Politecnico di Milano Scuola di Architettura Urbanistica Ingegneria delle Costruzioni ARCHITECTURE AND URBAN DESIGN

POLITECNICO DI MILANO

Scuola di Architettura Urbanistica Ingegneria delle Costruzioni

ARCHITECTURE AND URBAN DESIGN

Revitalizing and Sustainable Designing

The Ancient District Representing by Ciyun Pagoda in Ganzhou

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ABSTRACT

Contemporary Chinese cities are undergoing a period of rapid construction and development, with the scale of cities gradually expanding and their infrastructure becoming increasingly sophisticated. Wide carriageways are replacing narrow, winding alleys, and high-rise residential buildings are replacing old and, dilapidated historical buildings in the city Centre. People who used to live here have gradually moved into high-rise housing with modern facilities away from the city Centre, enjoying the dividends of urban development but being evicted from their original living areas.

Our cities are losing their uniqueness, and their historic fabric is vulnerable to destruction or outright disappearance at the hands of market capital. In today's world of scarce natural resources, the process of construction is often accompanied with a plethora of environmental problems such as wasted resources, traffic congestion and greenhouse gas (GHG) emissions.

Ganzhou, a medium-scale city in Southern China with an ancient history and a dense population, has experienced many similar problems during its rapid urbanization. The area of the site to be renewed has a mixture of old and modern buildings. The Confucian Temple, Ciyun Pagoda, and early 1900s dwellings are mixed with dwellings built at a later date in a different era; some of the roads are narrow and inaccessible to vehicles, posing a fire hazard; the historical buildings are in serious disrepair and the new buildings are either uniform or crude and straightforward imitations of the monuments; causing a certain degree of damage to the appearance of the old city.

The aim of our project is to provide a new way of life for the citizens and to re-energies the site, based on a low carbon construction design concept that follows the urban fabric and urban culture. We have reconstructed the site from three perspectives: urban, architectural and sustainable construction.

Firstly, from an urban point of view, we have analyzed the urban fabric and the current state of the site. It is intended to demolish buildings those do not have historical value, affect the urban fabric and are an obstacle to the life of the citizens. The streets and road networks inside and outside the site were then sorted out, opening up stagnant traffic nodes and providing paths for pedestrians, vehicles and cyclists alike. The new buildings reweave the fragmented urban fabric, transforming the previously congested and disorganized urban space and providing a space for people to meet and relax

In architectural terms, the linear library links the external street and the inwardly oriented Ciyun Tower in both a physical and spiritual sense. The long façade and the stairwell with its raised roof form a cultural counterpart in a sense to the city walls of the old city. However, in contrast to the heaviness and closure of the city walls, the large glass curtain wall brings transparency and draws people from the street into the ancient building area. The new area on the north combines commercial, event and residential functions, filling in the traditional areas of dilapidated historic buildings both functionally and spatially.

Finally, we followed the LEED Green Building Rating System and the Chinese Green Building Rating Standard guidelines to reverse the design. The design is guided by seven aspects: location and traffic, sustainable site construction, water and efficiency savings, energy and atmosphere, materials and resources, and indoor environmental quality. Through the optimization of group layout, building form, materials and construction, the greenhouse gas emissions during the construction process and building operation phase are reduced and the application of clean energy is increased, helping people to understand more deeply the meaning of green buildings.

Key words: Sustainable Building, LEED, Historic District of Ganzhou, Building Energy Calculation, Renewable energy

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1.INTRODUCTION

1.1 Background of necessity of developing sustainable design in China and around the world.

1.1.1 The losing track of the Decarbonization of the Building Stock

Since the marking of the Paris Understanding in 2015, CO_2 outflows from the construction and development area have reached highest level lately and, in this manner, tumbled to 2007 levels in 2020. This ongoing decay is expected generally due to the COVID-19 pandemic, though groundbreaking, long haul progress in area decarbonizing stays restricted. Be that as it may, beginning around 2015, some emission decrease in the power area is apparent also, more nations have taken on strategies and codes that might have a future effect on the outflows and energy proficiency of buildings.

In 2015, the development and construction activity were answerable for 38% (13.1 gigatons) of worldwide energy-related carbon dioxide (CO_2) emissions. By 2020, CO_2 emissions in the area had fallen a roughly by 10% to 11.7 gigatons, a level not seen since 2007[1]. This is a very big improvement due to the presence and worldwide spread of covid-19, which has resulted in massive shutdowns in the construction industry in 2020. In 2019, since the signing of the Paris Agreement, carbon emissions from the building sector have reached a peak. The global total global building sector CO_2 emissions are about 1 billion tons, accounting for 10% of the global energy-related carbon emissions. Combining with emissions from the construction industry segment (the part of the industry used to make building materials such as steel, cement and glass) the ratio rises to 38%. The development of the industry deviates from the 2°C which is the temperature control target of the Paris Agreement. An upturn in 2020, however, does not mean plans are on track, the reduction in energy-related emissions from buildings and construction is likely to be short-lived, and energy demand is expected to rebound in 2021 as economies emerge from the pandemic[2].

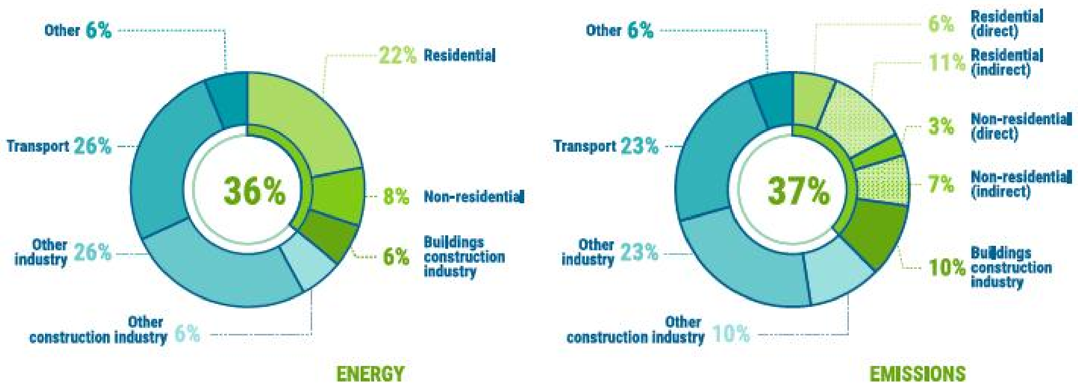

Figure 1 Buildings and construction's share of global final energy and energy-related CO_2 emissions, 2020 (Source: IEA 2021a. Adapted from "Tracking Clean Energy Progress")

[1]: IEA. 2021 Global status report for buildings and construction[J]. United Nations Environment Programme, 2021.

[2] UNFCCC 2021; Buildings-GSR 2021; IEA 2021a.

In response to the environmental pressure of global warming, most of the countries in the world has signed the Paris Agreement and made efforts to strengthen restoration, adaptation and sustainable development. The construction industry is the key to achieve these goals. The contract proposes a three-fold strategy: reducing energy demand and improving energy efficiency and addressing carbon storage in building materials. Various countries such as Europe, China, the United States have formulated plans and tasks to achieve the goal of comprehensive decarbonization of the construction industry, taking China as an example, a 14^{th} Five-Year Plan (2021-2025), has progressed plans to construct low-carbon urban communities and commands for green structures and green structure materials, expanding on the 13^{th} Five-Year Plan's prerequisites for energy protection in structures and green structure targets.

As bright the future is, however, the challenge still exists and considerable. The main problem is that there is still a large demand for building products on a global scale. By 2060, the floor area is expected to double, increasing by more than 230 billion square meters[3]. Most of the development is concentrated in Africa and Asia. Due to economic development and improvement of living standards, residents of these regions have increasing demands for living space and quality. Another concern is that future climate change increases the likelihood of extreme weather and further requires improvements in building performance. The longevity of buildings is also an important factor in decarbonization, so more durable buildings should be built. Therefore, low-carbon policies should be clear and effective, enable technological and industrial innovation, and be flexible in solving problems based on consideration of economic development and dwindling unsustainable energy sources.

1.1.2 The development and performance of sustainable Buildings and Construction Policies

The development of the sustainable building industry in the world is inseparable from the development of the green building rating system. Since 1990, the rating system has been developed for more than 30 years, especially in 2000, there was a significant increase in the number. Building energy efficiency is the most important rating criteria followed by "site", "indoor environment", "land and outdoor environment", "materials", "water" and "innovation"[4]. The global policy landscape for building decarbonization continues to change, and the building industry relies on countries' own commitments to achieve the Paris Agreement and deliver plans for efficiency through policy measures such as national building codes and renewable energy, which an increasing number of countries and regions are putting into practice. Such actions within Nationally Determined Contributions[5] (NDC), more and more

[3] Global Alliance for Buildings and Construction, International Energy Agency and United Nations Environment Programme (2018). Global Status Report 2017: Towards a Zero-emission, Efficient, and Resilient Buildings and Construction Sector. https://globalabc.org/sites/default/ files/2020-09/2017%20GlobalABC%20GSR%20.pdf.

