Energy Conservation and Consumption Reduction in Residential Quarters: Taking Cuihu Garden Residential District in Pingxiang City as an Example

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Abstract. This paper uses Auto-Revit for an energy assessment of Cuihu Garden Residential District located in Anyuan District, Pingxiang City, Jiangxi Province. Comparative analysis of building energy consumption before and after energy-saving renovation. Through simulation analysis, it can be concluded that replacing LED light sources, enhancing natural ventilation efficiency, and increasing green roof construction can effectively reduce building energy consumption. This article draws the following conclusions: Firstly, by replacing the LED light source, the energy of the residents in the community can be reduced by 65.2%; secondly, the combination of mechanical ventilation and natural shaft ventilation can reduce 73kWh of electricity in ten hours; finally, the green roof energy effectively alleviate temperature changes on the surface of the building, and indirectly reduce the power consumption of heating and air conditioning in the building. The research results can serve as a reference for the improvement of building energy efficiency in cities with subtropical monsoon climate regions represented by Pingxiang City. The direction of energy-saving improvement can be extended to inland small cities in the country and the world.

1. Introduction
Nowadays, the construction industry is developing steadily [9]. According to the survey data of the National Bureau of Statistics of China, the proportion of energy consumption in the construction sector has grown rapidly. It increased from 17.7% in 2014 to 27.9% in 2018[25]. To improve the land utilization rate, high-rise buildings are constantly replacing bungalows, and the energy consumption is also increasing, which brings enormous pressure to the environment. But only paying attention to improving the land utilization rate, neglecting the necessary energy-saving measures can easily cause the building energy consumption to be too high. Therefore, the research on the building energy consumption has attracted attention in China.

Lan Lidang[1] confirmed through experiments that updating the power distribution system and using LED light sources can reduce emissions; Tan Donglai[2] suggested the use of high-efficiency lamps and optimized circuits to reduce building circuit energy consumption, while as far as the circuit system is concerned, the circuit cross-sectional area, transmission voltage, and load length cannot be optimized at the existing technical level. An Jingjing[3] believes that the effect of natural ventilation and mechanical ventilation is not much different, but the energy consumption is significantly reduced; Wang Fangyi[4] proposed to increase the lighting level of underground buildings and inspired the author’s research on ventilation shafts; Zhang Yaqin[5], through the Fluent software simulation, confirmed that the underground ventilation shaft is more energy-saving than the traditional mechanical...
exhaust. Yu Xiaohui[6] used infrared remote sensing and the three-temperature model to confirm that green roofs have a positive effect on weakening the roof surface temperature; Wan Jiehu[7] and Niu Hao[8] made researches on green roof fraud and investment payback period. However, there are currently few proposals for building energy efficiency in small cities in inland China.

Reducing the energy consumption of buildings will drive the national economy and indirectly guarantee the quality and safety of buildings [10], which is necessary for the sustainable development of cities and countries. Pingxiang City pays far less attention to building energy than big cities such as Beijing and Shanghai. However, building energy efficiency cannot be limited to developed cities. Hence, this paper will take the B2-04-06 plot of Cuihu Garden Residential District in Anyuan District, Pingxiang City as an example to conduct energy consumption analysis and energy-saving transformation. This article analyzes the building by Auto-Revit for its more intuitive illustration and higher speed compared with the traditional 2D drawing. This article focuses on the building energy-saving schemes for small cities in inland China. Combining the three perspectives of the lighting system, exhaust system, and green roof, a more comprehensive building energy-saving scheme is proposed for small cities in inland China. Through research and adhering to the concept of sustainable development, several effective suggestions will be put forward for the building energy of Cuihu Garden Residential District. Pingxiang City will represent one of the small inland cities in southern China and will make heuristic attempts at building energy efficiency. At the same time, this series of practical attempts will also promote the concept of building energy efficiency in more small cities.

