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Algorithm for Optimizing Control of Energy Conservation and Emission Reduction in Smart Buildings Assisted by Cloud Computing

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Abstract: *In recent years, energy conservation and emission reduction have received widespread attention, but there is no more research data on energy conservation and emission reduction in smart buildings. Therefore, this article analyzed the energy conservation and emission reduction, and optimization control of smart buildings. The main focus of this article was on the optimization of cloud computing in building energy efficiency. By monitoring five aspects: environmental utilization rate, electrical energy consumption, carbon emissions, water consumption, and new energy utilization rate, the effectiveness of cloud computing in optimizing building energy efficiency can be analyzed to make further optimization measures. Firstly, this article explored the overall data processing system through the use of cloud computing, which enabled artificial intelligence of the overall data. The experimental results showed that the average environmental utilization rates of smart building energy-saving systems and traditional building energy-saving systems assisted by cloud computing were 56.5% and 43.1%, respectively, based on the data after one month of building energy-saving optimization. Based on the data from two months after optimizing building energy efficiency, the average environmental utilization rates of smart building energy efficiency systems and traditional building energy efficiency systems assisted by cloud computing were 64.3% and 45.3%, respectively. Therefore, applying cloud computing to the optimization control of smart building energy conservation and emission reduction systems is effective in increasing the environmental utilization of building energy saving systems.*

Keywords: *Energy Conservation and Emission Reduction; Cloud Computing; Smart Building; Neural Network Algorithm*

1. Introduction

The Earth is the place on which humans rely for survival. Mountains and rivers meet people’s water needs, while forests and wetlands meet people’s air needs. Both water and air are indispensable for human survival. However, with the progress of technology, environmental issues such as energy waste and excessive emissions are becoming increasingly severe. The emergence of energy waste is mainly caused by human unreasonable large-scale mining. Excessive emissions have led to global warming and the destruction of the ozone layer. Environmental issues need more publicity. At the same time, some promotion activities carried out by non-governmental environmental protection organizations have impressed people with the way of environmental performance art.

Green building is an inevitable development trend in the construction industry. To promote the long-term healthy and stable co-development of the building industry and nature, measures have been proposed to promote the concept of building energy conservation and emission reduction. Many researchers have conducted in-depth thinking on how to save energy and reduce emissions. Among them, Rebelatto Bianca Gasparetto discussed the opportunities, threats, strengths, and weaknesses of applying energy efficiency in universities, as well as its contribution to sustainable development goals [1]. Murshed Muntasir explored the nonlinear impact of information and communication technology trade on the prospects of renewable energy transformation, improving energy efficiency, and increasing access to cleaner cooking fuels [2]. He Lamei used samples from 30 provinces in China from 2005 to 2013 to decompose their changes [3]. Koronen Carolina realized the potential of data center energy system integration through demand response and waste heat utilization, and reviewed relevant policies. The analysis showed that demand response and energy system integration had considerable potential, which urged greater efforts to be made in formulating future policies, policy coordination and regulatory, tax and power market design changes [4]. Although energy conservation and emission

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reduction can effectively address environmental issues, energy conservation and emission reduction is a long-term and arduous task.

Cloud computing is a typical data processing method that can provide complex functions such as data storage and computation. Many researchers have conducted research on how to apply cloud computing to energy conservation and emission reduction. Among them, Vila Sergi proposed a multi-objective genetic algorithm to determine the most suitable cloudlet to assign to the available virtual machines. This innovative method can generate scheduling decisions that evade system allocation and provide new scheduling opportunities for the remaining clouds to reduce overall execution time and energy consumption [5]. Hashmi Shahwaiz Ahmed introduced the architecture, design, and implementation of an energy management system based on the Internet of Things and cloud computing. The energy management system generates consumer load profiles that are remotely accessed by utility companies or consumers. The results indicated that the generated load configuration files for user loads in terms of current, voltage, energy, and power can be accessed through the portal website [6]. Karthiban K proposed a cloud computing model for fair energy allocation, providing efficient energy allocation solutions for network users. This model, combined with fair energy allocation in cloud computing, provides a better allocation scheme than traditional models [7]. Panda Sanjaya K proposed an efficient task scheduling algorithm (ETSA) to address the shortcomings related to task integration and scheduling. The results showed that ETSA had a significant improvement in energy efficiency [8]. The use of cloud computing to assist in energy conservation and emission reduction in smart buildings can effectively address environmental issues, but there is a lack of comparative analysis of different cloud computing methods to assist in energy conservation and emission reduction in smart buildings.

