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The Impact of Passive House Construction on Energy Consumption and Living Experience in Chongqing

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Abstract: This research investigates the impact of passive house construction on energy consumption and living experience in Chongqing, China. The study involves both primary and secondary methodology, which is represented in both qualitative and quantitative formats. The primary research evidence is collected from an online questionnaire and interviews with designers and engineers in the industry. The secondary evidence is collected from a range of online sources including relevant and credible academic articles, essays and news reports, and government reports. A case study based on a passive house project in Hebei is used to compare with passive house construction in Chongqing. The key areas considered in the study are the environment, policies, and social aspects and the impact of passive house construction on the living experience of the residents. The research concludes that passive house construction has positive results from both climate and policy perspectives. In terms of climate, it is environmentally friendly and energy-efficient. The development of more policies technologies will be the main driving force or motivation for more passive house construction.

Keywords: Passive house construction, Energy consumption, Living experience, Policies technologies.

1. Introduction

The Chinese government has committed to the world to achieve carbon peaking by 2030 and carbon neutrality by 2060 (the double carbon goal) to the world [1]**.** In order to achieve the "dual carbon" goals, high-efficiency building energy efficiency measures are a necessary tool. The 'passive house' approach protects the environment from decarbonization, in order to become more carbon neutral, and it will build a more sustainable future for society and for future generations. However, "building operations and construction currently account for nearly 40% of global energy-related CO2 emissions." [2] According to the 11th and 13th UN goals, "Sustainable Cities" and "Communities and Climate Action", the global society should start to take action to build with decarbonization and reach the goal in 2030. Therefore, the passive house is the initial approach to achieving efficient structures in housing; the use of passive houses is vital for the world with high expectations of achieving carbon neutrality.

Chongqing, as a municipality directly under the central government of China, has been vigorously promoting the construction of passive buildings since 2020 [3]. In this paper, Chongqing will be used as a case study for the impact of 'Passive House' on both energy consumption and living experiment aspects.

Nevertheless, there are a variety of political, and social impacts on the construction of energy-efficient housing in Chongqing. In this context, a case study on emission reduction is used to analyze the impact of environmental and technical features of a passive house; a questionnaire is used to study the living experience of passive house residents. Through interviews, architects and engineers were asked about the implementation of a passive house in Chongqing. As a result, this research examines the impact of the passive house approach on energy-efficient housing construction and living experience of people, with specific reference to Chongqing.

2. Literature Review

A number of relevant and credible secondary sources of information were employed to support the research, the most significant of which are referred to in this section.

2.1. Carbon emissions

Carbon emission is one of the most significant issues faced today, and for future generations. According to Our World in Data, carbon emissions increased from 6.00 billion tons in 1950 to 37.21 billion tons in 2021 [4]. This huge discrepancy in these statistics reflects the rapidly growing level of carbon emission in the world. Carbon dioxide is one of the greenhouse gasses that account for 80% of greenhouse gasses remaining on Earth [5]. It is the main factor that causes global climate change. When sunlight hits the Earth's surface, greenhouse gasses absorb heat and reflect it back into the atmosphere. In this way, the greenhouse effect keeps the Earth's climate suitable for life [6]. On the other hand, the large number of greenhouse gasses leads to global warming, and the temperature keeps increasing on the Earth every year, which creates tragic consequences. Such consequences are wide-reaching, for example, dirtier air, higher wild animal extinction rate, the melting of glaciers, higher sea levels, and ancient viruses being released into the glaciers. As a result, carbon emission leads to significant environmental consequences on the Earth.

2.2. A technology to solve the issue in China

China is known as the country with the largest population and the highest rate of carbon emissions in the world. According to the IEA Atlas of Energy, China is the highest annual CO2 emitter with 30% of its emissions in 2019 [7]. Chongqing is the most densely populated city in China, with a population of over 32 million [8]. Cities with relatively large populations will release more carbon emissions in their daily lives than cities with smaller populations. Since China has the largest carbon footprint and Chongqing is the most populous city in China, Chongqing can be used as a case study to delve into the carbon-neutral technology of passive houses. This technology is true of great interest to humankind, as it is about achieving a sustainable future for the planet by neutralizing carbon emissions; improving the thermal insulation and thermal insulating properties of buildings; improving the indoor thermal comfort environment of buildings; and reducing the energy consumption of heating and air conditioning equipment usage.

2.3. Passive House

Passive house technology is a highly energy-efficient building standard developed in Germany. The research has shown that passive house buildings can save up to 90% of energy in typical building stock and compared with 75% in average new buildings. It is known as a near-zero energy building technology system. The requirements for a passive house are very simple, as no high technology is

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required, only simple materials and systems are needed to meet the standards of a passive house. However, the most important and effective way to achieve the passive house standard is through a good design. There are some important tips to make the building functional and aesthetically pleasing, providing a comfortable indoor environment. Firstly, compact design with a low surface area to volume ratio, making maximum use of the free energy in the surrounding environment. Secondly, minimal geometric thermal bridges by using minimal energy for heating and cooling the building. Thirdly, appropriate levels of solar gain, shading, and ventilation. Passive houses are designed to take advantage of natural light and heat from the sun. This helps reduce the amount of energy needed for heating and cooling, reducing energy use and carbon emissions. However, the third tip is not compulsory. The passive house does not need to have a passive solar design, because the standard can work in different conditions; no matter if it is in cold, shady, or hot conditions or climate. In order to meet the passive house standard, five basic principles of energy efficiency should be considered in the design: thermal insulation, passive house windows, ventilation heat recovery, airtightness of the building, and the absence of thermal bridges [9].

