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Analysis of Factors Affecting Energy Consumption in Student Dormitories

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Abstract. Against the backdrop of accelerated construction and green development concepts in university campuses, energy analysis of campus buildings can effectively provide a reference for improving the problem of excessive energy consumption, promoting the green and low-carbon transformation of campuses, and facilitating green and low-carbon development. Therefore, multi-dimensional research on building energy consumption is of great significance. This paper takes the student dormitory buildings of a certain university in Nanchang as a case study, using Revit software for simplified digital modeling and annual building energy simulation analysis. For dormitory buildings, the paper analyzes the effects of different factors on energy consumption from multiple dimensions, including building orientation, geographical location, and internal components, and proposes relevant reasons. The results show that different factors have significant differences in their impact on dormitory energy consumption. Rotating the building orientation 90 degrees clockwise increases cooling energy consumption by over 38%, and the best energy consumption performance observed when the wall thickness is 300mm. Furthermore, the total energy consumption and heating/cooling demand structures differ significantly among Nanchang, Beijing, and Hainan due to climatic differences. The research findings provide ideas and methodologies for university building design and contribute to China's "dual-carbon" goals.

Keywords: Dormitory, energy consumption, Revit modeling, energy saving optimization, green building

1. Introduction

With the accelerating pace of university campus construction in China and the growing acceptance of green development concepts, dormitory buildings, as crucial spaces for students' daily study and life, directly impact the sustainable operation of the campus and have a profound influence on students' quality of life and well-being. This study aims to actively respond to the national "dual-carbon" strategic goal, effectively promote the transformation of campuses towards low-carbon and green development, and optimize building performance and effectively change energy consumption patterns through scientific methods. Therefore, a multi-dimensional and in-depth study of university student dormitories is necessary. This will not only help improve the energy efficiency of dormitory buildings and reduce carbon emissions but also create a more comfortable and healthy living

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environment for students, thereby promoting the overall green development of the campus and contributing to the achievement of China's " dual-carbon" goal.

Previous studies have focused on different types of buildings, indicating that the building's construction year and internal components affect energy consumption [1]. Different building forms correspond to different energy consumption. For example, in Changsha, the energy intensity of point-shaped Local Climate Zone(LCZ)-3, LCZ-6, and slab-shaped LCZ-4 is lower than that of enclosed office buildings LCZ-2 and LCZ-5 [2]. The properties of building components, including the type of exterior window glass and the thickness of exterior wall insulation materials, also affect energy intensity [3]. However, for the specific building type of dormitory, there is still a lack of research on energy consumption analysis under the changes in the internal properties and external factors of a single building unit.

This study focuses on the student dormitory building of a university in Nanchang. Closely adhering to the core concept of green development, it examines the dormitory building from multiple perspectives, including its orientation, location, and the properties of its building components. Utilizing the Autodesk Revit 2025 building analysis tool, the study employs simplified modeling and annual building energy simulation analysis to explore and uncover optimized pathways for energy conservation and efficiency improvement. The research findings aim to provide a scientific and practical reference for the renovation and upgrading of existing university dormitories and the design and planning of new dormitories, thereby contributing to the construction of a green, low-carbon, and sustainable campus environment.

2. Case analysis

The dormitory of a certain university, Nanchang City, Jiangxi Province, China, is used as the reference building for this case. To facilitate data analysis, the model is simplified. Nanchang City is located between 115°27' and 116°35' east longitude and 28°10' and 29°11' north latitude. Nanchang has a humid and mild climate and belongs to the subtropical monsoon region. It has abundant rainfall, distinct seasons, short spring and autumn, and long winter and summer. The average temperature in 2023 was 19.6℃, the extreme maximum temperature was 38.0℃, and the extreme minimum temperature was -3.5℃. The annual precipitation was 1848.7 mm, the number of rainy days was 127, and the annual average relative humidity was 72.3%, which is relatively high. The plum rain season (June-July) is particularly humid. The annual sunshine duration was 1638.4 hours. The annual average wind speed was 1.7 m/s [4]. Winters are predominantly northerly winds, and although not severely cold (belonging to the category of "warm winters"), the damp chill is pronounced, and it feels quite cold when cold air masses arrive. Frost is occasional. Summers are predominantly southerly winds, and July and August often experience drought, with concentrated and heavy rainfall. Figure 1 shows a schematic diagram of the case model , which has 8 floors (including the rooftop), is 70,000 mm long, 18,000 mm wide, and has each floor a height of 4,000 mm. It has no basement and can accommodate hundreds of students. Table 1 shows the model material settings , and Table 2 shows the model parameter settings, both based on the software's built-in properties.