[4] Shan M, Hwang B. Green building rating systems: Global reviews of practices and research efforts[J]. Sustainable cities and society, 2018, 39: 172-180.

[5] A nationally determined contribution (NDC) or intended nationally determined contribution (INDC) is a non-binding national plans highlighting climate change mitigation, including climate-related targets for greenhouse gas emission reductions, policies and measures governments aim to implement in response to climate change and as a contribution to achieve the global targets set out in the Paris Agreement.

countries are recognizing the importance of energy consumption of buildings and the necessity of building energy codes, but despite this there is no mention of NDC in parts of Africa. With population growth, 65% of the population growth by 2030 is expected to occur in countries that mention NDCs, of which only more than half of the population growth in European countries occurs in countries where NDCs are mentioned, while Asia and Africa perform well on the contrary, however, these two continents are the main force of future population growth. For Asia, the countries that did not mention NDC are mainly concentrated in South and Central Asia. Therefore, for the world, the promotion of sustainable architecture still has a long way to go, which is related to more than half of human habitation in the future.

Cooling system accounts for a huge share of the carbon emissions of the construction industry, taking up 5% of the total global energy consumption. Among them, after an estimated 30 years, about 75% of cooling energy consumption will occur in developing countries[6], looking at the whole world, there are about 4.7 billion people living in areas that need to cool in some seasons[7]. However, in most regions, refrigeration needs are still met by using energy-intensive air conditioning. China India and other Asian countries being the three regions with the most air conditioning installations[8]. Therefore, adopting more emerging or passive cooling technologies and green energy is an important part of sustainable development. It is imperative to upgrade refrigeration equipment, including the use of environmentally friendly refrigerants, improving the efficiency of cooling water use and recycling of electronic components that make air conditioning equipment. In addition, in the process of building design, passive ventilation, the use of building materials with low heat absorption and vegetation are all measures to solve the cooling demand and reduce energy consumption from the micro level.

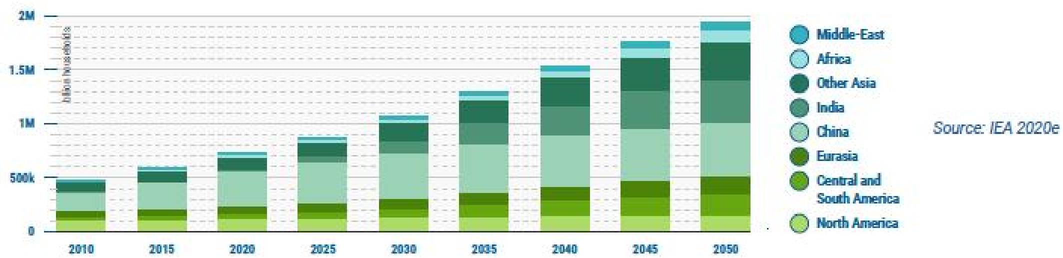

Figure 2 Number of households equipped with air conditioning by region, 2010-2050

(Source: IEA 2020e)

6 International Energy Agency (2021c). Net Zero by 2050: A Roadmap for the Global Energy Sector. Paris. https://www.iea.org/reports/net-zero-by-2050.

7 United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. Nairobi, p81.

8 International Energy Agency (2021e). Energy Efficiency Market Report 2021. https://www.iea.org/reports/energyefficiency-2021.

1.1.3 China's construction industry and carbon neutrality

With the global development paradigm shifting from resource-dependent to green and sustainable development, and the broad consensus on climate change caused by greenhouse gases, countries have taken climate action one after another. Among them, 9 of the top 10 countries in the world's GDP have announced full or partial declarations GHG emissions timeline. In 2020, the Chinese government announced a climate commitment to peak CO_2 emissions by 2030 and carbon neutrality by 2060. In 2019, the total carbon emission in the whole process of construction in China was 4.997 billion tons of carbon dioxide, accounting for 49.97% of the national carbon emission. From 2005 to 2015, the growth rate of energy consumption in the whole process of construction slowed down year by year. The energy consumption of building materials production reached a peak from 2005 to 2012, and then gradually decreased and stabilized after 2012. The main reason for the fluctuation is that in 2011 and the consumption in the 2012 building materials statistical is relatively large. Construction-level carbon emissions slowed down significantly after 2014, down 68.7% compared to the "11th Five-Year" period[9].

The growth rate of energy consumption and carbon emissions in the building operation stage has slowed down significantly, and the carbon emission growth rates of the "11th Five-Year Plan", "12th Five-Year Plan" and "13th Five-Year Plan" are 7.9%, 5.8% and 3.6% respectively. Population movement has also brought about the geographical transfer of building carbon emissions. Due to economic development, the influx of population in Guangdong has the largest impact on building carbon emissions of 33.77 million tons, while the decline in Heilongjiang population has the largest impact on building carbon emissions of 14.47 million tons[10].

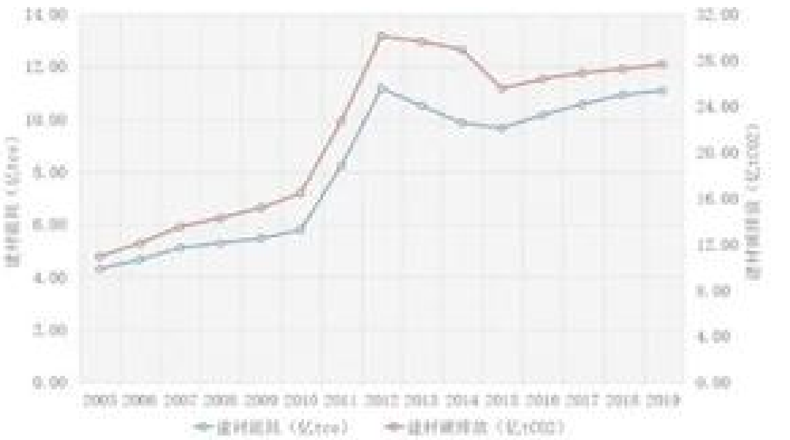

Figure 3 Changes in energy consumption and carbon emissions in building materials production stage (Source: CABEE)

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9 The Eleventh Five-Year Plan for National Economic and Social Development of the People's Republic of China (the "Eleventh Five-Year Plan" or the "Eleventh Five-Year Plan") is a five-year plan for the development of the national economy from 2006 to the end of 2010. It focuses on innovating the development model, improving the quality of development, implementing the "five integrated", while reflecting on the destruction of the natural environment in development, and effectively shifting the economic and social development to the basic plane of comprehensive, coordinated and sustainable development.

10 China Building Energy Conservation Association Building Energy Consumption and Carbon Emission Data Committee

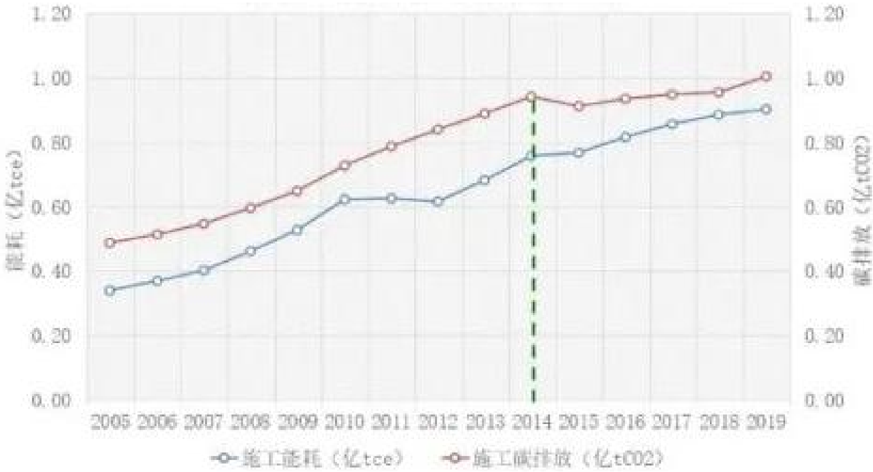

Figure 4 Changes in energy consumption and carbon emissions in building construction stage
(Source: CABEE)

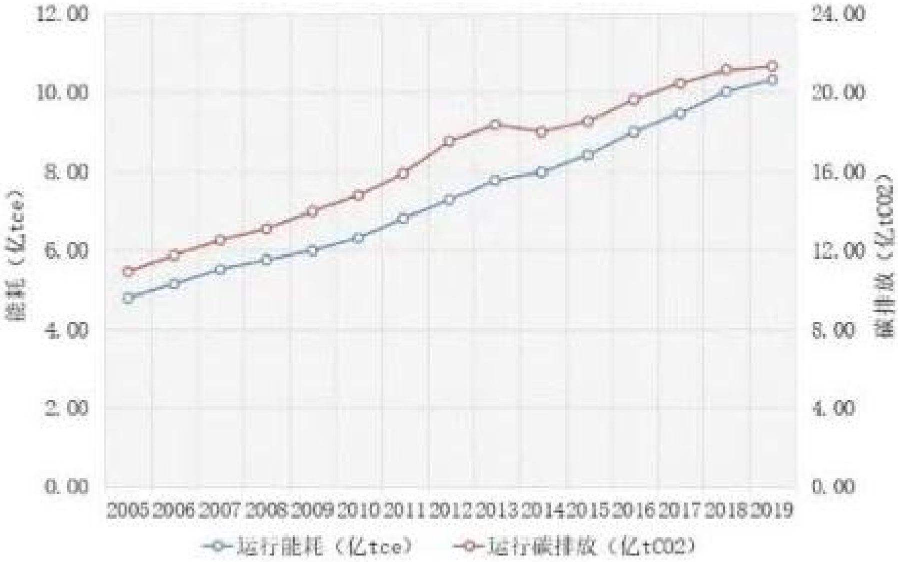

Figure 5 Changes in energy consumption and carbon emissions in building managment stage
(Source: CABEE)