Environmental issues are pressing. If energy conservation and emission reduction are not accelerated, the environment for human survival would be destroyed. In order to study how to use cloud computing as a resistance to energy conservation and emission reduction in smart buildings, this article analyzed its advantages compared to traditional energy conservation and emission reduction systems in five aspects: environmental efficiency, power consumption, carbon emissions, water consumption, and new energy utilization.

2. Optimization Methods for Energy Conservation and Emission Reduction in Smart Buildings

The optimization control of energy conservation and emission reduction in smart buildings assisted by cloud computing is based on the steps shown in Figure 1.

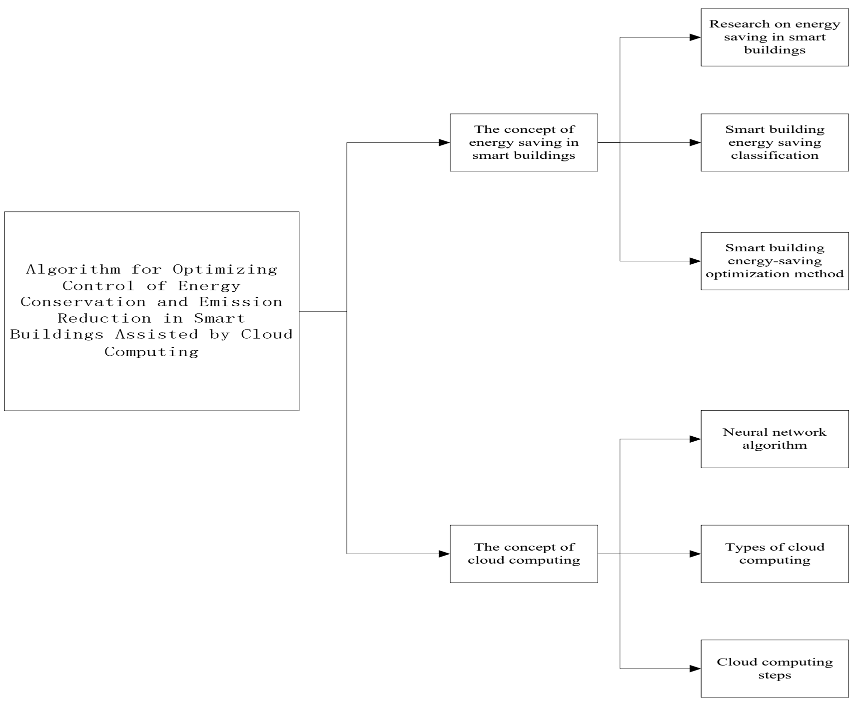

Figure 1 Outline of the article

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2.1 Smart Building Energy Conservation and Emission Reduction

In many countries, the project of building energy conservation and emission reduction started relatively late and is still in its early stages. Many people do not understand the basic concept of green buildings, and do not have a systematic understanding of the degree of energy consumption. The promotion of energy conservation and emission reduction awareness in relevant parts is far from enough.

Building energy efficiency is one of the important links related to low-carbon economic construction, achieving energy conservation and emission reduction goals, and maintaining sustainable economic development. To do a good job in energy-saving buildings and achieve various indicators, it is necessary to carefully plan, vigorously promote, and focus on details.

The energy-saving work of buildings is both complex and time-consuming, affecting governments, enterprises, ordinary citizens, many industries, as well as new and old buildings. In the initial process of promoting building energy efficiency, corresponding costs must be paid, such as energy and cost. From the actual results of recent years, the task and targets of building energy efficiency are very difficult to achieve by implementing a few simple measures and methods. It requires people to conduct more detailed and thorough research in order to understand the essence of it.

Strict management of new buildings must comply with building energy efficiency standards. For energy efficiency retrofitting of existing buildings, energy efficiency retrofitting needs to be enhanced. Multiple methods have been proposed, and more experimental experience has been promoted. The principle of simplicity before complexity, and public interest before personal interest has been adopted. In the process of building houses and energy-efficient buildings, the focus should be on the external walls and doors and windows. The external walls need to play a thermal insulation role, and the doors and windows should have a thermal insulation role. In addition, solar energy resources should be fully utilized and perfectly integrated with buildings in the design process to enhance the harmony and aesthetics of buildings. The rainwater collection system and the utilization of reclaimed water, as well as the vigorous promotion of the recycling and treatment of construction waste, have been fully implemented, enabling the full utilization of resources [9]. From a technical perspective, there are generally two technological means available, reducing total energy demand and utilizing new energy.

