value obtained from the survey and the energy efficiency standard [15]. The newly built buildings used 50 mm and 100 mm expanded polystyrene (EPS) insulation in the external concrete walls and roofs, respectively. The U-values of building envelopes are as follows: newly-built buildings' walls, 0.498 W/(m^2·K); newly-built buildings' roofs, 0.468 W/(m^2·K); renovated buildings' walls, 0.279 W/(m^2·K); renovated buildings' roofs, 0.428 W/(m^2·K).

TABLE I
VARIATIONS OF INPUT PARAMETERS

Variable	Range
Orientation	-45° to -15°(0° denotes north)
Building Scale	240 m^2 to 960 m^2

The main aim of energy demand is to understand the energy performance of the agritourism complex, the output performance indicators are annual heating, cooling and electricity intensity per floor area. The peak gains from lighting and equipment in the rural life pavilion, restaurant, academy and school are, respectively, 8 W/m^2 and 5 W/m^2, those of the cafeteria and the bakery are 5.5 W/m^2 and 13W/m^2, with home stays at 4.5 W/m^2 and 13 W/m^2, and the shop at 10 W/m^2 and 13 W/m^2. The occupant density of the rural life pavilion is 2.5 m^2/per and for the shop is 4 m^2/per. The occupant number of the café, restaurant, bakery, home stays, school and academy is respectively, 40, 68, 40, 36, 120 and 40. The single building HVAC system is used to provide heating, cooling, and ventilation for these buildings. Since the focus of this paper is to understand the energy performance of the agritourism complex, thus the energy planning proposal is put forward for it. The set-point temperature is 20°C for heating and 26°C for cooling.

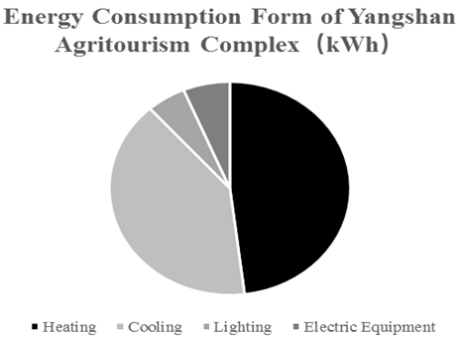

Fig. 2 Energy Consumption Form of Yangshan Agritourism Complex

In order to better understand the energy demand features, graphical results analysis are available which indicates the energy consumption form and energy consumption ratio of different buildings. What follows is a brief description. The overall electricity demand of the agritourism complex is 109.49 MWh, if the energy consumption is equal to electricity supply. The total energy consumption per conditioned area is 345.39 kWh/m^2, of which, the heating demand in winter has taken up 48% (Fig. 2). The HVAC load of each building varies with the function of the architecture (Fig. 3). It can be seen that the newly-constructed buildings such as the rural life pavilion and the school needs more energy for HVAC than the renovated buildings like the home stay and the café.

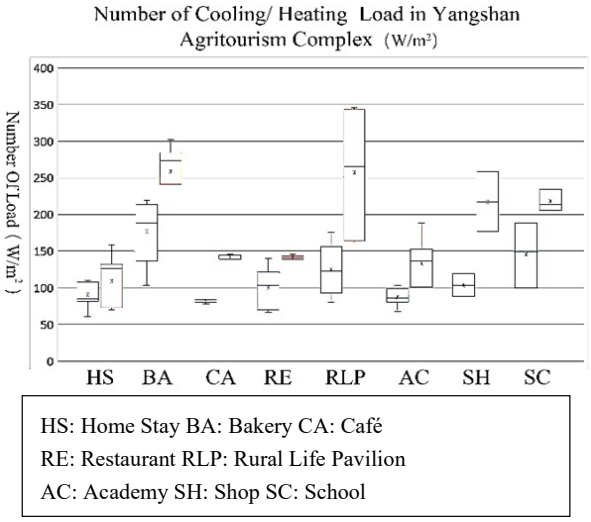

Fig. 3 Number of Cooling/Heating Load in the Case Agritourism Complex

Through the energy demand simulation process of the Yangshan Rural Complex, it was found that the energy consumption structure of agritourism complex is not particularly obvious. The reasons for this are complex, but it is clear that the diverse function of agritourism has led to the uncertain use time range and situation.

IV. LOCAL ENERGY SUPPLY

Regional building energy planning is often put forward from the perspective of demand side and supply side, so it is essential to analyze the current situation and resource condition of the local supply after the energy consumption and demand analysis in this study.