In 2020, China announced its goal of achieving carbon neutrality by 2060. Since then, China has committed to environmental remediation, accelerating the development of a sustainable renewable energy industry, curbing climate change and reducing pollution control costs. When designing the future economic route in the "14th Five-Year Plan" outline, addressing climate change is listed as the main goal. In the field of construction, energy-saving renovations are advancing in an orderly manner, prefabricated construction is accelerated, and photovoltaic building integration is gaining momentum. The Ministry of Housing and Urban-Rural Development and other departments have issued plans. By 2022, the proportion of green building areas in new urban buildings will reach 70%[11]. Climate action in China's construction industry is underway, and green concepts are constantly being integrated into the stakeholders of the construction industry, creating new models while driving an environmentally friendly and carbon-reducing industry, providing development for more sustainable emission reductions. Relevant technologies are also developing continuously. One is sustainable design and green construction to reduce energy consumption, taking prefabricated buildings and passive low-energy buildings as examples, and the other is to organically connect the interior of buildings through digital technology to optimize processes and energy efficiency management. The functional structure improves user experience and achieves energy saving and emission reduction. To sum up, in the future, China should implement green building certification and support high-quality buildings with green concepts, which will effectively enhance the market recognition of green buildings and lead the development of the real estate industry with safety, greenness and high-quality[12].

1.1.4 China's urbanization process and population loss situation

Another meaningful economical aspect of increasing the construction of third-tier cities such as Ganzhou, for example, is that the urbanization process leads to the migration of population from towns or small cities to first-tier cities, and for those areas that have experienced population loss, a chronic lack of vitality and overall development, and even ghost town phenomenon in some rural areas or towns. There is no doubt that this is not a sustainable situation for anyone; on the one hand, small cities do not have enough labor to develop their economies and local societies. On the other hand, big cities are overwhelmed and do not have enough resources to provide a decent quality of life for all yet. Ganzhou, the most populous and largest city in Jiangxi province with rich history and culture and beautiful scenery, is experiencing a massive population exodus. The reason is that the geographic environment, economic development and other factors have led young people to go out to other provinces seeking for work, making Ganzhou enter a lightly aging society. However, on the other hand, with the further acceleration of the new urbanization process, a large number of agricultural populations in Ganzhou city has moved to the city, and Ganzhou is still the first most populous city in Jiangxi province, with a total increase of 601,600 people or 7.19% in 10 years compared with the 8,368,400 people in the sixth national census in 2010.[13] With the gradual acceleration of urbanization and the gradual improvement of transportation and infrastructure construction, Ganzhou will become mean city of Jiangxi province that attracts rural population in the future.

However, the population flow and urban contraction in the process of urbanization should be viewed rationally. In terms of the overall development of the country, the transfer of population from less developed resource areas to developed areas is a reasonable phenomenon, which will also speed up the integration of labor force and resources and accelerate development. Ni Pengfei, director of the Center for

[11] Strive to achieve carbon peak by 2030 and carbon neutrality by 2060 - win the tough battle of low-carbon transition. http://www.gov.cn/xinwen/2021-04/02/content_5597403.htm
[12] Deloitte-cn-eri-china-construction-industry-annual-review-2020-210818
[13] Ganzhou Statistics Bureau

Urban and Competitiveness Research of the Chinese Academy of Social Sciences, pointed out that from the bearing capacity of resources and environment point of view, and the bearing capacity of resources and environment in the eastern coastal areas is larger, while the bearing capacity in some western areas is insufficient. Ganzhou, as a southeastern coastal city, has a polarization phenomenon. On the one hand, some counties are losing population; the main reason for this phenomenon is the problem of matching and distribution of public services. The higher the administrative level of a city, the greater the administrative power of the city, and the higher quality public resources can be allocated in these cities.[14] On the other hand, the population within the city limits is also flocking to cities with better resources and facilities, such as Guangdong and Fujian.

Therefore, compact cities can be developed for some cities or regions that have lost population due to the laws of economic development. At the same time, the quality of public products such as urban infrastructure, public services and business environment should be improved. It is also necessary to create differentiated public products and support and develop industries with comparative advantages. Only by developing industries can we cope with the development of compact cities and meet the well-being of the local population left behind.[15]

1.2 The evolution of green building

1.2.1 The history of green building development around the world

The concept of green building has been with human construction activity since time immemorial, although complete definition had not been developed in that period. In ancient urban construction, due to the lack of technology and the fact that raw materials for building were not easily available, many passive and energy-efficient ways of construction were used spontaneously in order to save materials and obtain a comfortable living space.

For example, in the Middle East area, due to the large temperature difference between day and night, people use rammed earth materials to build their houses. Rammed earth has excellent thermal mass, and it can hold heat for about 12 hours after which it is radiated out. At the same time, the building will be styled to minimize the area of window openings to prevent excessive heat intake. In the Loess Plateau region of central China, the lack of wood led to the same use of the soil. People digging of holes in the cliffs formed by the loess to form dwellings. The soil's ability to store heat in the ground was used to provide a warm climate in winter and cool in summer. In the far Arctic, the Eskimos also built their houses by digging and sourcing materials from the ground, but the material was changed from soil to snow and ice, and they called them Igloos. Igloos are dome-shaped dwellings constructed by circularly placing blocks of snow. The blocks of packed ice serve as insulation, creating a warm environment. The tunnel that leads into the dome helps preserve heat

[14] "China Economic Times" April 12, 2022 Author: Xu Weibing Editor in charge: Wan Shan

[15] At the 2022 Winter and Spring Forum of the China City Hundred People Forum speech, by Ni Pengfei, Director of the Urban and Competitiveness Research Center of the Chinese Academy of Social Sciences and Secretary General of the China City Hundred People Forum

inside, while a vent near the top helps in the escape of warm air, to prevent the melting of the ice blocks[16].

Figure 6 Ait Ben Haddou in Morrocco.(Source: larosedusable.com)

Figure 7 A typical Igloo.(Source: britannica.com)

With the modernist architectural movement, major changes took place in the field of building technology and materials, and people began to use technical measures to solve the problem of energy efficiency in buildings. The Crystal Palace in London, built in 1851, for example, uses a large glass maintenance structure to solve the problem of natural lighting. The transparent roof and facade are shaded with canvas to prevent glare and excessive sunlight. Taking into account the heat-collecting effect of the glazed greenhouse, the architects installed openable louvred windows at high and

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[16] Tirthika Shah,*10 Examples of Sustainability in Ancient Architecture* https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a918-10-examples-of-sustainability-in-ancient-architecture/

low intervals on the external walls to create a passive air circulation system by taking advantage of the difference in air temperature[17]. These technical measures may seem rather rudimentary today, but in the 19th century they were a revolutionary change from the classical masonry and provided the direction for future technical developments.

As we enter the 20th century, the rapid development of industrialisation and urbanisation has led to the rapid spread of modern architecture, many equipment systems have been added to the building design, the emergence of central air conditioning, 24-hour hot water systems and artificial lighting, and booming buildings that bring comfortable living and living conditions to people. But on the other hand, urbanisation exacerbated the damage to the environment and ecosystems until the second half of the 20th century, when the global energy crisis erupted and the importance of energy conservation was realised. Since then, a complete system of energy efficiency in contemporary buildings has been gradually established.

Duration	**Events**	**Initiator/Institution**
1960s	Proposed a new concept of ecological architecture	American architect Paul Soleri
1969	Publication of the book "Design Integrates Nature", which marked the official birth of ecological architecture.	American architect Ian McHarg
1970s	The energy crisis caused various building energy-saving technologies such as solar energy, geothermal energy, and wind energy to emerge	
1980	The slogan "sustainable development" was first introduced	World Conservation Organization
1987	Published the "Our Common Future" report, which established the idea of sustainable development.	United Nations Environment Program
1990	World's first green building standard "BREEAM-Building Research Establishment Environmental Assessment Method"published	British Institute of Building Research
1992	Launch of the Rio Declaration,promoted the idea of sustainable development, green buildings gradually became the direction of development.	United Nations Conference on Environment and Development
1993	the United States created the Green Building Association	
1996	Hong Kong introduced green building standards-"BEAM"	Hong Kong Green Building Council
1998	LEED 1.0 version of the pilot program (Pilot Program) officially launched	U.S.GREEN BUILDING COUNCIL

[17] Henrik Schoenefeldt, *Creating the right internal climate for the Crystal Palace,* Proceedings of the Institution of Civil Engineers - Engineering History and Heritage 2012 165:3, 197-207 https://www.icevirtuallibrary.com/doi/10.1680/ehah.11.00020

2000	Canada introduced green building standards-”R-2000”	Natural Resources Canada
2005	Singapore initiated the "BCA Green Building Mark"	Building and Construction Authority，BCA
2015	China implemented the "Assessment standard for green building"	Ministry of Housing and Urban-Rural Development, China

Table 1 History of green building development in the world[18]

(Source:Elaboration by author according to Wikipedia Green building/Development_history)

As can be seen from the above green building development history, the end of the 20th century to the beginning of the 21st century was a period of rapid development of green building design, during which countries around the world introduced corresponding policies to constrain and encourage sustainable construction.Today, green building has evolved into a complete concept,refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition[19].