(1) Reducing total energy demand

1) Architectural planning and design

Given global energy and environmental challenges, many new design concepts have emerged. Essentially, they require architects to work from a holistic design concept and to work closely with energy analysis specialists, environmental experts, facility engineers and civil engineers. Engineers consider the impact of various climatic conditions when planning and designing buildings. Based on specific environmental conditions and the climate characteristics of the building itself, attention should be paid to creating a favorable microclimate within the building by utilizing natural environments (such as outdoor airflow, rainwater, lakes, and green spaces) to reduce reliance on building equipment.

2) Enclosure structure

The design of the building envelope has a fundamental impact on the building’s energy consumption, environmental sustainability, indoor air quality, and the visual and thermal comfort of the building. Improvement of the thermal characteristics of the building envelope can reduce the entry of outdoor heat into the house in summer and the dissipation of indoor heat in winter. By improving the thermal environment of the building, the building’s consumption of heat and cold can be reduced.

3) Improving energy efficiency for end users

Efficient and energy-saving heating and air conditioning systems can indeed reduce energy consumption through parallel heating and air conditioning measures, in order to reduce the heat and cooling load in the room. Starting from designing energy-saving heating, ventilation, and air conditioning systems, energy management and monitoring systems are adopted to monitor and regulate indoor comfort, indoor air quality, and energy consumption.

4) Improving overall energy efficiency

Most of the energy is lost when converted into final energy. Therefore, a whole process assessment should be conducted to adequately reflect the efficiency of energy use and the impact of energy on the environment. Energy consuming devices inside buildings must have high energy efficiency. The second generation energy system allows for the full utilization of various types of thermal energy to achieve maximum energy efficiency [10].

(2) Use of new energy

From the perspective of energy conservation and environmental protection, the use of new energy plays a crucial role, including solar energy, geothermal energy, wind energy, biomass energy, etc. People have conducted in-depth research on various ways of utilizing solar energy and gradually determined the growth direction, enabling solar energy to be utilized in the first place. For example: 1)As an essential item in the field of solar energy utilization, solar thermal power plants have been widely used in the United States, Israel, and Australia, and are expected to achieve commercial production of solar heat in the future; 2)Tens of thousands of photovoltaic water pumps are operating around the world; 3)The technology of solar water heaters is relatively mature and has the corresponding technical ability to produce solar energy; 4)The technology of solar absorption and cooling appeared earlier and was utilized in the field of large air conditioning systems; 5) Solar drying and solar ovens have become popular and are used to some extent [11]. However, in general, the scale of solar energy utilization is still small, the technology is not perfect, and the level of commercialization is low, pending in-depth and comprehensive research.

The so-called smart building energy-saving, as the name suggests, is to establish an intelligent system to observe the energy consumption and emissions generated by the building in real time. When the energy consumption and emissions are too high, the system automatically reduces them, and this system is often composed of multiple independent systems, such as smart air conditioning, smart lights, and other smart homes. They can perform specific operations according to the actual indoor needs, such as automatically opening when the room temperature is too high in summer, and stabilizing at a constant temperature after a certain degree of decrease. If there is no one in the room, the lights are not turned on, regardless of the intensity of the light. If someone enters, they are turned on, and if no one is present, they are turned off to realize the goal of intelligent energy conservation.

2.2 Cloud Computing

Cloud computing refers to the decomposition of huge data computation and processing procedures into countless small programs through a network “cloud”, and then a system consisting of multiple servers to process and analyze these small programs and return the results to the user [12]. The cloud computing information service layer is responsible for evaluating and analyzing the overall energy consumption of large buildings, determining their energy efficiency, and controlling their energy consumption through certain control measures [13].

Neural network algorithm is currently one of the widely used algorithms. Due to its self-learning ability, a large number of studies have rushed to introduce this method into their own research fields, striving to complete experiments or research with faster speed and better accuracy. The neural network algorithm is implemented through two forward and backward propagation processes: error and information, where information is forward propagation and error is backward propagation [14].