2. Problems existing in building energy saving in Cuihu Garden Residential District

The building model of the plot is shown in Figure 1. The plot is located in Anyuan District, Pingxiang City, Jiangxi Province, with 113°56′ east longitude and 27°37′ north latitude. The construction area is 5147.33m² and the construction area is 44114.78m². The B2-04-06 plot has three buildings, one of which is 68800m long, 13500m long, and 51.2m high; the other two are 34400m long, 13500m wide, and 51.2m high. The area of the underground garage is 28752m². After modeling based on Auto-Revit software, using Ashrae 90.1 and Arch 2030 as standard analysis, the energy use intensity (EUI) of the building shown in Figure 2 can be obtained. The five influencing factors include lighting system and exhaust air system, wall construction, building direction, and roof construction. The EUI of the B2-04-06 plot in the Cuihu Garden residential area is 640kWh/m²/year. The experiment will analyze and transform building energy from the following three aspects, and find the most suitable building improvement suggestions.

![Fig. 1 Modeling diagram of Cuihu Garden Community](image)
2.1. The lighting system has low efficiency and high energy consumption

Whether the lighting system is installed in the light source circuit or daily power distribution will cause significant loss. If an energy-saving design is carried out on the lighting system, it can save power resources and reduce economic expenses.

According to the design plan of Cuihu Garden Community, the Cuihu Garden Residential District uses natural lighting, and the external windows use electric aluminum alloy blinds to shade the system; the lighting sources are incandescent lamps, fluorescent lamps, and HID lamps, and the lines use copper wires. Studies have pointed out that the use of ordinary incandescent lamps is estimated to be twelve times more expensive than the use of high-brightness light-emitting diodes [11]. The LED lamp has a long life and can continuously illuminate about 100,000 hours, while the incandescent and fluorescent lamps have only about 1,000 hours and 10,000 hours.

2.2. The underground parking lot uses only mechanical ventilation to cause energy loss

Besides, the underground parking lot ventilation system lacks natural ventilation function. Due to the limited land resources, to improve land utilization, many buildings have set up underground garages. Cuihu Garden Community also has an underground garage, of which the construction area of the underground garage set on the B2-04-06 plot is 28752 square meters. According to the design plan of Cuihu Garden Community, the inner wall of the parking lot uses a 200-perforated brick parking lot with a mechanical ventilation system. The air supply is 80% of the exhaust volume five times per hour. When the CO concentration in the air is more than 30mg / m³, automatic ventilation is turned on. If the concentration is less than 4 mg / m³, automatic ventilation will be turned off. The rational use of natural ventilation can reduce building energy consumption, and is beneficial to reduce indoor pollutants and carbon dioxide concentration [12]. Under the current circumstances, the enclosed underground garage space is often closed, and the problem of insufficient lighting will often occur, resulting in safety accidents [4]. At the same time, car exhaust is the main source of pollution in underground parking lots. The main categories are soot particles, CO, HC, SO₂, in closed spaces, heavy hydrocarbons, carbon monoxide, and nitrogen oxides in automobile exhausts can cause
respiratory diseases in the human body, especially children, and disorders of the central nervous system of the human body [12].

2.3. No green roof setting
Since the promotion of green roof technology in Pingxiang City is not comprehensive, all buildings in Pingxiang City currently have no green roof design. Pingxiang's subtropical humid monsoon climate zone has four distinct seasons and abundant rainfall. The average annual rainfall is about 1600 mm, the annual maximum rainfall is 2083.4 mm (1962), and the annual minimum rainfall is 1086.4 mm (1971), April-6 Monthly rainfall is concentrated, accounting for 44% of the annual average rainfall [13]. All buildings have sloped roofs for easy drainage. Studies have shown that the green roof has a significant effect of cooling and weakening the temperature change of the roof. In summer and winter, the temperature difference between the surface of the green roof and the cement roof reaches 9.94 and 9.35℃, and the temperature difference between the surface of the marble roof and the marble roof can reach 4.54 and 4.35℃. The day-to-day differences in surface temperature of cement roof, marble roof and green roof are 20.70, 14.80 and 10.30℃, respectively; the winter-day differences of the three are 17.60, 13.91 and 8.73℃, respectively [6]. Both Washington and Pingxiang belong to the monsoon climate, and Washington’s green roof technology and its environmental benefit evaluation have a reference for the research of this article. Studies have shown that in Washington DC greening 200,000 m^2 of roof area, 1600,000 m^3 of precipitation will be intercepted by the green roof every year, and it can reduce the overflow of 15% in rain and pollution areas [14]. The green roof can also significantly absorb greenhouse gases, and the results show that the green roof can absorb 375 g CO_2/m^2 annually on average [15]. In addition, the green roof can significantly reduce the energy consumption of the building and ultimately alleviate the heat island effect [16].