2.4. The history of the passive house

The innovative concept behind the passive house movement originated in the United States and Canada in the wake of the 1973 oil embargo that led to an energy crisis. This crisis led a group of engineers and architects to design the Lo-Cal house in 1976. This home used the principle of high insulation to consume 60% less energy than the most efficient buildings of the time. After, the American physicist William Shurcliff first referred to the concept of super-insulation and passive solar energy as the passive house in his book in 1982 [10]. The now well-known passive house was developed as a "Passivhaus" in Germany in the 1980s. At the time, Germany had higher minimum building code standards than other countries such as Australia and New Zealand, but it is still considered inadequate. By the late 1980s, the U.S. shifted the passive house movement away from energy efficiency and Germany took over. Wolfgang Feist, a German physicist, improved the design of the passive house by increasing efficiency to decrease heating demand. Later, he founded the Passive House Institute (PHI) and created the Passive House Performance Standard, which is often considered the most stringent standard in the industry of energy efficiency today. Katrin Klingenberg found PHI while studying in Berlin. She reintroduced the modified passive house principles to the United States. In 2003, Klingenberg completed the first home built to PHI standards in the U.S. and became a co-founder of the Passive House Institute of the United States (PHIUS). She and others at PHIUS discovered that PHI's single performance metric was not applicable to the extreme variations of the North American climate. In 2015, PHIUS released the PHIUS+ standard, the only passive building standard that considers cost-effectiveness and climate-specific performance criteria [10].

2.5. Research gap

According to historical records and passive house research, previous studies have focused on Europe and North America, but there are only a few studies on passive houses in China, which is a research gap. The purpose of this research is to evaluate whether passive houses have a positive impact on energy-efficient housing construction and if it is a worthwhile way of building energy conservation initiatives in the Chinese city of Chongqing.

3. Methodology

This research analyzes the impact of passive houses on energy-efficient housing construction from both primary and secondary evidence and assesses the extent to which passive houses are worth promoting in Chongqing.

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3.1. Secondary research

A reading log, which lists all the secondary sources employed in this research, is provided in the Appendix. The log also includes critical comments relating to each source's content, relevance, and reliability.

Secondary research is conducted by studying a range of relevant literature and reports including a case study; the aim is to use the secondary research reports to help to conduct an in-depth analysis of individual cases and explain the primary research results. Primary research methods involve a questionnaire and several interviews; the aim is to gather more information on the different impacts of passive houses in Chongqing. There is limited information about passive houses, especially within China that can be sourced on the internet. Therefore, the most direct and convenient way to gather useful and reliable information is through interviews and questionnaires methods.

3.1.1. Case study

The name of the case study is **'Longhu Gaobeidian Train New City Project,'** and it is located in Gaobeidian City, Hebei Province, China. This case study is used to study Chongqing from an environmental perspective, and evaluate the technology between both cities. The types of buildings from the project involved in the project include low-rise, multi-story, and high-rise structures; different building types have different energy efficiency rates. It is a large project in China with a construction area of approximately 40,000 square meters. The passive house construction unit is "Chongqing Three Primary Colours Energy-saving Building Engineering Co" [11] The reason for choosing to focus on this specific project is to analyze the extent to which the passive house neutralizes carbon emissions and the degree of impact on the environment. Also, another reason considered is the construction unit for this project is a company from Chongqing, which is relevant to this case study. This source [11] consists of both qualitative and quantitative research; there is analytical text content, as well as tables and bar charts. The information collected from the 'Ministry of Science and Technology 13th Five-Year National Major Project Report' is used to analyse the evidence. The report is published by the Chinese government, which is considered an authoritative and reliable source.

3.2. Primary research

3.2.1. Questionnaire

With regard to the primary research, the participants of the questionnaire are people who have been living in passive houses. All participants live in different cities in China, and they are of different genders and different socio-economic backgrounds. The private information of the respondents is not disclosed or recorded in the study due to confidentiality agreements. The purpose of the survey is to understand the living conditions, living information, living experience, and satisfaction of people living in passive houses. The questionnaire consists of ten questions carefully designed, with a range of single-choice, multiple-choice, and open-ended questions. These questions cover basic information about the passive house, as well as gender and reason for living in the house; living conditions, including the number of people living in the house; the monthly electricity bill and the year of living in the house; the living experience, including different feelings and thoughts about living in the passive house, as well as opinions and levels of satisfaction with the passive house. The questionnaire addresses moral and ethical aspects, reflecting the impact of passive housing on people from a social perspective. The results and analysis of the questionnaire are shown in the quantitative format in the Results section of the dissertation, together with summative comments which highlight the main findings.

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3.2.2. Interviews

The participants of the interviews are designers and engineers. They are all experts from the building energy efficiency industry with plenty of experience. All participants work in the passive house-related industry in China and have a deep understanding of passive houses in the region; their insight and knowledge base of the region exceeds that of many online sources. Apart from the job title of the interviewees, private personal information is not disclosed or recorded in the study due to confidentiality agreements. The interviews are conducted online with nine engineers and seven designers, which is more time-efficient and convenient and avoids potential issues regarding the distance of the location. The purpose of the interviews is to explore whether or not there are any obstacles to the implementation of passive house projects in Chongqing, and the nature of the impacts that building the passive house projects may bring. The questions for the interviews are mainly grouped into multiple-choice and open-ended questions. The advantage of multiple-choice questions is that the data can be more easily analyzed and represented visually in charts. Open-ended questions, on the other hand, focus on more specialized questions that require expert answers; this allows for comparison and analysis to learn and gather more comprehensive responses with a variety of aspects from different experts. The interview assesses the environmental, political, and social impacts of the Passive House in Chongqing from a more professional perspective, and also explores whether Passive House projects are suitable for implementation throughout Chongqing. The primary research contains mainly qualitative evidence because they had different insights into different aspects of passive houses and answers are deep and detailed evaluated.