BP (Back Propagation) artificial neural network is composed of two processes: forward propagation dominated by input samples and backward propagation dominated by output samples. The combination of forward propagation and backward propagation processes completes a learning iteration, and the BP network repeats this iteration multiple times until it reaches the preset number of learning times or meets the error requirements. The input vector y is subjected to linear operation, and the operation function is shown in Formula (1).

$$c_k = \sum_k x_{kj} \bullet y_j + a_k \tag{1}$$

By comparing the output loss value of the cross entropy loss function with the difference between the predicted output value of the building energy consumption prediction model and the actual value of the construction project, the prediction effect of the building energy consumption prediction model can be judged. The function can be expressed as Formula (2).

$$Q = -\frac{1}{m}\sum_i \left[b \log h(a_x) + (1-b)\log(1-h(a_x)) \right] \tag{2}$$

In Formula (2), b is the actual output value.

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$$P=\sum_{i\in A}(\frac{1}{M_i^{cls}}\sum_{j\in S_i}P_{cls}(l_j,l_j^*)+\delta_1\frac{1}{M_i^{reg}}\sum_{j\in S_i}LP_{reg}(k_j,k_j^*)+\delta_2 P_a(h_i,h_i^*)) \tag{3}$$

In Formula (3), i is the index of feature maps from different levels. S_i is a set of anchor points defined in i feature maps. l_j represents the classification probability value. l_j^* represents the truth class label of the object. k_j represents a prediction framework composed of four parameterized coordinate vectors. k_j^* is a real box similar to the anchor box; h_i is the attention mask. h_i^* is the true mask. During the backpropagation process, the function gradient propagates from front to back and is distributed throughout the entire neural network. According to the gradient descent of the function, the gradient descent is maximum along the backpropagation process, as shown in Formula (4).

$$x=x_k-lr\bullet\omega \tag{4}$$

3. Smart Building Energy Conservation and Emission Reduction Optimization Experiment

To verify the effectiveness of cloud computing in building energy efficiency, a conceptual survey was conducted first, and 200 passersby were asked what they understood about building energy efficiency. The results are shown in Table 1.

Table 1 Questionnaire on building energy efficiency concepts

Object	Concept	Number of people	Percentage
Building energy saving	Low-power equipment	45	22.5%
	Insulation materials	28	14%
	Sealing materials	23	11.5%
	New energy	61	30.5%
	Air conditioners	43	21.5%

In the data in Table 1, it can be learned that 61 people believed that using new energy was building energy efficiency, accounting for 30.5%, ranking first. Secondly, low-power devices and air conditioning were considered, with 45 and 43 people respectively, ranking second and third. The number of people who believed that using insulation and sealing materials could achieve building energy efficiency was only 28 and 23, ranking fourth and fifth. However, from a practical perspective, using insulation materials and sealing materials as enclosure structures makes buildings energy-efficient once and for all. By using more insulation materials, indoor temperatures in summer are much lower than outdoor temperatures. By using sealing materials, cold air in winter cannot enter the room, thus eliminating the need for air conditioning. However, under current conditions, it is difficult for the enclosure structure to meet the temperature requirements of most people, and it still cannot avoid the use of air conditioning. Therefore, a small number of people is also a normal phenomenon.