1.2.2 The development history of green building in China

Urbanisation in China started later than in the West, but has developed very rapidly. At the same time, the demand for green buildings is gradually growing. Below are some of the key events in the history of green building development in China[20].

In 1986, China released the industry standard JGJ26-86 "Energy-saving Design Standard for Civil Buildings (Heating and Residential Buildings)", setting a target of 30% energy saving, which was also the first building energy-saving standard in China.

In 2004, the Ministry of Construction launched the "National Green Building Innovation Award" to encourage the development of green buildings.

2006, the Ministry of Housing and Urban-Rural Development issued the first version of "Assessment standard for green building(GB/T50378)". This is the first official green building evaluation standard in China.

On August 27, 2009, the Chinese government issued the Resolution on Actively Responding to Climate Change, proposing to develop a green economy and low-carbon economy based on national conditions.

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18 https://en.wikipedia.org/wiki/Green_building

19 EPA,Definition of Green Building https://archive.epa.gov/greenbuilding/web/html/about.html

20 PU Wan’li,ZHU Ming’hua.“*The development status and Countermeasures of modern green building in China”*.SCIENCE&TECHNOLOGY FOR DEVELOPMENT,2019-08-28,P1-6. http://www.chinastd.net/kjcjfz/article/html/20190708002

In April 2012, the "Implementation Opinions on Accelerating the Development of Green Buildings in China" (No. 167,2012) was issued.

In 2015, the Ministry of Housing and Urban-Rural Development issued the "Technical Guidelines for Passive Ultra-low Energy Green Buildings (Residential Buildings)".

In 2019, China made the third iteration of the green building standards "Assessment standard for green building". This update changes the previous criteria for evaluating buildings on the basis of construction and instead resets the evaluation system in terms of human perception.

From the end of the last century to the present day, China's green building development has gone through several stages. In the early days, the evaluation system was sketchy and the types of green buildings involved were limited to office and residential buildings. As the system has been improved, the vast majority of building types in the market have now been included in the evaluation criteria. The focus of evaluation has also transitioned from the early focus on the energy-saving technology of the building itself, to the harmonious co-existence of the building and the environment, to the current human-centred evaluation approach, which places more emphasis on the feelings of the building users.

1.3 Comparative Analysis of Green Building Evaluation Standards

Since the 1960s, the concept of green building has been spreading, countries around the world have gradually established green building evaluation systems that are in line with their own national conditions.

At present, the major global green building assessment systems include the British system BREEAM, the US system LEED, the Japanese Comprehensive Environmental Performance Evaluation System CASBEE, the Australian Building Environmental Assessment System NABERS, the Singapore Green Building Mark, the French ESCALE assessment system, the German DGNB, and the Chinese Assessment standard for green building.[21] The British BREEAM system, established in 1990, is the world's earliest green building assessment system and currently has the largest number of certified buildings. LEED is currently the most widely used rating system and is used in around 200 countries. Although the Chinese Assessment standard for green building system started later, its principles are based on Chinese policies and national conditions and are more suitable for Chinese building projects. The following is a comparative analysis of the similarities and differences between Chinese and US green building evaluation standards, using LEED and ASGB as examples.

1.3.1 Introduction to the LEED Green Building Rating System

LEED (Leadership in Energy and Environmental Design) is the most widely used green building rating system in the world.It was published and implemented by the

[21] Rochelle Ade,Michael Rehm, *The unwritten history of green building rating tools: a personal view from some of the 'founding fathers,* June 2019,Building Research and Information 48(2):1-17, P35 https://www.researchgate.net/publication/333912838_The_unwritten_history_of_green_building_rating_tools_a_personal_view_from_some_of_the_'founding_fathers'

United States Green Building Council (USGBC) in 1998 and considered to be the most complete and influential assessment standard in the world.

(1) Content of evaluation

LEED looks at the environmental impact of buildings in a comprehensive way in eight main areas: integrated design, location and access, sustainable site design, efficient use of water resources, energy and environment, resources and materials, indoor air quality and innovative design. Each of these areas is subdivided into a number of scoring clauses. The LEED certification system (V4) includes the following five categories: LEED BD+C: for new buildings or buildings with a large degree of renovation; LEED ID+C: for the evaluation of interior finishes; LEED O+M: for the evaluation of the operational and maintenance performance of existing buildings; LEED ND: for the evaluation of community planning and development; and LEED H: for the evaluation of the design of existing buildings. LEED ND: for community planning and development assessment; LEED HOMES: for residential assessment[22].

(2) Grade Classification

Each section of LEED has its own scoring criteria, and the final total score is based on four levels of certification: Certified 40-49; Silver 50-59; Gold 60-79; Platinum 80+.

1.3.2 Introduction to the "Assessment standard for green building" in China[23]

China promulgated the first version of the Assessment standard for green building (GB/T 50378-2006) in June 2006, which marked the initial establishment of a green building evaluation system in China based on the country's national conditions. The various green building refinement standards published later, such as the Green Industrial Building Evaluation Standard and the Green Retrofit Evaluation Standard for Existing Buildings, are all based on this standard as an outline.

(1) Content of evaluation

In the latest 2019 edition, the evaluation index system has been updated to five major index systems: safety and durability, health and comfort, convenience of living, resource conservation and environmental livability. It is mainly applicable to residential buildings and public buildings such as office buildings, shopping malls and hotels.

(2) Grade Classification

Each of the five categories of the index system includes two types of evaluation items: control items and scoring items, and the evaluation levels are classified as basic, one star, two star and three star. The basic level is achieved when all indicators meet the control items. When the total score reaches 60, 70 and 85 points respectively, the green building grade is one, two and three stars respectively.

1.3.3 Comparison between LEED and ASGB

(1) Comparison of development history

[22] USGBC, *LEED rating system*, https://www.usgbc.org/leed

[23] Ministry of Housing and Urban-Rural Development of PRC*, Design standard for energy efficiency of public buildings (GB50189-2019*),Issued on February 2,2019,Implemented on October 1,2019

The United States Green Building Certification Council (USGBC) issued the first version of the LEED-NCv1.0 standard in 1998, evaluating building types mainly for office and commercial buildings, and updated it to LEED-NCv2.0 in 2000. v3.0, issued in 2009, is the longest-running version, increasing the total score from 64 points in 2.0 to 110 points, with "Version V4.0 was released in 2013 and updated to V4.1 in 2019, and is still in use today. The latest version has refined the various clauses, adding the 'Site and Transport' and 'Integration Process' score categories compared to version 3.0.

The first version of the Assessment standard for green building was released in 2006 to evaluate residential and public buildings based on the indicators of "energy saving, land saving, water saving, material saving and environmental protection", and was updated in 2014 to change the scoring method from indicators to points. 2019's latest annotation regroups the overall evaluation indicators into the latest marking in 2019 regroups the overall evaluation indicators into five main categories: "safety and durability, health and comfort, convenience of living, resource conservation and environmental friendliness", and adds a "basic level" evaluation level.

As can be seen, these two kinds of evaluation systems are not static, but are constantly being modified in line with the development process of green buildings in their countries and the changing climatic environment of the world.

(2) Comparison of evaluation system

From the point of view of the rating process, the LEED rating process is mainly market-based, with voluntary participation and the application process can be completed online. For projects covered by the Assessment standard for green building, there are both voluntary applications and policy requirements, and the application process is also online and offline.

The LEED rating system addresses a wide range of building types and is divided into five main categories, covering almost all building types currently on the market. The green building rating standards, on the other hand, are mainly for new civil buildings.

The LEED rating system evaluates buildings in terms of "Site and Transportation", "Sustainable Sites", "Water Conservation", "Energy and Atmosphere", "Materials and Resources", "Indoor Environmental Quality", "Innovation", "Regional Priorities", "Environmental Quality", "Materials and Resources", "Indoor Environmental Quality", "Innovation" and "Regional Priority " are examined in 8 areas containing 12 prerequisites out of 110 points. The Assessment standard for green building index system consists of seven categories of indicators, including "control points", "safety and durability", "health and comfort", "convenience of living", "resource conservation", "environmental livability" and "improvement and innovation", with a total score of 110 points.