4. Results

4.1. Environmental Impact of Passive Houses

The results of the secondary research are represented as a series of bar charts and tables in this section.

4.1.1. Impact of power consumption

The project of Longhu Gaobeidian Train New City Project saves 50% to 70% on top of the original 65% energy efficiency of residential buildings in Hebei Province, reaching 82.5% to 89.5%. Since there are multi-story and high-rise buildings, different types of buildings have different energy efficiency rates. [11] The following tables show data from Longhu Gaobeidian Train New City Project.

Table 1: The energy saving rate of the Longhu Gaobeidian Train New City Project

Heating energy consumption guide value	Actual heating energy consumption	Energy saving rate	Indicator requirements
$6.4Nm^3/m^2 \cdot a$	$2.64Nm^3/m^2 \cdot a$	50.6%~72.4%	≥50%

Calculated by the above average data (heating energy guide value and actual heating energy consumption), the energy saving rate reaches 61.6%, which exceeds the index requirement. Although the energy-saving rate varies among building types, the lowest energy-saving rate also meets the index requirement of passive houses.

Table 2: The technical measures and indicators from Longhu Gaobeidian Train New City Project

Technical measures	Basic Structure	Indicators	Standard recommended value
Level insulation	XPS	K=0.09/0.15/0.15	0.10~0.20
External wall insulation	Graphite EPS thin plastering system	K=0.12/0.13/0.14	0.15~0.20
Floor insulation	XPS/Superfine inorganicfiber	K=0.15/0.17/0.17	0.20~0.40
Exterior Windows	Aluminum clad wood windows with three glass and two chambers	K=0.8 SHGCS=0.5	K⩽1.2 SHGC⩾0.45
Heating and Ventilation(HVAC) Equipment	Unit pendingin udara segar all-in-one	HRE=80%	HRE⩾75% ERE⩾70%

The technical measures of energy saving are based on five aspects: level insulation, exterior wall insulation, floor insulation, exterior windows, and heating and ventilation equipment. This data shows one of the indicators of the 'level insulation,' all the indicators of the 'exterior wall insulation' and the 'ground insulation' did not reach the standard recommended value. It shows that there is still some small technical problem with the passive house project. However, it does reach the energy saving rate of indicators requirement as the Figure 4.1.1. showed.

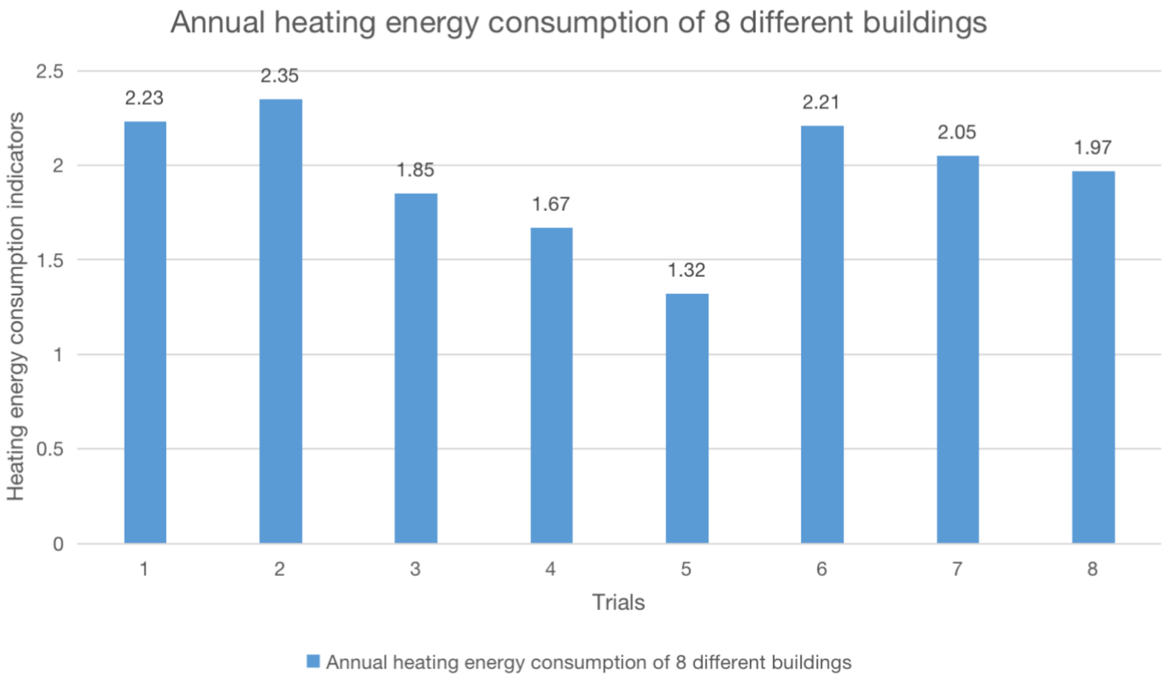

Figure 1: Annual heating energy consumption of 8 different buildings

The above figures show the annual energy consumption of eight buildings of the Longhu Gaobeidian Train New City Project. From the above data, the average annual energy consumption is 1.97, and the average monthly energy consumption is 0.16. The figure showed that the indicator of heating energy consumption is unstable between different buildings. Therefore, it explains there is a range of energy-saving rates from Figure 4.1.1., and the technology should still improve in China.