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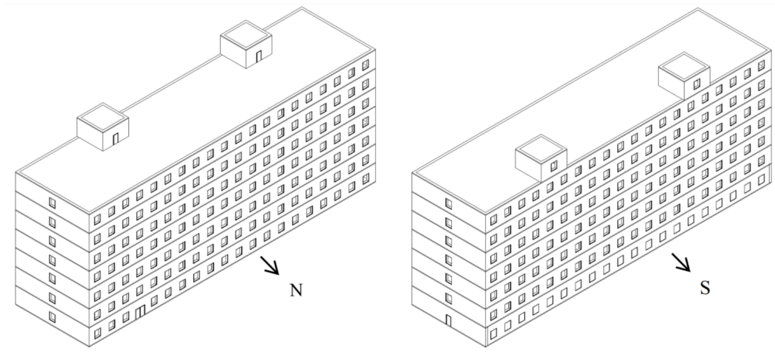

Figure 1. Schematic diagram of the case model (picture credit : original)

Table 1. Model material settings

Element	Parameter
Floor slab	Standard - 150mm
Wall	Standard - 300mm ; Height: 4000mm
Window	1/8 - inch Pilkington single-pane glass; 1750mm×1400mm
Door	Metal door frames, single-pane glass doors, glass windproof equipment;1000mm×2000mm

Table 2. Model parameter settings

Parameter	Value
Building type	Dormitory
Building Operation Schedule	Default
Building equipment	VAV - Single Duct
HVAC system	Residential 14 SEER/8.3 HSPF Split/Integrated Heat Pump

3. Original model annual simulation energy analysis

3.1. Original model analysis results

Energy consumption analysis was performed using Revit software, and the results are shown in Table 3. Site Energy refers to the total amount of energy directly consumed by the building in actual use, including electricity consumed by user terminal equipment, heat energy from heating systems, and cooling energy from air conditioning systems. Source Energy refers to the total amount of raw energy required to produce Site Energy, covering all losses in the extraction, conversion (e.g., power generation from power plants), transmission, and distribution of primary energy sources (fossil fuels, renewable energy, etc.).

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Table 3. Energy consumption analysis results

	Energy consumption [GJ]
Site Energy	7396.04
Source Energy	14980.67
Heating Energy	508.62
Cooling Energy	4106.22

3.2. Energy-saving discussion of the original model

Based on the energy consumption analysis results in Table 3, the total Site Energy is 7396.04 GJ, of which cooling energy accounts for as high as 55.5% and heating energy accounts for only 6.9%. The simulation results are highly consistent with the characteristics of the subtropical monsoon climate in Nanchang. The summer is long and hot and accompanied by high humidity. The long period of high temperature leads to strong demand for air conditioning cooling, while winter is not really cold but damp, and the demand for heating is relatively mild. Cooling energy is 8.07 times that of heating energy, which shows that the cooling demand is long during the school period. Therefore, from the perspective of cooling, can explore optimization schemes from the short-term and long-term dimensions of the internal components of the building. In the short term, the cooling system can be adjusted by cleaning the filter and adding refrigerant to improve cooling efficiency and reduce unnecessary energy consumption; or the insulation at the indoor and outdoor interface can be strengthened, such as adding an insulation layer to the exterior wall or adding double-glazed windows to the existing exterior windows to reduce the rate of low temperature loss through the building and reduce the cooling burden of air conditioning [5]. Long-term strategies of high investment but high efficiency are adopted, such as updating old equipment components in buildings to reduce energy consumption from the equipment end and optimize the energy efficiency of the cooling system [6]; or installing solar panels in the roof space of buildings to improve energy efficiency and reduce energy demand by utilizing solar energy [7].

4. Factors affecting model energy consumption

4.1. Orientation layout

Figure 2 shows the modified scheme, which involves rotating the original model 90 degrees clockwise and then performing an annual simulated energy analysis, resulting in the energy consumption analysis results shown in Table 4.