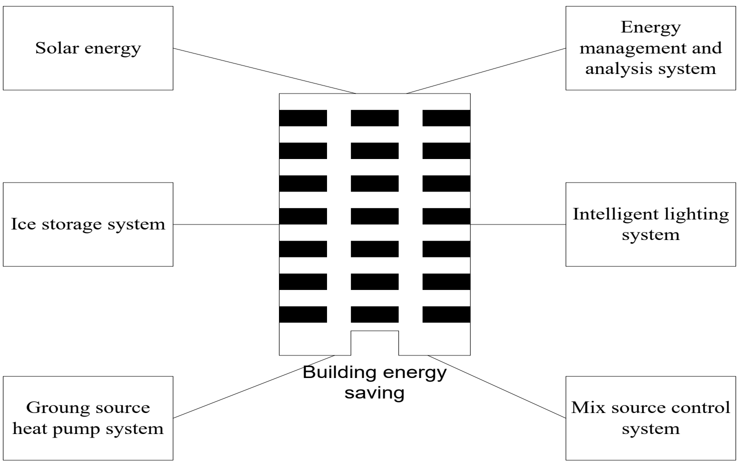

Figure 2 Overview of building energy efficiency system

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As shown in Figure 2, it is a general overview of building energy conservation system, which is divided into six parts, solar energy building solar thermal integration system, ice storage system, geothermal heat pump system, energy management and analysis system, intelligent lighting system and hybrid source control system. Building energy conservation is a systematic engineering project. During the comprehensive promotion process, relevant supporting policies and regulations need to be formulated, and enforcement efforts should be increased if necessary. For new technologies, processes, equipment, materials, and products, policy support should be provided to increase market promotion efforts.

Due to the survey in Table 1, new energy is the most well-known energy-saving method among the public. At present, the energy used in the majority of building air conditioning cold and heat sources is non renewable. Therefore, integrating new energy utilization technologies in the optimization process of building energy-saving systems is an important means to reduce building energy consumption and an important way to achieve green development [15]. Therefore, the experiment conducted research and analysis on country C. The results showed that the city belongs to a region with a shortage of total solar radiation, and the distribution of total solar radiation in each month throughout the year is extremely uneven, as shown in Table 2.

Table 2 Survey of annual solar radiation in a city in country C

Month	Solar radiation	Month	Solar radiation	Month	Solar radiation
1	3.9%	5	9.6%	9	10.8%
2	5.3%	6	11.3%	10	7.4%
3	7.3%	7	15.8%	11	4.7%
4	8.7%	8	13.2%	12	2.7%

In the data in Table 2, it can be learned that the proportion of solar radiation in the city was the highest in July, reaching 15.8%, while it was the lowest in December, only 2.7%. The total solar radiation in July was nearly 1.9 times the average value of each month, which was 5.8 times the minimum month. From April to September, it was above average for 6 months, accounting for approximately 69.4% of the total solar radiation throughout the year. Therefore, solar radiation in the city is concentrated in summer, and the application of solar photovoltaic power generation technology and solar hot water technology in the renovation of existing buildings in the city can be considered. In addition, solar assisted ventilation technology, such as solar chimneys, can also be considered to enhance indoor ventilation and increase the frequency of indoor air changes.

4. Experimental Results of Optimizing Energy Conservation and Emission Reduction in Smart Buildings

4.1 Environmental Utilization Rate

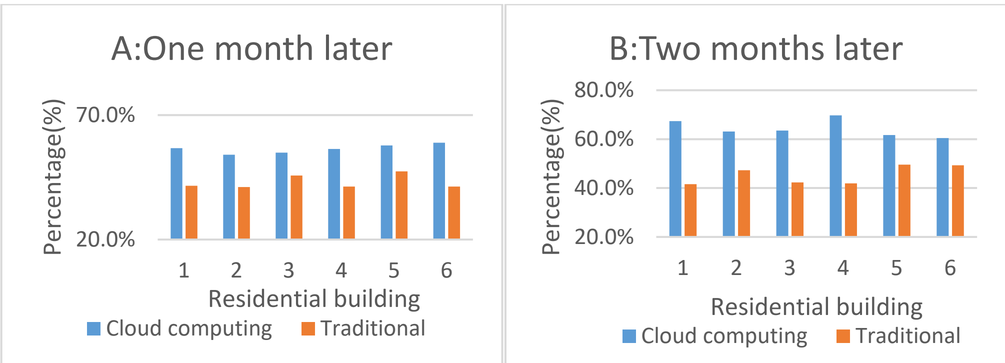

Figure 3A shows the environmental utilization rate after one month of the experiment
Figure 3B shows the environmental utilization rate after two months of the experiment

Figure 3 Comparison results of environmental utilization

The cloud computing smart building energy-saving system can effectively utilize external airflow, rainwater, lake greening, and even terrain in the natural environment by identifying the surrounding environment of the building. For example, fresh air systems, water circulation systems, and so on all utilize the natural environment, and any energy-saving system is designed, constructed, and put into production and use simultaneously with the project. Therefore, energy-saving systems are crucial in the

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field of construction. Therefore, the experiment selected 6 residential buildings in a certain community and collected environmental utilization data after using cloud computing to assist smart building energy-saving systems for one month and two months, as well as environmental utilization data during the first two months when using traditional building energy-saving systems for these 6 residential buildings. Meanwhile, the environmental utilization rates of the two were calculated and compared. The results are shown in Figure 3.