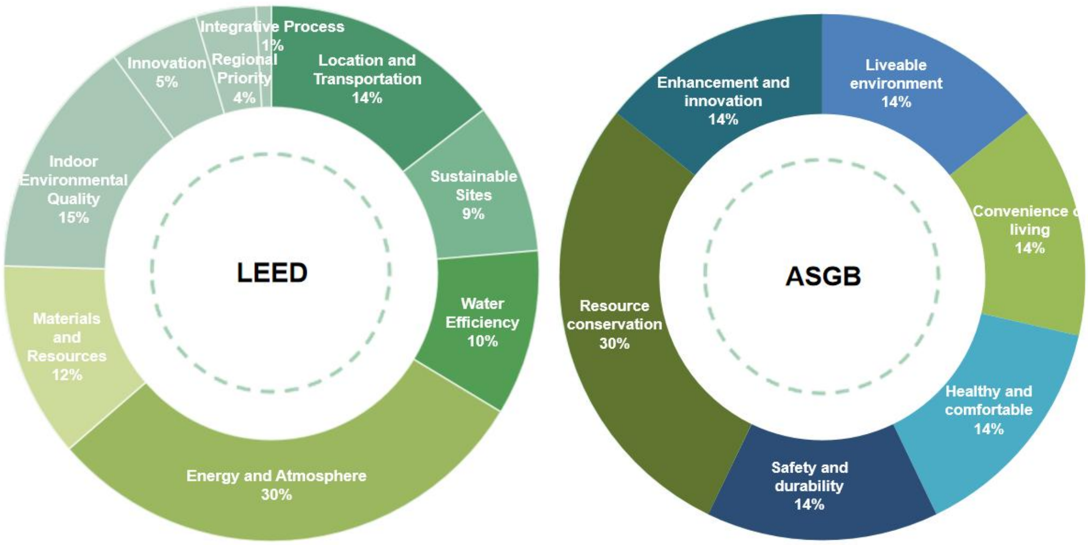

Figure 8 Comparison of LEED and ASGB scoring items and weights.
(Source:Elaboration by author according to LEED and ASGB evaluation criteria document)

(3) Comparison of evaluation result

The evaluation results are based on the scores obtained by the participating projects to classify the green building grades, from low to high, with the US LEED standard being Certified, Silver, Gold and Platinum, and the evaluation results are valid forever. China's green building evaluation standards: basic, one star, two star, three star, valid for 2-3 years. One of the evaluation levels, Basic, was added in China with the 2019 edition update.

(4) Conclusion

The comparison shows that the LEED standard is much more detailed than the ASGB in terms of the types of buildings that are involving, covering almost every aspect from construction to operation, from community to interior. This is also due to the late establishment of the ASGB, which prioritised the focus of evaluation on the broadest range of building types on the market (public and residential buildings). From 2013, China also introduced green evaluation standards for industrial buildings, expo buildings, shops, hospitals and renovation of existing buildings to complement this.

In terms of the way of evaluated, both evaluation criteria contain primary and secondary indicators, with LEED having nine categories of primary indicators and ASGB having five categories. Their secondary indicators both contain prerequisites that must be met. The difference is that ASGB has minimum score limits for each of the primary indicators, whereas LEED does not. In addition, both standards have the highest weighting in terms of energy efficiency, which shows the importance of energy in green buildings.

From the perspective of the evaluation mechanism, the ASGB rating is organised by the government, using a combination of online and offline methods, and is mandatory. LEED, on the other hand, is a market-driven, commercial model, which is entirely online and based on voluntary participation.This is related to the building development in both countries, where the green building process started late and the short-term economic benefits were not significant. In order to achieve environmental protection as soon as possible, the government adopted a semi-compulsory and semi-incentive approach to promote green buildings.

Both green building evaluation systems have their strengths and weaknesses. We can choose the most appropriate evaluation system by taking into account the location and characteristics of the project when selecting the evaluation criteria.

1.4 Case studies

1.4.1 Highest LEED score building globally-Pixel

Situated in a major metropolitan market in the former CUB Brewery, Pixel is one of Melbourne's largest and most active undertakings.

Pixel has received an ideal 105 Green Star focuses and has also completed 102 points in the US LEED rating program, making it the highest guaranteed LEED rated work anywhere on the planet today. It intends to exceed the most noteworthy scores under the UK's BREEAM rating system. To put this in perspective, there are approximately 740,000 buildings listed under all three rating schemes, and Pixel will be at the top of all of them. It is Australia's most memorable carbon neutral business location, producing all of its own electricity and water.

The outer layer of Pixel is not only beautiful to look at, but also gives the building in encapsulates many sustainable technologies within, one including Living Edge border planters, fixed concealed blinds, double coated window dividers and sun powered charger concealed frames.Studio505's work on the Pixel pavilion included cultivating the Living Edge reed bed frame, making concealments, treating sewage water (or black water, roughly the water used in the toilets and kitchen), and providing individual vegetation for each office floor. The structural façade is a frame that integrates boundary build-up boxes, fixed concealed louvers, double-coated partitions and solar chargers for concealment. studio505 developed a complex but easily applied design framework that adds a human-scale "flow" quality to the project, advancing the consistency of the flow based on different levels of recorded information, utilitarian prerequisites, electrostatic cutoffs, and materials.

Figure 9 Shading device of the façade (Photo by: Ben Hosking , John Gollings)

The following aspects describe in detail the sustainability of the Pixel.

(1) The Pixel Pavilion is carbon neutral, meaning that the building itself generates electricity and energy to sustain daily operations, and that the recovered energy offsets the energy needed, and CO2 emitted by petroleum byproducts in the production of building materials. A huge photovoltaic frame is introduced at the highest point of the structure, combined with sun-seeking hardware, so the photovoltaic panels point to the sun for a long time, improving the panels' advantages. The pixel pavilion includes the latest and earliest introduction of wind turbines, which surpasses the range of kilovolt turbines currently delivered worldwide.

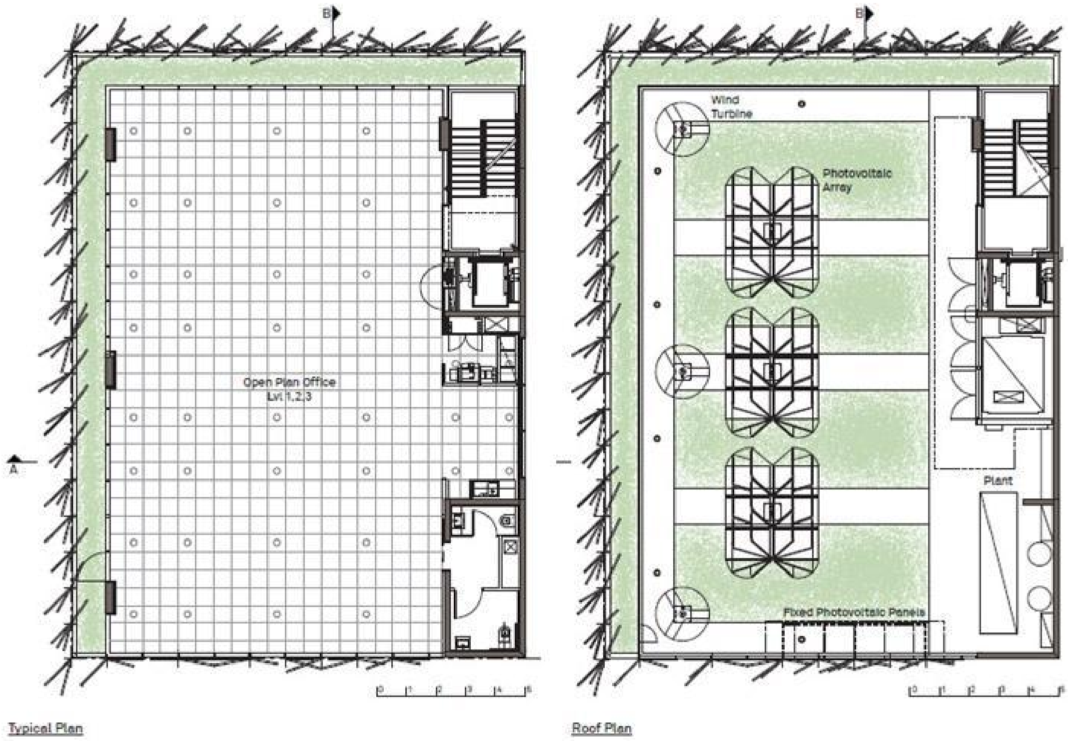

Figure 10 Roof plan of the solar panels wind tunnel and vegetation (Source: Studio 505)

(2) Ventilation: All air circulated and utilized within the Pixel Pavilion is 100% outside air. With a high-level energy replenishment framework, the warming or cooling components are removed before they are released into the climate, thereby reducing general energy use. The exterior partitions are equipped with savvy window innovations so that opening the exterior partition windows on cool nights brings the evening breeze into the structure to cool the building.