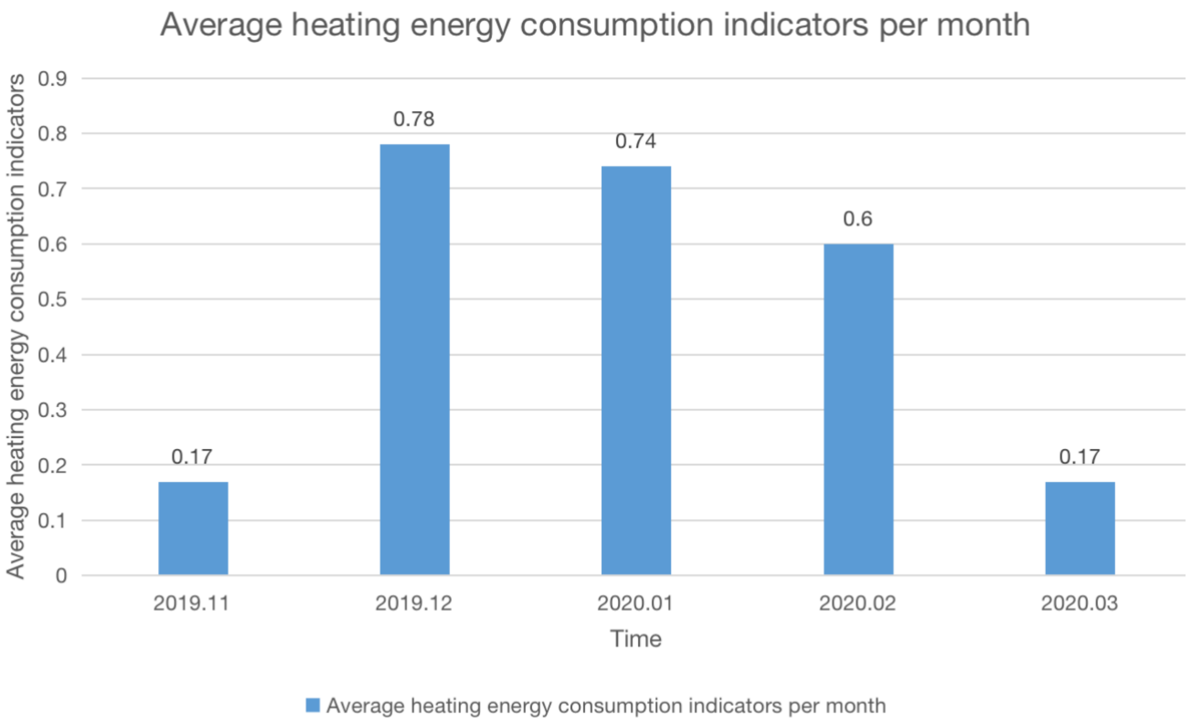

Figure 2: Average heating energy consumption indicators per month

The bar chart above shows the heating energy indicators for five months, from December to March. Among them, December, January, and February have the highest indicators, while the other two months are low. This shows that the heating energy indicator consumed is the highest in winter, with an average heating energy indicator of 0.71. Therefore, the hotter the weather, the higher the heating energy consumption with more electricity used.

4.1.2. Impact of carbon emissions in different regions of China

Table 3: The carbon footprint factor values in the electricity grid of China

Electricity grid	Unit	Carbon footprint factor values	Scope
North China		1.27	Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia
Northeast China		1.36	Liaoning, Jilin, Heilongjiang
East China	$kgCO2/kwh$	1.04	Shanghai, Shandong, Jiangsu, Zhejiang, Anhui, Jiangxi

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Table 3: (continued).

South China	0.88	Fujian, Hainan, Guangdong
Northwest China	0.94	Shanxi, Ningxia, Gansu, Qinghai, Xinjiang
Central China	0.85	Henan, Hubei, Hunan
Southwest China	0.85	Guangxi, Sichuan, Guizhou, Yunnan, Chongqing, Tibet

The Chongqing region is part of the southwest grid, and every 1 kWh saved in Chongqing reduces carbon dioxide (CO2) emissions by 0.85 kg. The Hebei region in this isolation study is part of the North China Power Grid, and every kWh saved in Hebei reduces CO2 emissions by 1.27 kg.

This shows that there is a large gap between the Hebei and Chongqing areas in terms of reducing dioxin emissions. For comparing the two regions for every 1 kWh saved, Chongqing reduces 0.42 kg of CO2 emissions than Hebei; when the two regions save 100 kW each, then Chongqing emits 42 kg less CO2 than Henan. Therefore, there is a difference between this individual study and the actual examination in Chongqing.

4.2. The impact of passive housing on the quality of life of residents

4.2.1. The impact on the quality of life of passive house residents

A total of 22 questionnaires were collected, and the information was screened. The results of the primary research are represented by the following pie charts and bar charts in this section.