From the results shown in Figure 3, it can be seen that the overall cloud computing data after two months was higher than that after one month. After calculation, using cloud computing to assist in energy conservation and emission reduction of smart buildings for one month, the average environmental utilization rate of residential buildings reached 56.5%, and after two months, it reached 64.3%, an increase of 7.8%. However, traditional energy conservation and emission reduction methods did not have much fluctuation, with 43.1% after one month and 45.3% after two months, only an increase of 2.2%. It can be seen that cloud computing can effectively enhance the environmental utilization rate of residential buildings.

4.2 Electrical Energy Consumption

Electric energy can be said to rank first in the energy consumption of the people. Electric lights, air conditioners, water heaters, computers, refrigerators, washing machines, and so on are essential household appliances, and household appliances are all electricity consuming. From the lowest powered electric lights to the top ranked refrigerators, water heaters, and air conditioners, all of these add up to a relatively high monthly electricity consumption in households. If cloud computing smart building energy-saving systems are used, these appliances can be controlled according to the actual needs of households to achieve the optimal energy consumption. Therefore, in the experiment, six households consisting of three people from one of the six residential buildings mentioned above were selected. The electrical energy consumption data of these six households after using cloud computing to assist in smart building energy-saving systems for one month and two months, as well as the electrical energy consumption data of these six households during using traditional building energy-saving systems for the first two months, were collected and compared. The results are shown in Figure 4.

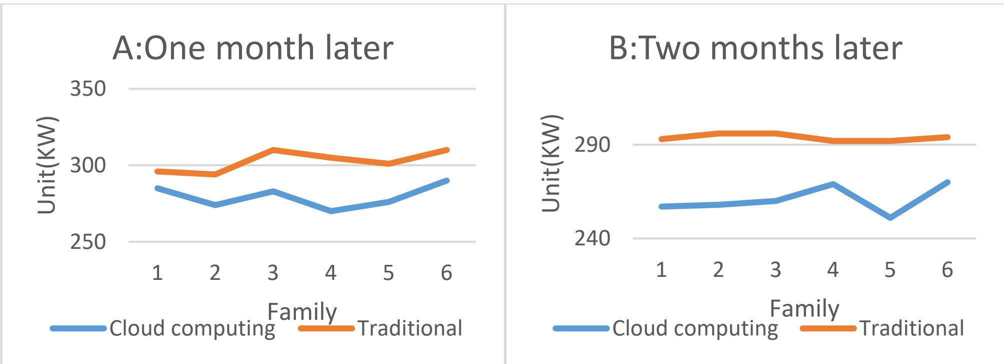

Figure 4A shows the electrical energy consumption after one month of experiment
Figure 4B shows the electrical energy consumption after two months of experiment

Figure 4 Comparison results of electrical energy consumption

From the results shown in Figure 4, it can be seen that the overall cloud computing data after two months was lower than after one month. After calculation, it was found that one month after using cloud computing to assist in energy conservation and emission reduction in smart buildings, the average electrical energy consumption of a household was 280 kilowatts. Two months later, it was only 261 kilowatts, a decrease of 19 kilowatts. However, the reduction in traditional energy conservation and emission reduction was not significant. One month later, it was 303 kilowatts, and two months later it was 294 kilowatts, only a decrease of 9 kilowatts. It can be seen that cloud computing can effectively reduce the electrical energy consumption of a household.

4.3 Carbon Emissions

Carbon emissions, which have been appearing increasing frequently online in recent years, is an umbrella term for greenhouse gas emissions. Due to the high transmittance of these greenhouse gases to visible light from solar radiation and the high absorption of longwave radiation reflected from the

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Earth, global climate warming is caused. From a family perspective, the main culprits of carbon emissions are air conditioning and water heaters. Cloud computing energy-saving systems can monitor air conditioning and water heaters in real-time to avoid unnecessary waste and reduce carbon emissions, while also reducing electrical energy, killing two birds with one stone. Therefore, the experiment also collected and compared the carbon emission data of these six households. The results are shown in Figure 5.