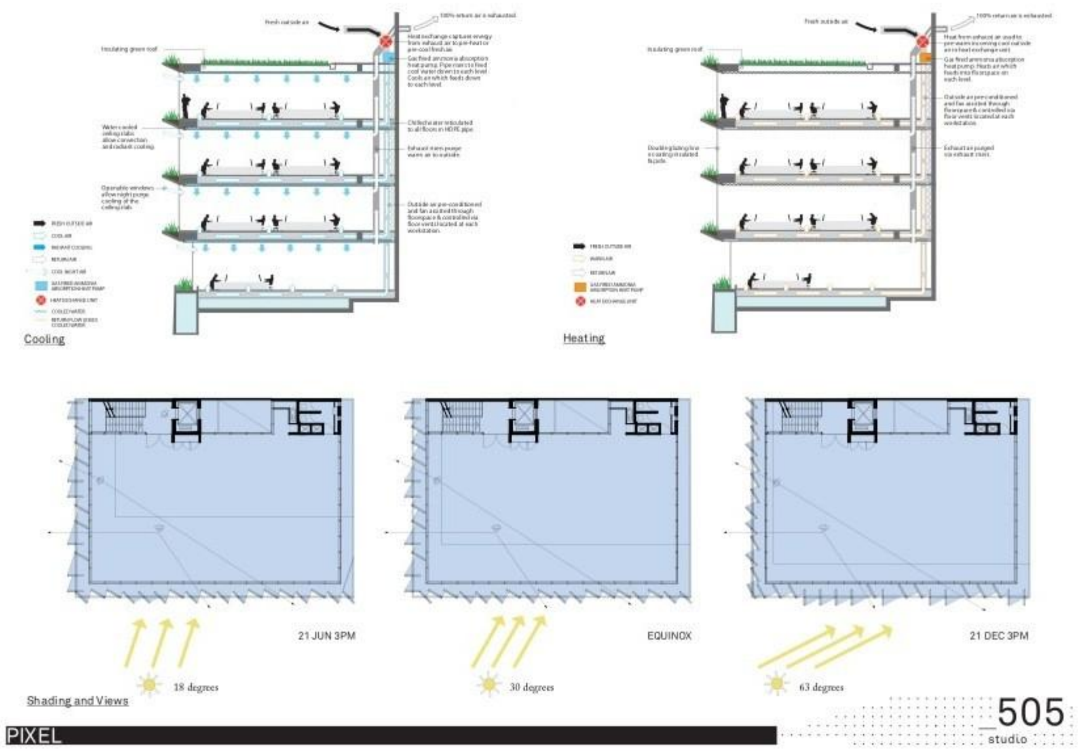

Figure 11 Ventilation and lighting scheme(Source: Studio 505)

(3) Material recycling: The architects developed a new concrete structural design that halves the carbon content of the concrete while maintaining the strength of traditional concrete. the composition of Pixelcrete is primarily industrial waste, recycled or reclaimed materials, which significantly reduces the amount of traditional Portland (Portland) cement. Since Portland cement production accounts for 6% of global greenhouse gas emissions each year, this new product (Pixelcrete) will have a huge potential and impact on the world.

(4) Lighting: The Pixel Pavilion was designed to allow 100% natural light penetration into its office spaces, using screen-based technology that eliminates the need for blinds and design simulations using 3D CAD to maximize exterior shading systems and natural light penetration.

(5) Water reuse: The building captures rainwater for irrigation and green roofing. Rainwater is also stored in barrels and treated by reverse osmosis to meet water quality standards. The treated water is diverted to different installations within the building. The gray water is filtered and directed to the Living edge reed beds on each floor for irrigation of plants. This process keeps the Pixel Pavilion from discharging grey water and greatly reduces the amount of effluent flowing into the waterways. The Pixel Pavilion is the first project in Australia to use small vacuum toilet technology to minimize water consumption. A storage tank system located on the ground floor stores all the effluent from the toilets and kitchen facilities, from which

methane is extracted as a heat source for the rooftop hot water boiler used to provide hot showers and the grey water from the showers is used to irrigate the reed beds. The final methane content of the effluent is reduced and flows into the waterways in liquid form.[24]

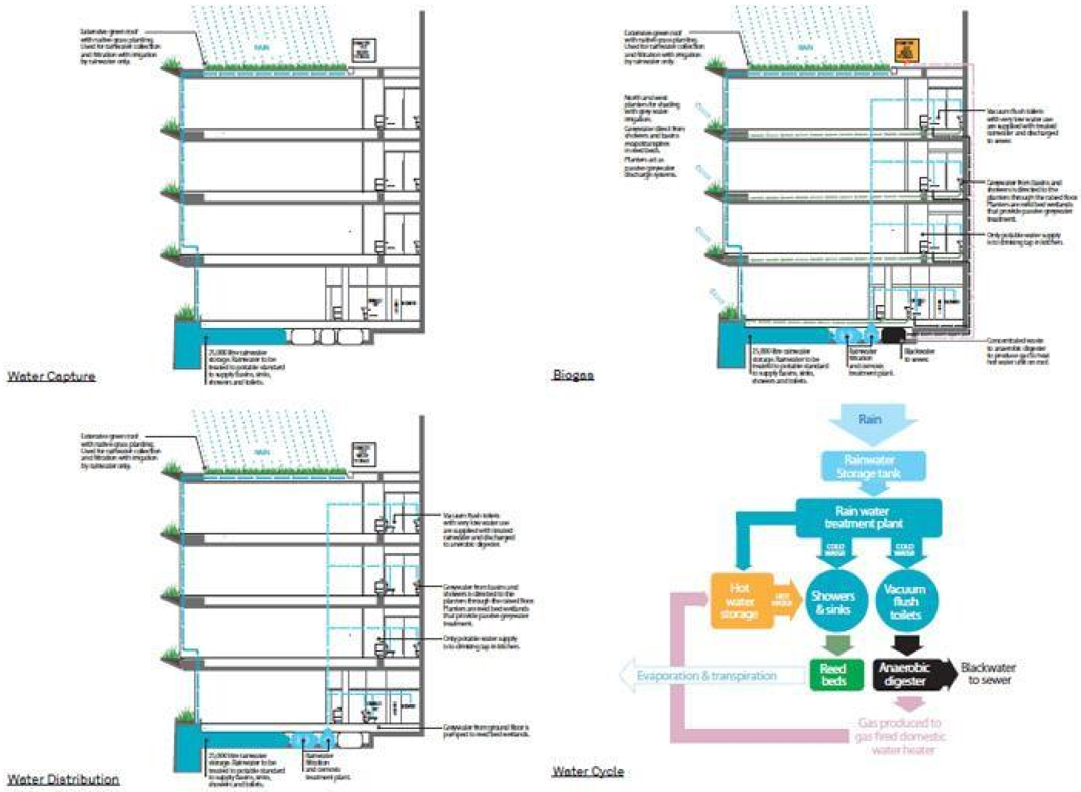

Figure 12 Water recycle scheme(Source: Studio 505)

This project is very informative for all sustainable building projects, especially for the buildings participating in the LEED scoring, where the energy system recovery system, the ventilation system and the elaborate façade shading are worth analyzing. For the Ganzhou project, we also used rainwater and graywater recycling to irrigate landscape plants and replenish landscape water, and solar panels on top and in the connecting corridor part of the site to meet building operation. However, because of the climate in Ganzhou, renewable wind energy is not a good choice, but natural ventilation can be used to increase the number of air changes inside the building.

1.4.2 Bangkok Residential Building and Adaptive of Passive Cooling In Computational Architecture

Another worthy example comes from Bangkok, one of the most densely populated cities in the world, with high temperatures and humidity according to the

[24] LEED Masterpiece - Pixel Gallery, 2022, Prc-Magazine.Com. http://www.prc-magazine.com/sc/leed-%E4%B9%8B%E4%BB%A3%E8%A1%A8%E4%BD%9C-%E5%83%8F%E7%B4%A0%E9%A6%86/.

tropical climate. Almost 30% of the energy consumed in housing comes from air conditioning.

Figure 13 Rendering view (Source: MaCAD)

In order to reduce the carbon footprint of the home, the design adopted passive ventilation as well as environmentally friendly wood. The high-pitched roof design is derived from the local thatched roof typology, this high-pitched roof facilitates the upward flow of hot air and accelerates air circulation.

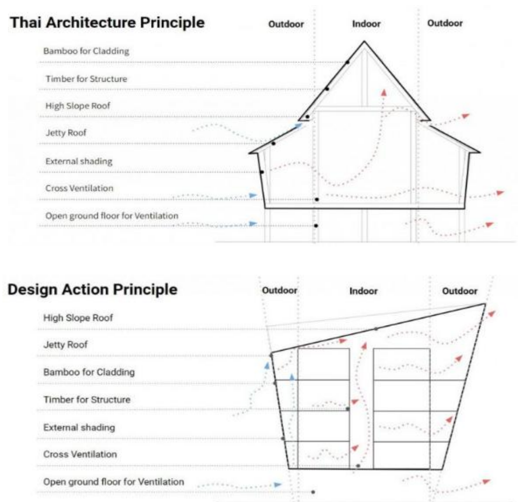

Figure 14 Adopted Strategies (Source: MaCAD)

The project includes 2 design strategies related to environmental data, including molding optimization based on solar radiation and comfort temperature, and secondly, façade opening based on wind pressure analysis, solar radiation optimization and daylighting factors to achieve efficient interior visibility.[25]

[25] Bangkok Residential Project : A Contemporary of Passive Coolinghttps://www.iaacblog.com/programs/bangkok-resedential-studio-project/

The exterior of the building is equipped with shading devices, and by simulating the sunlight and wind environment, three openings with different area ratios have been designed corresponding to different sunlight hours and surface wind pressures. By combining the three different frames, the total area of the building's openings reaches 40%, allowing the occupants to live without artificial lighting during the day.