3. Optimization measures proposed for the design of building energy efficiency

3.1. Replace with the LED light source to reduce energy consumption of lighting systems
Electrical energy saving is an essential part of the field of building energy saving. In the daily electricity consumption of civil buildings, lighting electricity accounts for about 20%. If the following measures are taken to improve electrical lighting facilities, building energy consumption can be reduced [2], and the most consistent application of building resources can be realized. The environmentally friendly living environment has excellent socioeconomic and environmental benefits.

The light of the LED lamp is produced by superconducting luminescent crystals with super-high-intensity light. It uses an electric field to emit light and generates less heat than incandescent and fluorescent lamps. LED lights do not waste too much electricity in the form of heat. The spectrum is almost entirely concentrated in the visible light band. There are almost no ultraviolet rays and infrared rays in the spectrum, high color rendering, no radiation, no harmful substances in use, while the fluorescent lamps will evaporate mercury vapor [17].

After the fluorescent lamp is broken, the mercury concentration in the surrounding air can reach 10-20 mg/m^3, which causes dizziness, cough, fever, difficulty breathing, and memory loss. If waste fluorescent lamps are buried underground, the mercury contained in a fluorescent lamp can directly cause pollution of 180 tons of groundwater [18]. Incandescent lamps, fluorescent lamps, HID lamps and other light sources are much lower in energy consumption than LED light sources. Compared with incandescent lamps of the same brightness, it can save nearly 80% of power consumption [1]. The efficiency of ordinary incandescent lamps is 10-15 lumens /watt, fluorescent lamps are 50-90 lumens /watt, and the luminous efficacy of LEDs can reach 50-200 lumens /watt [19]. It can be seen that the luminous efficiency can be increased by up to 20 times after replacing the light source with a light-emitting diode LED light source. It is very beneficial for the sustainable development of energy [17]. Although the initial investment of LED lamps is relatively large, the investment recovery period is only 3 years. The energy saving effect and economic benefit are also considerable [17]. According to research by Tian Xiangwe’s team[17], the actual power of a 15 W LED lamp is 16 W, while the
actual power of a 40 W fluorescent lamp is 46 W. Taking Cuihu Garden Community as an example, according to the daily lighting time of 7 hours, the number of days used in a month is 30 days, and the use of 12 months in a year is calculated.

For a 15 W LED lamp, the actual power consumption per year is:

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\[ 16 \times 7 \times 30 \times 12 = 40320 \text{w} \cdot \text{h} = 40.32 \text{kw} \cdot \text{h} \]  

(1)

For a 40 W fluorescent lamp, the actual power consumption per year is:

\[ \text{For a 40 W fluorescent lamp, the actual power consumption per year is:} \]

\[ 46 \times 7 \times 30 \times 12 = 115920 \text{w} \cdot \text{h} = 115.92 \text{kw} \cdot \text{h} \]  

(2)

(1) Adopt the coefficient method to calculate the illuminance and solve the number of lamps

Illuminance coefficient formula:

\[ N = \frac{E_{av}A}{\phi U K} \]  

(3)

(2) Determination of parameters in the formula:

- \( E_{av}\) —— Average illuminance on the work surface, \( E_{av}=150 \text{ lx} \)
- \( A \) —— Working area, 130\( \text{m}^2 \);
- \( \phi \) —— Light source luminous flux; \( \phi = E_w \cdot S \)
- \( E_W \) —— Outdoor illumination, \( \text{lx} \): the average value of the road illuminance of the residential area is 0.6
- \( S \) —— Effective lighting area; \( S=49.69 \text{m}^2 \)

\[ \phi = E_w \cdot S = 102 \text{ lm} \]  

(4)

\( U \) —— Utilization factor: Check the "Lighting Design Manual" and use the coefficient \( U=0.69 \),
\( K \) —— Maintenance factor of lamps, Check "Building Lighting Design Standards" GB50034-2013, the maintenance factor of lamps and lanterns \( K = 0.8 \).

(3) Substituting the determined parameters into formula (3)

\[ N = \frac{E_{av}A}{\phi U K} \times 7.9 \]  

(5)

The actual number of lamps is 8, so the annual power consumption of LED lamps is:

\[ 8 \times 40.32 = 322.56 \text{kw} \cdot \text{h} \]  

(6)

The annual power consumption of fluorescent lamps is:

\[ 8 \times 115.92 = 927.36 \text{kw} \cdot \text{h} \]  

(7)

Under this circumstance, a household consumes 604.8kWh less electricity per year than fluorescent lamps. If all fluorescent lamps are replaced with LED lamps, each household can save 65.2% energy.

3.2. Increase natural ventilation shaft device

This paper proposes that specific improvement measures such as adding natural ventilation shaft devices and adding waste energy recovery devices can alleviate the current energy and safety problems.

If the parking lot increases the number of air changes and the amount of fresh air, to dilute the pollutants in the underground parking lot, it is easy to increase energy consumption, which is contrary to the concept of energy conservation and environmental protection [20]. Therefore, comprehensive consideration is given to the addition of ventilation shafts to assist the natural ventilation effect and communicate with the air above the ground in real-time. Outdoor air enters the opening of the underground garage ventilation shaft from the gap of the garage door, ventilation shaft, lighting shaft, etc., and flows upward along the axial direction of the connected air pipe, and finally is discharged to the outdoor. Hot pressure ventilation is natural ventilation formed by the difference in air pressure.
between indoor and outdoor caused by temperature difference. The air absorbs solar radiation, expands in volume, decreases in density, and rises under the action of buoyancy. The main factor that determines the amount of heat and pressure ventilation is the temperature difference between indoor and outdoor. The ventilation effect caused by this heat and pressure effect is also called the "chimney effect". The intensity of the chimney effect is related to the height of the building and the temperature difference between inside and outside [21]. When the air is circulated, harmful gases are discharged into the atmosphere. According to Zhang Ye’s team’s simulation of natural and mechanical ventilation through DeST, the following conclusions are drawn:

Through a total of 154 days of research from May 1st to October 1st, under the ventilation strategy that maintains 0.5 h-1 ventilation times throughout the day, the indoor thermal environment is harsh, and the room temperature is higher than 30 ℃ for more than 500 h.

Under the ventilation strategy of opening the window all day, the indoor thermal environment is significantly better than the previous one, and the time when the room temperature is higher than 30 ℃ is about 150 h.

Under the night-only ventilation strategy, the indoor thermal environment is superior to the first two cases, and the time at room temperature above 30 ℃ does not exceed 50 h [12]. The indoor air quality of natural ventilation is similar to that of mechanical ventilation, and the energy consumption is lower than that of mechanical ventilation systems [3]. Under the original ventilation system, there is no need to add an additional motor, and there is no need to increase the number of air changes. According to the experiment of Zhang Yaqin's team[5], for the ventilation shaft set in the parking lot of the residential area, if the ventilation time is set from 08:00 to 18:00, the electric power consumption when using mechanical ventilation is 110 kWh; when the system is used, the electric power consumption is 37 kWh. As a result, 73 kWh electric energy be saved in these 10 hours.