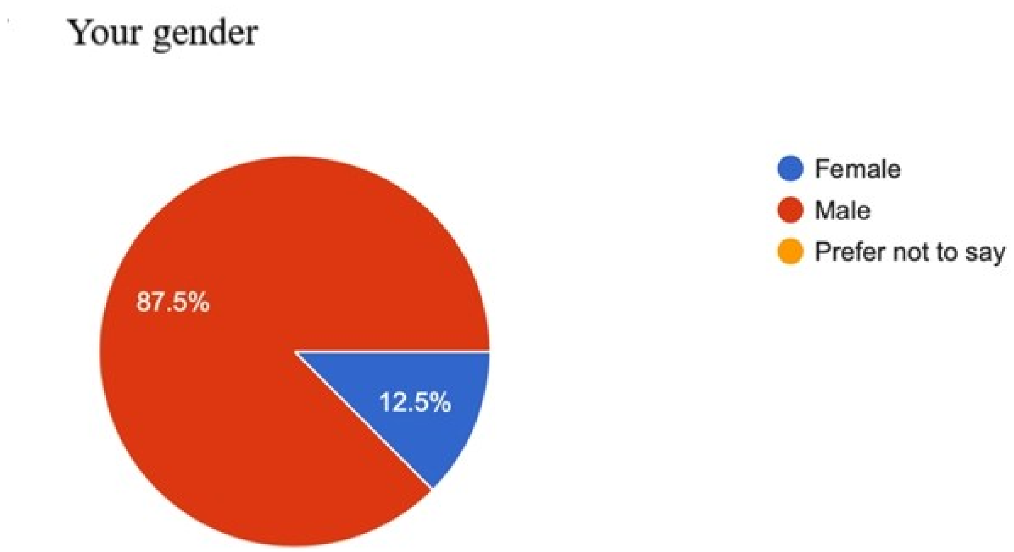

Figure 3: The gender of responders from the questionnaire

A higher percentage of men than women filled out the questionnaire, with the percentage of men accounting for about 90% and 10% of women.

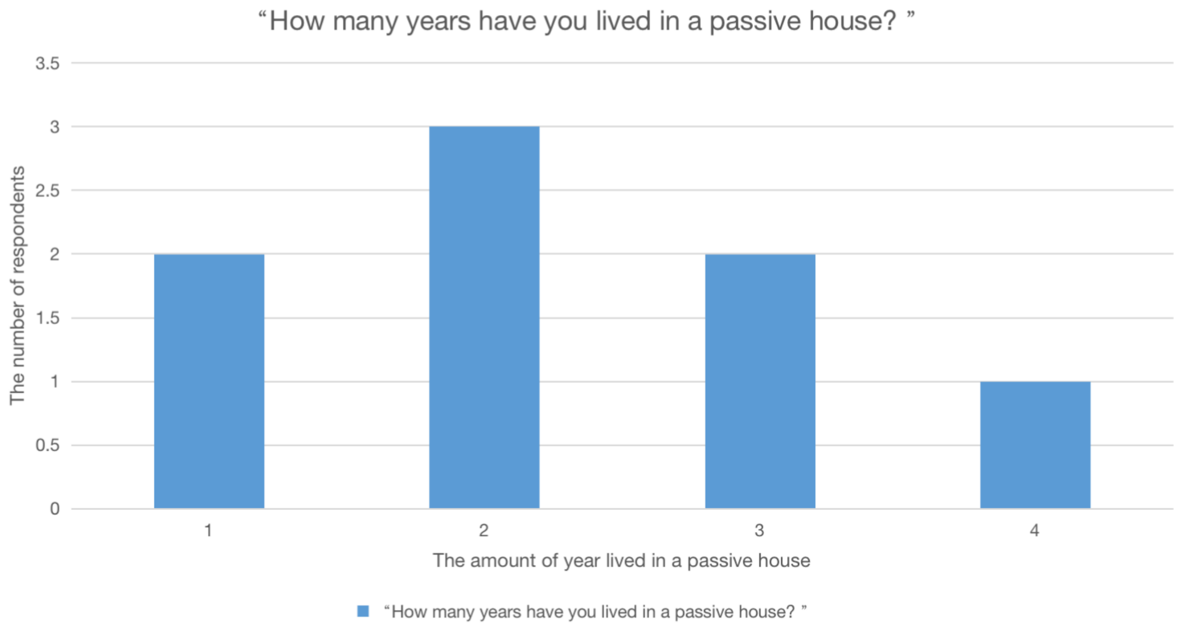

Figure 4: The number of years responders lived in a passive house

These families or companies have lived in the passive house for one year, two years, three years, and four years, respectively. Of these, the highest percentage of the two years was approximately 40%. The average year of residence is 2.25, which is two years.

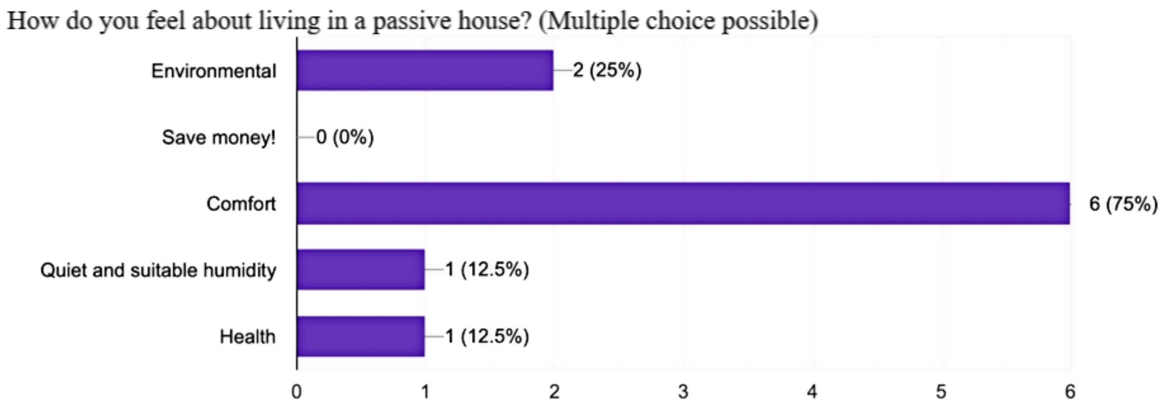

Figure 5: The feelings of responders living in a passive house

All the respondents who filled out the questionnaire had a positive opinion about passive houses, indicating that living in a passive house is comfortable, healthy, good for the environment, quiet, and humid. Among the choices, most people think living in a passive house gives them a feeling of comfort.