Yangshan Agritourism Complex is in a rural region and mostly uses electricity, where the electricity supply is sufficient and no peak of electricity consumption exists. With regard to traditional resources such as coal, oil, natural gas and other primary sources of energy, Jiangsu is dependent on imports from other places. For renewable energy, the main composition includes solar, wind and biomass resources, the production of which are on the rise in Jiangsu [18].

Firstly, the energy supply possibility will be studied. Wuxi is an important photovoltaic production area in China, although the local solar energy resource is not abundant. The average number of monthly available hours is about 211 and the average annual global radiation is 1218.7 kWh/m^2 [19]. What is more, the shallow geothermal energy in Wuxi can be plentiful, the utilization of which has developed for decades, and the ground source heat pump is the main form. Over the years, the number of geothermal heat pump projects used for geothermal

water heating and supply of hot water in Jiangsu province have been increasing.

Wind energy resource is available due to the proximity to a body of water, the nearby Tai Lake; however, it is not very abundant as the annual average wind speed and wind power density at a height of 10 m is 4.46 m/s and 100.22 W/m^2, respectively. The main wind direction of the project is NNE (northeast northerly wind). The high wind months appear in January to May, November and December. The small wind months appear in June to October, with the smallest in July. In general, the wind energy resource level in the region is determined at level 2, but the wind power plant may have some risks [18].

On the balanced basis of energy supply-demand of Yangshan Agritourism Complex as well as the comprehensive thought of economic, technical, and the current situation in the existing local planning construction, the use suggestion of renewable energy is finally determined (Table II).

TABLE II
RENEWABLE ENERGY UTILIZATION GRADE

Energy Type	Applied Grade
Solar Energy	More Suitable
Wind Energy	Basically Fit
Geothermal Energy	More Suitable

V. ENERGY PLANNING ANALYSIS

It is clear that the energy planning procedure of agritourism complex is complicated because of its features, of which, the planning and design of buildings is usually the most important factor. So in order to ensure the rationality, it is suggested to analyze the factors affecting energy planning in the process of whole domain planning. That means, addressing the following three factors:

Construction situation: Buildings in the agritourism complex include newly-built buildings and renovated ones, which have an important influence on the plan of energy planning. The new buildings, for example, are more flexible in form and in their choice of energy supplies, as well as more scientific in terms of their location. In addition to the technical measures of a building itself, the energy supply method of renovated buildings can also draw on the potential of environmental resource supply from around the site.

Building types: Considering that the potential relationships between buildings are complicated due to the differences in their use and role within the agritourism complex, it is necessary to group the buildings by function. Firstly, the buildings in the complex can be divided into two types according to their functions: life service style together with cultural and educational style. Life service style includes the restaurant, shop, and home stay, while the cultural and educational style includes rural life pavilion, school and the academy. The use time in the life service buildings is more intermittent and fixed; while for the cultural and educational facilities it is less regular.

Energy demand types: different buildings will have different energy needs due to the impact of activities and function inside. Restaurants and cafe, for example, have similar functions, which leads to the consistency of occupancy time. Therefore, the significant building energy demand can be organized to maximize the efficiency of building energy supply in the whole area. Afterwards, according to the importance of these influencing factors, the top-down hierarchical structure model on behalf of the building energy planning structure in Yangshan Agritourism Complex is concluded (Fig. 4). The buildings listed in each group are able to share the same energy system; this can help in deciding the location of the newly-built buildings, for those not yet constructed. What is more, this will help to determine the building plan on the demand side for energy planning.

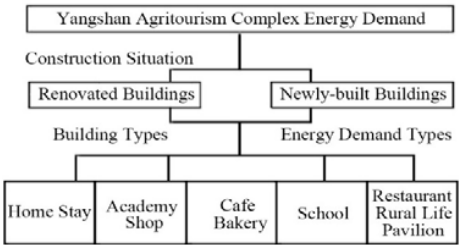

Fig. 4 The Hierarchical Structure of the Agritourism Complex Energy Supply Group

VI. CONCLUSIONS

In order to determine the energy conditions of an agritourism complex, an energy performance simulation was conducted for the case of Yangshan Agritourism Complex. Afterwards, the energy source background and hierarchical analysis of the agritourism complex building characters were carried out. The hierarchical structure of the agritourism complex was made and utilized in the final energy planning optimization.

The main findings are listed below:

The heating and cooling consumption of the agritourism complex is respectively up to 48% and 41%, which in total takes nearly 90% of all energy consumption.

The construction situation, building types and energy demand types are the main factors affecting the building energy demand on the part of design.

The method proposed in this study combined design with energy planning of an agritourism complex, although the output numbers are unique and may not be suitable for other same cases, which will make the energy planning clearer. Future research opportunities exist to further fulfill the design procedure of energy planning in the agritourism complex.

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