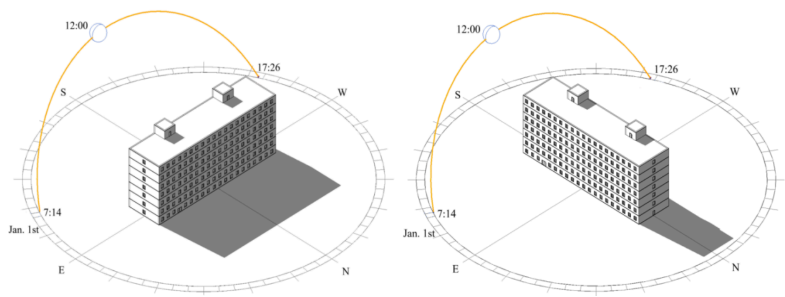

Figure 2. Before orientation change (left), after orientation change (right) (picture credit : original)

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Table 4. Energy consumption analysis results

	Energy consumption [GJ]
Site Energy	9146.16
Source Energy	17182.35
Heating Energy	447.44
Cooling Energy	5675.68

As shown in Table 4, it can be seen that both Site Energy and Source Energy have increased significantly. Site Energy increased by about 23.66% and Source Energy increased by about 14.70%, indicating that the modified orientation makes the building interact with solar radiation more frequently, and the building needs more energy to maintain a suitable environment, and the overall energy consumption burden becomes heavier. In terms of heating energy consumption, it decreased from the original 508.62 GJ to 447.44 GJ because the east and west sides can be exposed to the sun after the rotation, the load of the heating system is reduced, and the heating energy consumption is reduced; while cooling energy consumption increased from 4106.22 to 5675.68, an increase of more than 38%, because the solar radiation surface increased, the building absorbed more heat, and the cooling system needed to operate at high intensity continuously, resulting in a significant increase in cooling energy consumption. Studies have shown that the influence of building orientation on energy consumption has a significant linear relationship [8], so when designing dormitory buildings, orientation should be selected according to their characteristics.

4.2. Geographical location layout

Due to climate differences across regions, energy consumption varies. By adjusting the geographical location of student dormitories, primarily changing their latitude, and selecting representative cities, this study specifically investigates the impact of geographical location on energy consumption differences. In this study, the original model was adjusted from Nanchang to Beijing and Hainan, and annual simulated energy analyses were conducted again, resulting in Figure 3 .

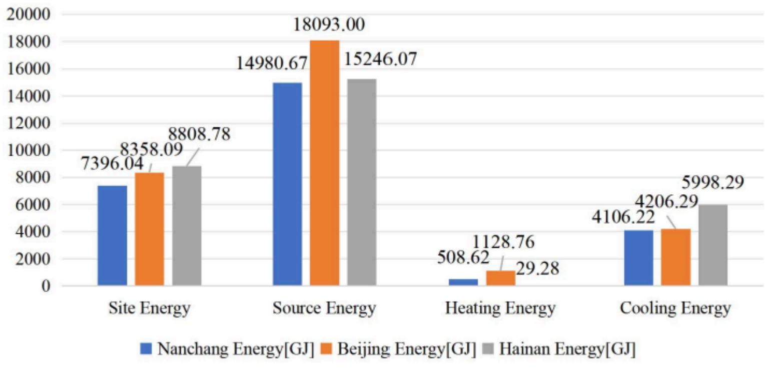

Figure 3. Comparison of data from Nanchang, Beijing, and Hainan (picture credit : original)

Beijing has a temperate monsoon climate, characterized by distinct seasons and simultaneous rainfall and heat. Influenced by the thermal differences between land and sea, summers are hot and rainy, with rainfall concentrated in July and August, accounting for over 60% of the annual precipitation, and temperatures typically range from 25-35℃. Winters are cold and dry, with average January temperatures below -5 ℃ and little snowfall. Spring and autumn are short, with rapid

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temperature fluctuations and mostly sunny and windy weather. The large annual temperature range and annual precipitation of approximately 600-800 mm, concentrated in summer, contribute to Beijing's distinct seasonal variations in temperature and humidity.

Hainan is primarily characterized by a tropical monsoon climate, with southern areas like Sanya also exhibiting tropical maritime monsoon characteristics. High temperatures year-round and distinct dry and rainy seasons are its core features. The average annual temperature is 22-27°C, and even in January, the coldest month, the average temperature is above 16°C, with no true winter. The rainy season lasts from May to October, with abundant rainfall, including frequent typhoons and convective rain, reaching 1500-2000 mm annually. The dry season runs from November to April of the following year, characterized by sunny weather, little rain, and ample sunshine.

From the comparison of data from Nanchang, Beijing and Hainan in Figure 3, it can be seen that Beijing's temperate monsoon climate has high demand for both heating and cooling due to the large temperature difference between the four seasons, resulting in high total energy consumption; Hainan's tropical monsoon climate has no true winter and is warm all year round, so the demand for cooling is long-term and there is almost no need for traditional heating, resulting in lower source energy than Beijing; Nanchang's subtropical monsoon climate has cold winters and hot summers, but the temperature difference is smaller than that of Beijing, resulting in a more balanced total energy consumption. Some studies have pointed out that the window-to-wall ratio is related to cooling and heating energy consumption. When the length-to-width ratio increases, cooling and heating energy consumption will increase [9]. Therefore, the parameters of building components can be adjusted according to different geographical locations to match the different needs of the location.