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Is the passive house you live in durable? Are the signs damaged in the exterior walls?

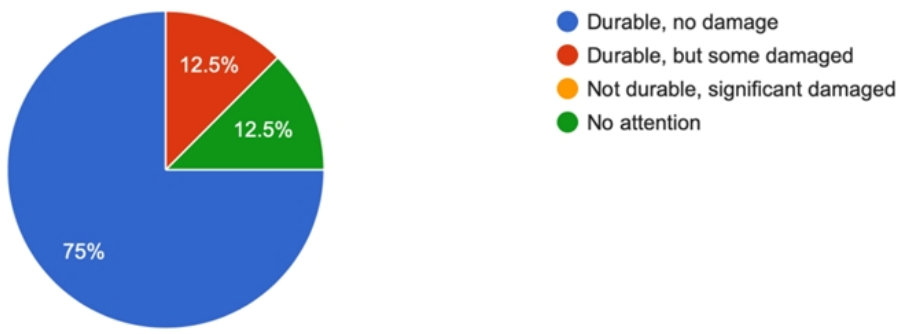

Figure 6: The point of view of durability of a passive house from passive house residents

Most of the people who filled out the questionnaire thought the passive house was durable. 75% of the people answered that there was no damage in their passive house, and their house is durable; 12.5% thought there was some damage, but it was still durable.

4.2.2. Explaining the living experience of passive house residents from the literature

4.2.2.1. Comfort

The five major aspects of passive houses to improve comfort are constant temperature, constant humidity, constantly clean, constant oxygen, and constant quiet [12] Passive houses keep the air clean, domestic PM2.5, with a daily average of 75 micrograms per cubic meter; it is easier to keep the temperature at 18 to 26 degrees Celsius; it keeps the humidity at 40 to 60%; it keeps the oxygen content of the air 21%; and it keeps the sound penetration below 40 decibels. Thus, the passive house brings an extremely high level of comfort to those who live in it in five ways [11].

4.2.2.2. Durability

The Kranichstein Passive House Project was investigated and observed over a period of 25 years, confirming that Passive Houses possess a high degree of durability [13]. Some of the principles that led to the excellent durability of the passive house include excellent thermal insulation, a well-designed airtight envelope, and the use of thick mineral plaster on the exterior walls (which improves hygrothermal performance and leads to very long durability). These steps help to extend the life of a passive house to about 50 years [9].

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5. Discussion

5.1. The future development of passive houses in Chongqing

5.1.1. The Climate

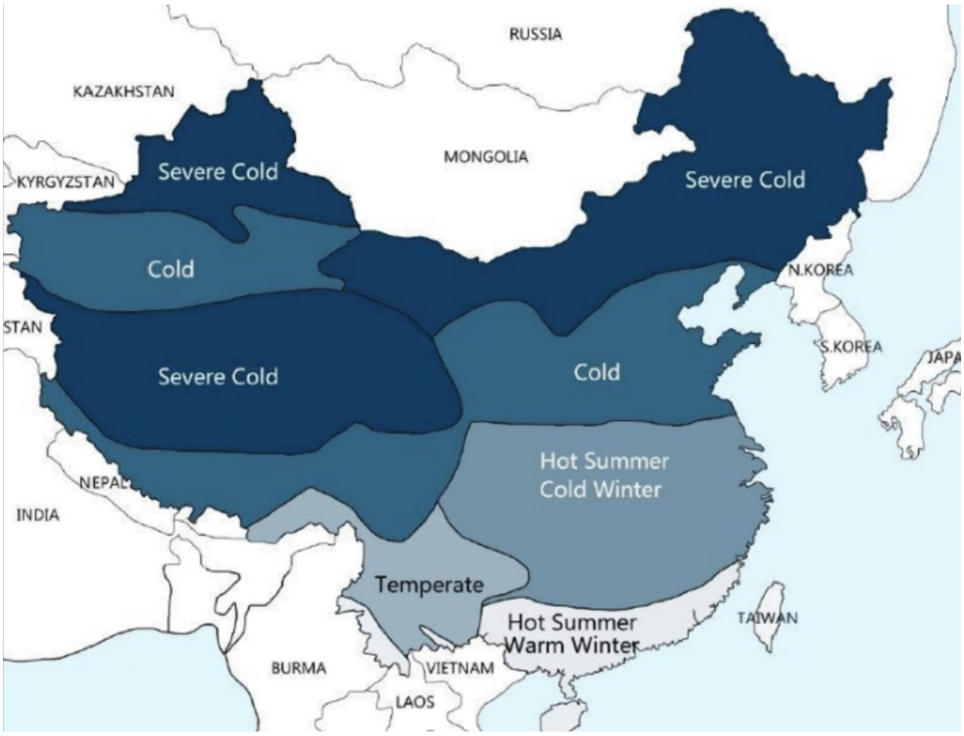

Figure 7: The climate zone in mainland China

Chongqing is located in the southwestern part of China. As shown in the map above, Chongqing is located in the subtropical climate zone with hot summers and cold winters, lots of haze, continuous rains in autumn, and high humidity [14]. If there is no air conditioning and heating, indoor comfort is poor in summer and winter in Chongqing. Passive houses improve the quality of life since they provide the conditions of constant temperature, constant humidity, constant cleanliness, constant oxygen, and constant quiet [9]. Moreover, passive houses can also achieve less energy consumption while significantly improving the comfort of the indoor environment. Therefore, the development of passive houses in Chongqing is necessary to improve the quality of life of citizens due to the climate.