Pingxiang has a subtropical monsoon climate, with sufficient light and heat, foggy and windy, prevailing northeast and southwest winds. However, in winter, the temperature in this city is low, the temperature difference between indoor and outdoor is small, and the parking lot does not provide a heating system. The solid natural ventilation shaft system cannot be used in winter.

3.3. Construction of the green roof

The roof serves as the "fifth facade" of the city, accounting for about 40% to 50% of the total area of the impervious underwater cushion surface [22]. Studies have shown that the green roof has a significant effect on cooling and weakening the temperature change of the roof. In summer and winter, the temperature difference between the surface of the green roof and the cement roof reaches 9.94 and 9.35℃, and the temperature difference between the surface of the marble roof and the marble roof can reach 4.54 and 4.35℃. The day-to-day differences in the surface temperature of cement roof, marble roof, and green roof are 20.70, 14.80, and 10.30℃ respectively; the winter-day differences of the three are 17.60, 13.91 and 8.73℃, respectively [8].

Because Pingxiang is located in the hilly area south of the Yangtze River in China, it has a subtropical humid monsoon climate. Every year from April to July, there is abundant rainfall, which is easy to cause urban waterlogging. Starting in 2017, Pingxiang began to build a sponge city, and urban waterlogging was effectively alleviated, from an average of 1 meter in 2016 to 3 centimeters in 2017. The construction of the sponge city continues to extend, and the construction of green roofs can be introduced, which can relieve the pressure of the drainage system during the rainy season [23]. The roof of Cuihu Garden is flat. In the design of the green roof, green plants can be combined with the pool. To realize the recycling of rainwater through the green roof, a storage tank should also be connected under the roof to form an integrated slope house drainage collection system [24]. In the construction of the sponge city, adding green roofs and spreading to the whole city can play a proper role in saving energy. Green roofs can also beautify buildings and purify the air. The cost of an ordinary roof garden is generally 300~700 yuan/m², and the maintenance fee is generally 30~70 yuan/m²·year[7]. Draw out the range of a single building, the fastest investment recovery time for a green roof is 8 years[8]. Studies have shown that the green roof has a significant effect on cooling and
weakening the temperature change of the roof. In summer and winter, the temperature difference between the surface of the green roof and the cement roof reaches 9.94 and 9.35°C. The day-to-day differences in the surface temperature of cement roof, marble roof, and green roof are 20.70, 14.80, and 10.30°C respectively; the winter-day differences of the three are 17.60, 13.91 and 8.73°C, respectively [8].

![Benchmark Comparison](image)

**Fig. 3 Reconstructed building benchmark comparison**

4. Conclusion
In this simulation experiment, an exploratory study was conducted on the Cuihu Garden residential area. By comparing the bills before and after renovation, and using Auto-Revit to model and analyze the transformed B2-06-04d plot of Cuihu Garden Community. As shown in Figure 2, the energy consumption is reduced by 25.47% compared to the time when it was not renovated. The results show that by taking corresponding improvement measures on the lighting system and the ventilation system, and adding a green roof design, building energy consumption can be effectively reduced from 640 to 477. A practical building energy-saving design of a building can not only apply the saved energy to more necessary places but also more deeply alleviate the urban water-logging and urban heat island problems in Pingxiang City. At the same time, it can also play a role in alleviating environmental pressure, saving social resources, and promoting sustainable development. Building energy efficiency cannot be limited to these three aspects. From the perspective of future development, breakthrough research is also needed in the following areas:

Firstly, how to reduce carbon emissions during the entire building life cycle of the building design stage, building construction stage, building use stage, and building the demolition stage should be considered. Secondly, promotion and use of new energy sources such as geothermal energy and solar energy. Third, the ventilation system improvement measures in winter still need to be considered in combination with actual conditions and costs.

The implementation of the building energy improvement plan mentioned in this paper will bring a necessary cost increase, however, in the future, the building can be used in the process, it can effectively reduce energy consumption, thereby alleviating the pressure on social resources.

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