4.3. Component parameters

Building energy consumption can be altered by adjusting the properties of building components. This study analyzes the impact of changes in wall thickness on energy consumption by altering the wall thickness from the original model (300mm) to 100mm and 500mm, and conducts annual simulated energy consumption analysis, resulting in Figure 4 comparing the wall thicknesses .

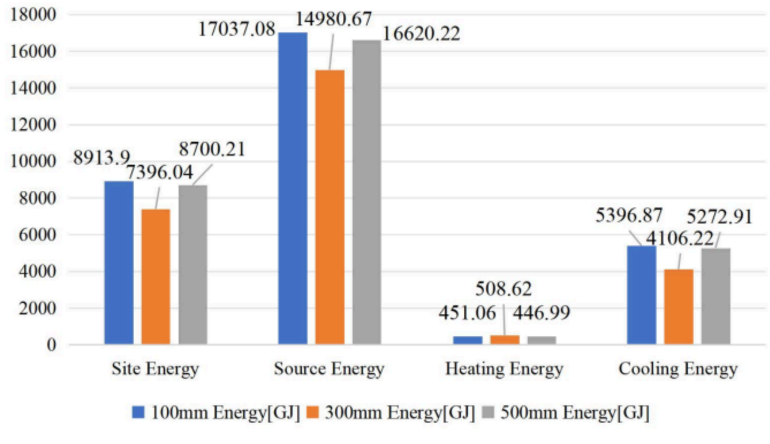

Figure 4. Comparison of data for different wall thicknesses (picture credit : original)

The relationship between different types of energy consumption and wall thickness is not a simple linear one. Taking Site Energy as an example, a wall thickness of 300mm is significantly lower than that of 100mm (thinner) and 500mm (thicker), and Source Energy shows a similar trend. This indicates that there is an "optimal range" for the impact of wall thickness on energy consumption, and simply increasing or decreasing the thickness does not necessarily optimize

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energy consumption. Using a 300mm wall as a baseline, heating energy consumption decreases by 11.2% when the wall thickness is changed to 100mm, and by 12.1% when it is changed to 500mm; cooling energy consumption increases by 31.4% when the wall thickness is changed to 100mm, and by 28.4% when it is changed to 500mm. This is because thinner walls have lower thermal resistance and weaker heat storage capacity, making it difficult to maintain a stable indoor temperature during heating, and making them more susceptible to outdoor heat during cooling, leading to increased energy consumption. Thicker walls have excessive thermal inertia; during heating, the thermal resistance reaches saturation and cannot continuously prevent heat loss, and during cooling, a large amount of solar radiation heat is stored during the day but cannot be effectively dissipated outdoors at night, both of which increase energy consumption.

Of course, in addition to the comparison of wall thickness alone, whether or not an insulation layer is added will also affect building energy consumption. Compared with buildings without insulation layers, buildings with insulation layers can effectively save heating energy consumption and total energy consumption [10]. In addition, more comprehensive research can be conducted on climate adaptability and the application of emerging technologies to explore energy consumption optimization schemes under the combined effect of multiple fields.

5. Conclusion

This study, based on the green and low-carbon development and 'dual-carbon' strategic goals of universities, uses student dormitories of a university in Nanchang as the research subject. A simplified digital model was constructed using Autodesk Revit 2025 software to simulate annual energy consumption. From key dimensions such as building orientation, geographical location, and internal components, the study systematically explored the influencing factors of dormitory building energy consumption. Combining the subtropical monsoon climate characteristics of Nanchang, the study analyzed the differentiated effects of different factors on building site energy and source energy consumption, verifying the value of building design and environmental adaptability in energy conservation and efficiency improvement, and energy consumption reduction.

Compared to previous studies, this research's multi-dimensional variable analysis of a single dormitory building unit fills the gap in targeted studies of similar buildings and provides more solutions for optimizing energy consumption in dormitory buildings. The research findings not only provide a scientific reference for the renovation and upgrading of existing university dormitories and the design and planning of new buildings, but also provide a valid basis for the practical application of building energy-saving technologies.

This research can be further expanded by incorporating dynamic factors such as the occupancy rate of actual university dormitories and behavioral differences between men and women to conduct more precise energy consumption research.

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