Based on the interview, approximately 60% of engineers consider climate to be one of the conditions needed to implement passive house projects. According to **the Chairman of Shandong Qinheng Technology** from the interview, passive house technology originated in Central and Northern Europe, where the climate is cold in some regions, while Chongqing is a hot summer and cold winter region with high seasonal humidity. Since there are significant climatic differences between the two regions, the applicability of the technology cannot fully meet the requirements of Chongqing. However, a passive house is a highly efficient energy-saving structural solution, which is theoretically applicable to all climatic zones [15]. Therefore, the technical means of optimizing and implementing the corresponding energy-efficient and comfortable buildings can be tailored to the characteristics of different climate zones, and for specific building forms, by considering a reasonable input and output ratio; as long as this demand exists, it is suitable and not limited by region. People have applied this technology from Germany to a Chinese city that has a similar climate to its original country; the ‘Longhu Gaobeidian Train New City Project’ is one example. However, the results from

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the project have shown the technology should still improve. It implies that while it is possible to learn the technology and convert it to use the right technology for the local climate, more advancement of the technology is still needed.

According to **Hanaixing, Director General, Department of Building Energy Efficiency and Science and Technology, Ministry of Housing and Construction,** "Compared to northern areas, like Chongqing and other hot summer and cold winter areas, in fact, the temperature difference is smaller throughout the year, so that the indoor temperature is maintained at 20 ℃ more easily, more suitable for the promotion of 'passive house' to improve the living environment, rather than the less progressive way of centralized heating." Passive house construction in Chongqing has climatic factors that make it more difficult to implement. However, after overcoming the difficulties, there will be more benefits, especially enhancing the comfort of the human lifestyle. Therefore, Chongqing is more suitable for the promotion of a 'passive house' to improve the living environment, rather than through the use of central heating, which is not environmentally friendly and not suitable for social progress.

As a result, local building departments should develop ultra-low or near-zero energy building standards suitable for the local environment in Chongqing; and companies need to develop locally appropriate technologies, product systems, and construction specifications so as to promote the development of passive houses in Chongqing.

5.1.2. The Policies

The Chinese government has pledged to the world to achieve carbon capping by 2030 and carbon integration by 2060 (double carbon target) [1]. According to **the Director of Beijing Building Energy Efficiency Technology Center** from my interview, ‘Passive house projects’ refers to the ultra-low energy buildings currently being promoted in China, such as ‘Ultra-low energy buildings’ and ‘near-zero energy buildings.’ They are now being promoted on a large scale in China, making full use of passive house technology, and will be upgraded to ‘low carbon buildings’ and ‘zero carbon buildings’, and ‘zero carbon buildings’ in the future.

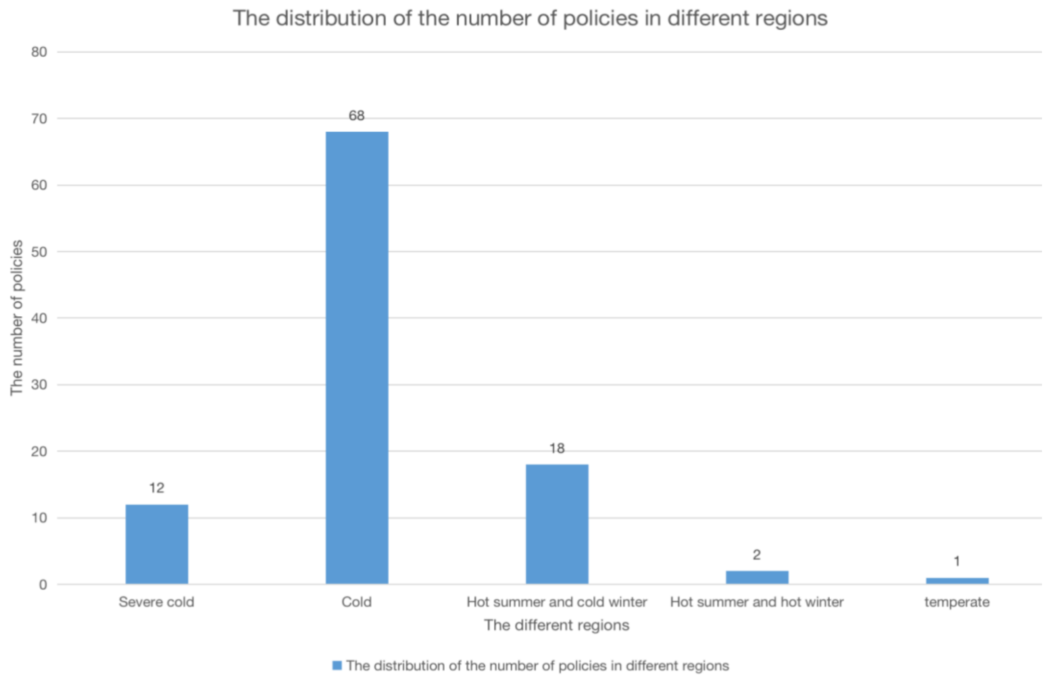

Figure 8: The distribution of the number of policies different regions

Based on the interview, all engineers consider policies to be one of the strategies needed to implement passive house projects. Geographically, the cold regions account for 79% of the total published policy documents; this shows that the policies are influenced by the origin region of the passive house. As a city with a similar cold climate to Germany, Hebei enjoys more policies and more examples of passive house implementation. Although China has learned to apply this technology to different zones, the technology in hot regions is not mature enough; the technology in Chongqing is relatively well-developed compared to severe cold, hot summer and hot winter, and temperate regions. The hot summer and cold winter region to which Chongqing belongs has issued a total of 18 policies, which is not many compared to the cold regions with 68 policies [16].