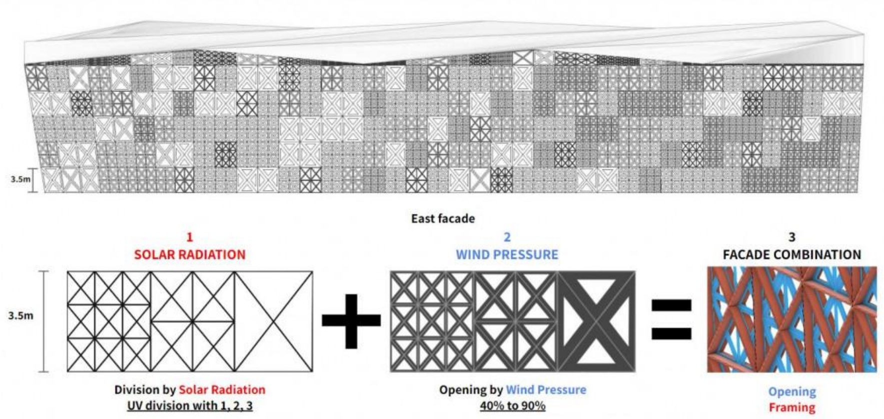

Figure 15 Opening Strategies (Source: MaCAD)

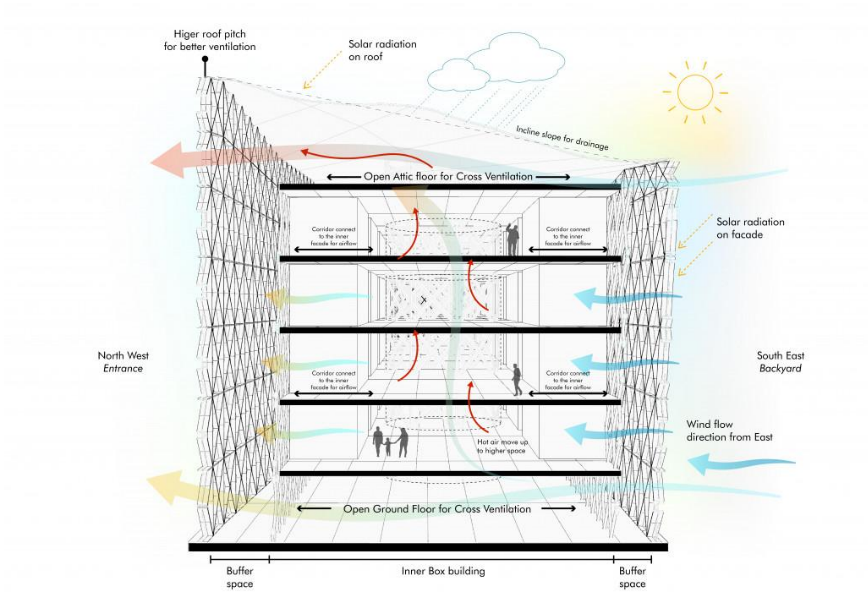

Figure 16 Lighting and ventilation diagram (Source: MaCAD)

In summary, the project strategy was designed to reduce the temperature by 3.3 °C based on the simulation results. The facade openings provide wind ventilation, creating cross ventilation from southeast to northwest. In addition, we have achieved the use of wood as the primary structural material, and we aim to create sustainability in terms of carbon neutral architecture.

1.5 The role of the green building evaluation system in guiding the design of building schemes

As one of the most widely used and well-established green building evaluation systems in the world, LEED's assessment requirements for participating projects are, to some extent, a reflection of the conditions that a building needs to meet in terms of sustainability.

However, for reasons of construction duration, financing and approval procedures, some investors often wait until halfway through the construction cycle, or even after construction is complete, before deciding whether to declare a high level of sustainable building certification for their projects. As a result, many designers specialising in green building declarations often become formally involved at a later stage. And at this point in time, the only objective and requirement is to score against the criteria in order for the project to meet the corresponding rating (LEED base level to Platinum). But by this time the overall project design is already in place and the designers involved can only cobble together scores and make minor tinkering with the design scheme to a limited extent, which is not really effective in improving the performance of the building and can add unnecessary costs.

Therefore, architects need to understand the concept of low carbon buildings and consider low carbon emission reduction design solutions from the early stages of design, in terms of planning layout, floor plan and material selection in parallel to prevent subversive changes at a later stage. Detailed comparisons are also required in terms of the building's massing, orientation and envelope form, as they play a decisive role in the overall energy consumption of the building.

Chapter Summary

To some extent, building design itself is the result of a balance of conditions and techniques. If we can introduce more technical constraints in early building layouts, design discretion will be greatly reduced and the logically derived results in terms of form and energy efficiency will be more likely to be accepted by investors. As a relatively well-established green building rating system, the requirements of the various scoring sections of LEED can be seen as a concrete expression of this restrictiveness.

We have therefore categorised the LEED score items, analysed the rating items that can be introduced at the early stages of design, and used the example of the renovation of the site around Ciyun Pagoda in Ganzhou, China, to illustrate their application in the design scheme.

2. DESIGN INTRODUCTION FOR THE RENOVATION OF THE SITE AROUND CIYUN PAGODA, GANZHOU, CHINA

2.1 Background of the project

2.1.1 Historical features of urban

Ganzhou is an ancient city located in Jiangxi Province in southern China, with initial city-building activity dating back to the Jin Dynasty in 349 AD. In its early days the city of Ganzhou was merely a military stronghold at the confluence of two rivers. Along with military activity and population growth, the city continued to expand southwards, giving rise to a number of controlling axes related to the surrounding topography and landmark buildings in the city. The historic buildings in the design site, Ciyun Pagoda, Confucian Temple, and the ancient houses on Nanshi Street, are all influenced by these axes.

Figure 17 The evolution process of axis(Source:Elaboration by author)

As the city is located at the confluence of two rivers, it has been plagued by floods since ancient times. After a continuous struggle with nature, the ancients built a large drainage system in the city, naming it the Fushou Ditch, which still functions to this day. This can also be seen as a passive technique used by the ancients in their fight against nature.

2.1.2 Local architectural character

Ganzhou is located in the southern region of China and its architectural form is heavily influenced by Lingnan architecture and Southern Yangtse River dwellings. The overall colour styles is characterised by white walls and grey tiles. In terms of form, the buildings are grouped together with each other in courtyards. The public buildings emphasise a sense of axis and symmetry, and the dwellings are compactly laid out, with ventilation channels between the buildings to solve the problem of humidity and heat. The external boundaries of the building are more enclosed and the interiors are open to each other through courtyards and corridors. These features help us to understand the local architectural culture and to keep the subsequent design from deviating from the local architectural vocabulary.

2.2 Site Analysis

2.2.1 Strengths

Within and around the site there is a large amount of historical architectural heritage, such as Ciyun Pagoda, Confucian Temple, and the ancient houses on Nanshi Street. During the long historical changes, the ancient city district has spontaneously developed a unique texture, and with a staggered building height and a rich urban skyline.

2.2.2 Weaknesses

(1)Disordered Urban Fabric

The site area is filled with buildings of different types, heights and ages, resulting in the destruction of the original historical urban fabric. Some historical axes have been blurred by the city's constant building activities.

(2)Isolated Historic Buildings

Ciyun Pagoda, Confucian Temple are surrounded by walls and schools, and are obscured from view by dilapidated buildings. For visitors, there is a lack of clear pathways to visit the site and the internal interconnections between the architectural heritage are fragile.

(3)Poor Living Environment Quality

Some existing buildings have poor ventilation and lighting conditions, and some buildings have no stable structure； Lack of green space, public space and parking facilities in the surrounding area, resulting in disorderly conditions: Many old or dilapidated houses are under great pressure for demolition and high renovation costs.