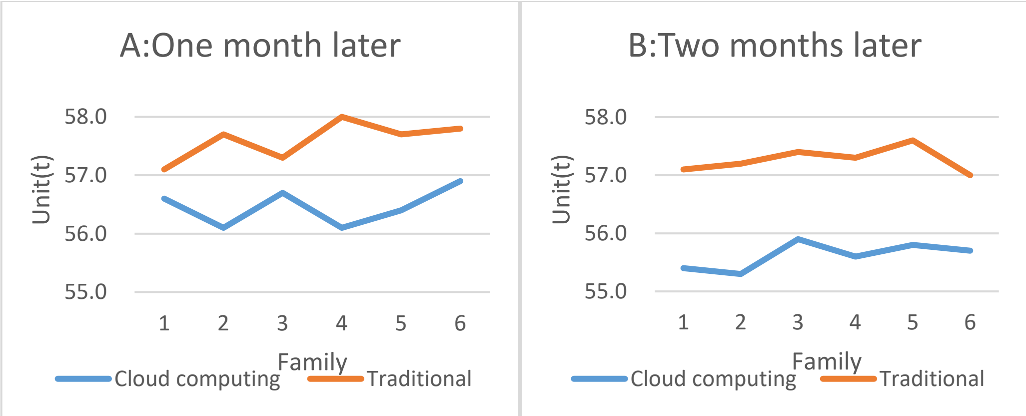

Figure 5A shows the carbon emissions after one month of the experiment
Figure 5B shows the carbon emissions after two months of experiment

Figure 5 Comparison results of carbon emissions

In Figure 5, after using cloud computing to assist in energy conservation and emission reduction of smart buildings for one month, the average carbon emissions of a household were 56.5 tons, which decreased by 0.9 tons to 55.6 tons two months later. However, traditional energy conservation and emission reduction methods did not significantly reduce emissions. One month later, it was 57.6 tons, and two months later, it was 57.3 tons, only a decrease of 0.3 tons. It can be seen that cloud computing can effectively reduce household carbon emissions.

4.4 Water Consumption

Water is the most indispensable thing for humans, ranking second after air. From drinking water to taking a shower, human daily life is closely related to water. The substances contained in the human body are mostly composed of water, so water is very important for humans. In recent years, more and more water is wasted, and water resource depletion has gradually occurred. Cloud computing energy-saving systems can effectively control water consumption. The most commonly seen intelligent switch faucet is the sensing faucet in public facilities. However, it has not yet become widespread among families. Therefore, the experiment collected and compared the water consumption of these six households. The results are shown in Figure 6.

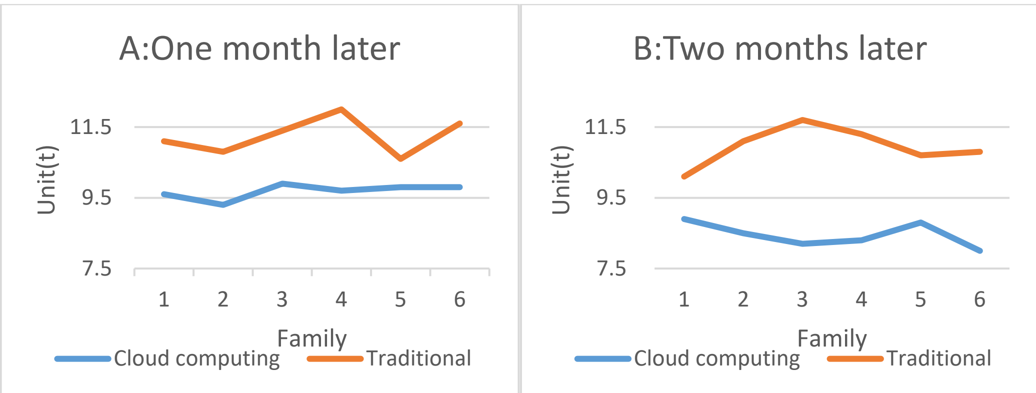

Figure 6A shows the water consumption after one month of the experiment
Figure 6B shows the water consumption after two months of experiment

Figure 6 Comparison results of water consumption

In Figure 6, it can be seen that the overall cloud computing data after two months was lower than after one month. After calculation, it was found that one month after using cloud computing to assist in energy conservation and emission reduction in smart buildings, the average water consumption of a household was 9.7 tons. Two months later, it was only 8.5 tons, a decrease of 1.2 tons. However, traditional energy conservation and emission reduction methods have not achieved significant results. One month later, it was 11.3 tons, and two months later, it was 11 tons, a decrease of only 0.3 tons. It can be seen that cloud computing can effectively reduce household water consumption.