At present, there are obvious regional differences in the development of passive houses in China, with Chongqing belonging to the not-quite-cold and not-quite-hot regions, which are neither ahead nor behind in the development of passive houses. From the perspective of real estate development, the cost trap of materials, technical design, construction, certification, and maintenance in the construction of ultra-low energy buildings has increased significantly. However, with the continuous development of domestic upstream and downstream industries, the material and construction costs of ultra-low energy buildings are decreasing year by year, but the current situation is not ideal. Since there are cost concerns, construction companies are not inclined to build passive houses in Chongqing. If Chongqing is restricted by policy pressure and has to develop passive buildings to promote and apply them, the development will become more successful with time. Nevertheless, the contradiction between policy requirements and practical implementation is still prominent now, and it is still in the optimization stage. In terms of the development of passive houses in Chongqing, with the further development of high-quality buildings to hotter areas, and subsequent promotion of the policies, there can be a positive future for the passive house industry.

5.1.3. Perceptions from citizens in Chongqing

According to the interview, 'passive house' has been primarily a residential project in the past 10 years. Public awareness of passive houses is still superficial, and the population has purchased passive houses without fully understanding the concept. Although the Chinese government has introduced government financial subsidies in some provinces and cities, these subsidies are aimed at real estate developers, not home buyers (the general public). There is no direct financial subsidy policy for homebuyers; Outreach to the public is done through real estate developers (who receive subsidies), and the outreach is generally not effective. The future promotion of passive houses still relies on mandatory regulations of the Chinese government and public acceptance is not a decisive factor. For example, a policy that all real estate sectors should use passive house construction or that all buildings should be renovated to passive house. As a result, the impact of publicity on the general public will not be evident for some time.

The cost of passive houses will be further reduced if the technical route is further optimized, the insulation requirements are fully considered in the design, and natural ventilation and sun shading are emphasized. According to Chongqing Daily (2013), if the use of a "passive house" per square meter increases to more than the ordinary building by about 400 yuan input, based on their estimation, approximately 10 years of the price may be paid back.

It is beneficial thing for the residents of the passive house in Chongqing to purchase it either because they have no choice, or because they are committed to the concept. In the long term, the durability of a passive house with less electricity consumption will be more cost-effective and more comfortable than an ordinary building.

5.2. The possible dilemma of passive house development in China in the future

There are two dilemmas associated with passive building construction in China: there are no passive building standards currently available in China, and the complexity of training workers [17]. First of all, many real estate developers are reluctant to develop and build passive houses because China has different regions, and there will be complex standards in different regions.

Therefore, they have to put much effort in designing and constructing requirements for materials in different regions. The projects without standards will require more effort, labour, and time. Secondly, many workers have not been involved in passive house construction, and developers need to give them time, manpower for teaching, and money to train these workers. As a result, many Chinese real estate developers are reluctant to build passive buildings when they could make more money by building more ordinary buildings for the same amount of time and effort.

6. Evaluation

6.1. Limitations and strengths

The strengths of the study are primary research and credible literature. There are two approaches to primary research: questionnaires and interviews. This provides additional channels to obtain useful and credible information, which is objective and fair, with respondents from different age groups, backgrounds, and genders. A total of 22 completed questionnaires were received and 16 interviews were carried out; this could be suggested that this is quite a small sample. The interviewees were all experts on the passive houses: designers and engineers. In the case of experts, the information was synthesized from their insights on different aspects to produce more objective text. Moreover, credible literature with a formal in-text citation format is included, as well as a comprehensive bibliography. All of the literature comes from authoritative and credible websites or reports and is documented in a Reading Log.

The case study could be perceived as a limitation of the research. The initial idea was to focus specifically on Chongqing. However, there were limited secondary sources, as a result of which the focus was moved to Hebei, another city in China, where the climate and policies differ. Despite this change in a specific location, the study has produced valid research on the topic and has achieved the project aim, to investigate the environmental impact of the Passive House approach.

6.2. Research implication

Significant aspects of this research project are: improved self-awareness of the industry, self-management, research, critical thinking, and communication skills. The self-awareness of the industry have been improved through make a developmental analysis of the industry from different aspects of critical thinking. Two research methods were employed. For the primary research, communication skills were required to interact with engineers and designers, and to convert useful information into textual form. Furthermore, throughout the project, self-management skills were required to manage the tasks and the time needed to complete them. Overall, all of these skills were essential in this research study, and have improved throughout the process of the project.

7. Conclusion

The findings of this research are based on both primary and secondary methodology. From the secondary method, the case study obtain results suggest that savings can be made on electricity and that carbon emissions can be reduced. Through the primary research, the questionnaire and interviews are used to gather detailed information; questionnaire reports from passive house residents

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demonstrate the comfort and durability of passive houses; and interviews suggest that climate and policy are the two most important factors driving passive housing. Moreover, from in-depth research, it is clear that passive housing in Chongqing is receiving positive results and support from both climate and policy perspectives. The passive house is environmentally friendly by reducing carbon emissions, energy efficiency by decrease energy use and with some policies support. All engineers and designers agrees the implement of passive house in Chongqing. However, there are still some constraints on technologies and support from technologies. Therefore, the future development of the passive house in Chongqing will depend on the development of policies and technologies that support the approach to construction, in order to reduce energy consumption and make people have better quality of life in Chongqing.

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