4.5 New Energy Utilization Rate

Applying cloud computing to building energy efficiency can enhance the utilization of new energy. For example, when taking a shower, cloud computing can determine whether to use solar energy or electrical energy based on the actual situation. The energy stored by solar energy can still be used even when the sun sets at night. Therefore, if the solar energy stored during the day is sufficient, the cloud computing smart building energy-saving system can prioritize the use of solar energy, and vice versa, use electrical energy. In this way, the waste of new energy is avoided, while also saving electricity and reducing electricity bills. The experimental data was collected from the six residential buildings mentioned above, and the new energy usage data of these six residential buildings after using cloud computing to assist in smart building energy-saving systems for one month and two months, as well as the new energy usage data of these six residential buildings when using traditional building energy-saving systems for the first two months, were collected. Meanwhile, the new energy utilization rates of the two were calculated and compared. The results are shown in Figure 7.

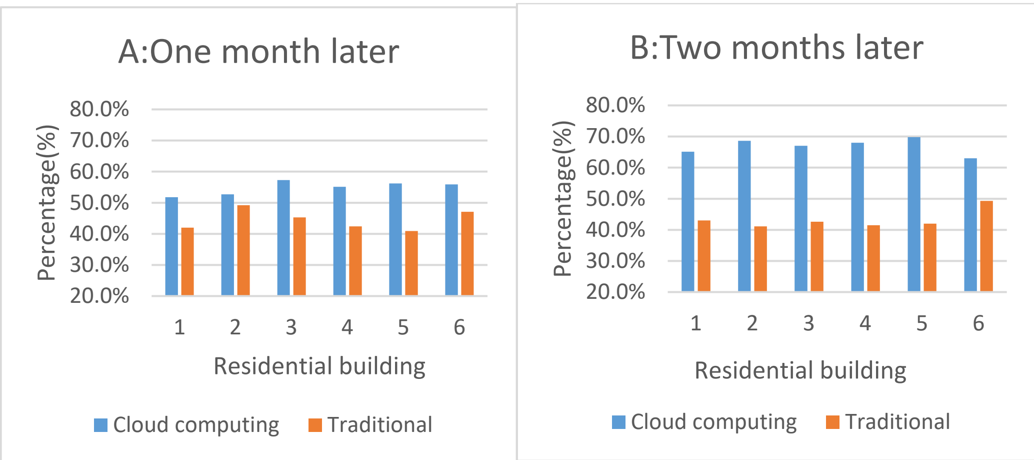

Figure 7A shows the utilization rate of new energy after one month of experiment
Figure 7B shows the utilization rate of new energy after two months of experiment

Figure 7 Comparison results of new energy utilization efficiency

In Figure 7, it can be seen that the overall cloud computing data after two months was higher than after one month. After calculation, it was found that one month after using cloud computing to assist in energy conservation and emission reduction in smart buildings, the average new energy utilization rate of residential buildings reached 54.8%. Two months later, it reached 66.9%, an increase of 12.1%. However, traditional energy conservation and emission reduction methods did not fluctuate much. One month later, it was 44.5%, and two months later, it was 43.3%. Not only did it not increase, but it also decreased by 1.2%. It can be seen that cloud computing can effectively enhance the utilization rate of new energy in residential buildings.

5. Conclusions

Due to the limited research on energy conservation and emission reduction control methods for smart buildings, this article optimized the energy conservation and emission reduction system of smart buildings by combining cloud computing. The research results showed that building energy-saving systems assisted by cloud computing were more effective than traditional building energy-saving systems in terms of natural environment and new energy utilization, as well as in optimizing power consumption, carbon emissions, and water consumption. Although experimental research has obtained some achievements, the article study still has some deficiencies. The article only conducted research at the household level, and the corresponding amount of data obtained was relatively small, which can

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only serve as a basic reference for smart building energy-saving systems. When facing the optimization of energy-saving systems for larger buildings such as office buildings, the method studied in the article may fail because the optimization of energy-saving systems for large buildings requires obtaining more data. The methods studied in the article may not meet the requirements of data analysis, data calculation, and data storage in the context of big data. Therefore, more experiments are needed in the future to meet the optimization needs of energy-saving systems in larger buildings.

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