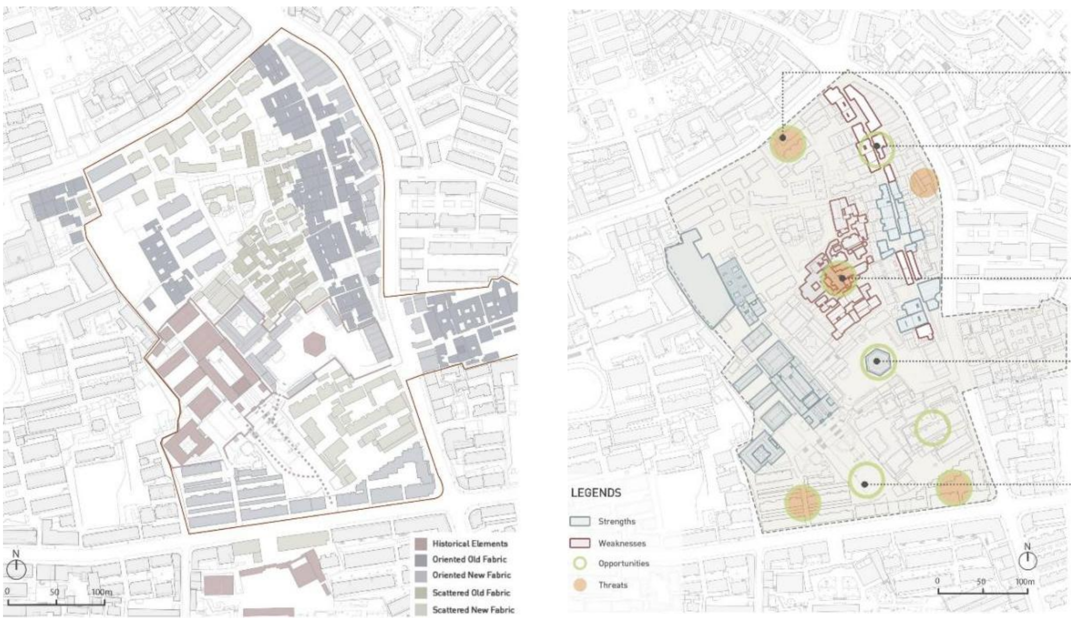

Figure 18 The strengths and weaknesses of the site(Source:Elaboration by author)

2.3 Design strategies

2.3.1 Design Objectives

Create the historical & cultural commercial street

The current commercial layout is relatively scattered, and we hope to build it into a coherent historical and cultural commercial street, thereby driving the local economic development, tourism enthusiasm and cultural dissemination.

Micro regeneration of the old residential block

In the block, the quality of houses is uneven, the infrastructure is scarce, and fire hazards are large. We hope that the old buildings can be graded to determine which buildings can be preserved, renovated or demolished. By implanting some micro-renovation measures, the quality of life of residents will be improved.

Preserve and create cultural space

Ciyun Pagoda does not fit well with the surrounding environment. Buildings around it can not only protect historical buildings, but also spread local culture.

Create a cultural landscape axis

The square in front of the Confucian Temple is full of cars on both sides, and the entrance lacks a sense of guidance and ritual. We hope to extend the landscape axis of the Confucian Temple and strengthen the sense of history and culture through landscape reconstruction.

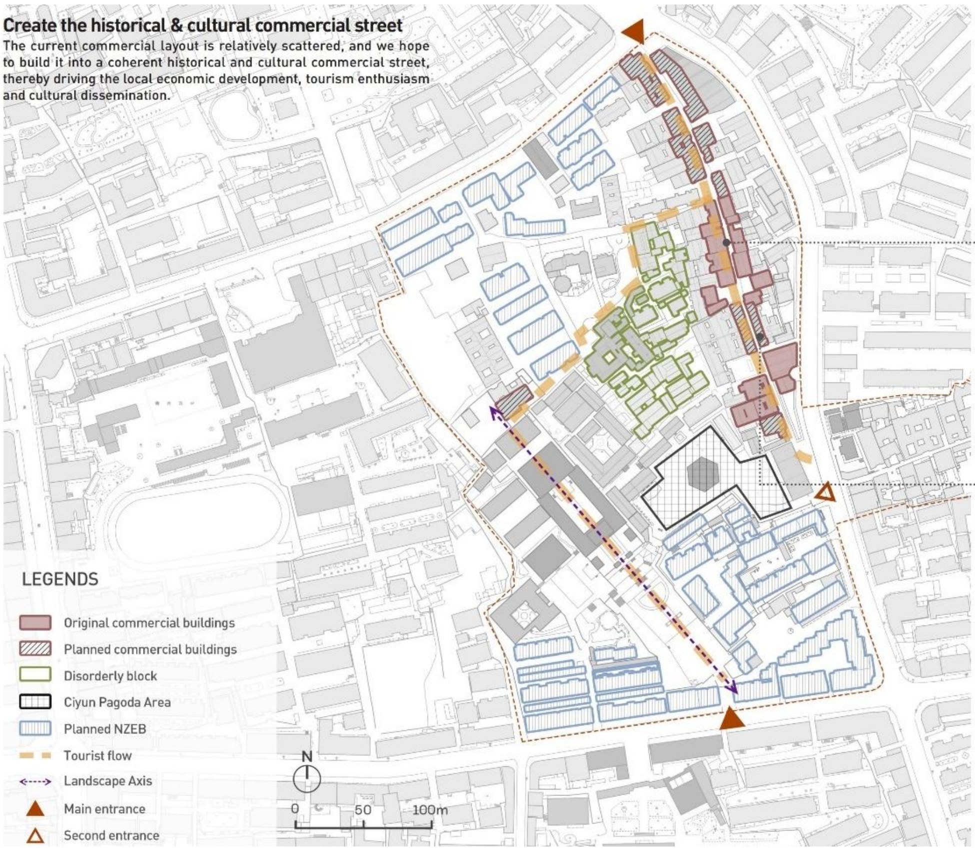

Figure 19 The design strategies about urban fabric and axis(Source:Elaboration by author)

2.3.2 A solution from a historical and muscular perspective

The strong presence of the historical heritage was first highlighted through the removal of some obstructive buildings. The relationship between the historic buildings became clear after the removal of a number of dilapidated, view-blocking buildings. We have added a outdoor corridor between the Ciyun Pagoda, Confucian Temple and the dwellings on Nanshi Street to strengthen the internal links. On the eastern side of the site near the main road, the new built two-storey library addresses the 4m height difference between the historic building area and the main road, with a striking new building guiding external foot traffic into the tour. It conforms morphologically to the fabric of the old city and functionally combines reading and exhibition functions, providing a public activity space that is lacking in this area, with the aim of stimulating the vitality of the community. The façade effect is in dark grey, in keeping with the colour tone of the old city.

Figure 20 Design of the building in relation to the axis of the site (Source:Elaboration by author)

Figure 21 Design Masterplan (Source:Elaboration by author)

Chapter Summary

By analysing the urban context, local architectural features and the site, we have arrived at a basic direction regarding the design of the renovation of the Ciyunta site in Ganzhou. But beyond that we wanted it to remain as green and environmentally friendly as possible in a carbon neutral context. Therefore, we will subsequently use the sustainable design approach to help the design to align the outcome in a sustainable direction without compromising the history and culture of the building.

3. SUSTAINABLE DESIGN WITH THE EXAMPLE OF THE CIYUN PAGODA LIBRARY IN GANZHOU

After completing the combing of the historical axes, we adopted a sustainable design approach, using the LEED green building rating criteria as a guide for the in-depth design of the scheme. In the latest version of LEED 4.1, participating projects are evaluated in nine main sections：Integrative process (IP)，Location and transporation (LT)， Sustainable sites (SS)， Water efficiency (WE)， Energy and atmosphere(EA), Materials and resources (MR), Indoor environmental quality (EQ), Innovation (IN). Of these sections, the Integration process, Innovation is more related to the design process and technology. In the following we will focus on the remaining seven sections that are more relevant to architectural design.

3.1 Location and Transportation

"Location and Transportation" is the first section to be scored in the LEED certification system and is the most relevant to the architectural scheme design. The "LEED for Neighbourhood Development Location" section requires projects to be located within the boundaries of LEED ND certified developments, in order to avoid energy wastage and inconvenience caused by location. "Sensitive Land Protection" requires the development to be located on previously developed land, reducing the impact of land development on the surrounding environment. "High Priority Site" encourages infill development of vacant sites in historic conservation areas. "Surrounding Density and Diverse Uses" requires a standard of development density within a 400 meters radius of the project site, or a variety of infrastructure service points to promote walking and efficient public transport access and reduce vehicle miles travelled. "Access to Quality Transit", "Bicycle Facilities", "Reduced Parking Footprint", "Green Vehicles" all relate to transport facilities, and the following is a specific analysis of the projects that are more relevant to the library scheme design.

Location and Transportation		**16**
Credit	LEED for Neighborhood Development Location	16
Credit	Sensitive Land Protection	1
Credit	High Priority Site	2
Credit	Surrounding Density and Diverse Uses	5
Credit	Access to Quality Transit	5
Credit	Bicycle Facilities	1
Credit	Reduced Parking Footprint	1
Credit	Green Vehicles	1

Table 2 LEED Scorecard (The part of Location and Transportation)

Source:https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version

3.1.1 Surrounding Density and Diverse Uses

The project site is located in the heart of the old town with mature and well-established surrounding facilities. Within a walking radius of 800m from the main entrance to the building, there is a large hospital, a post office, a laundry, two hairdressers, five kiosks, four hotels, four pharmacies and dozens of restaurants of various sizes. It basically meets most of the needs of residents and visitors.

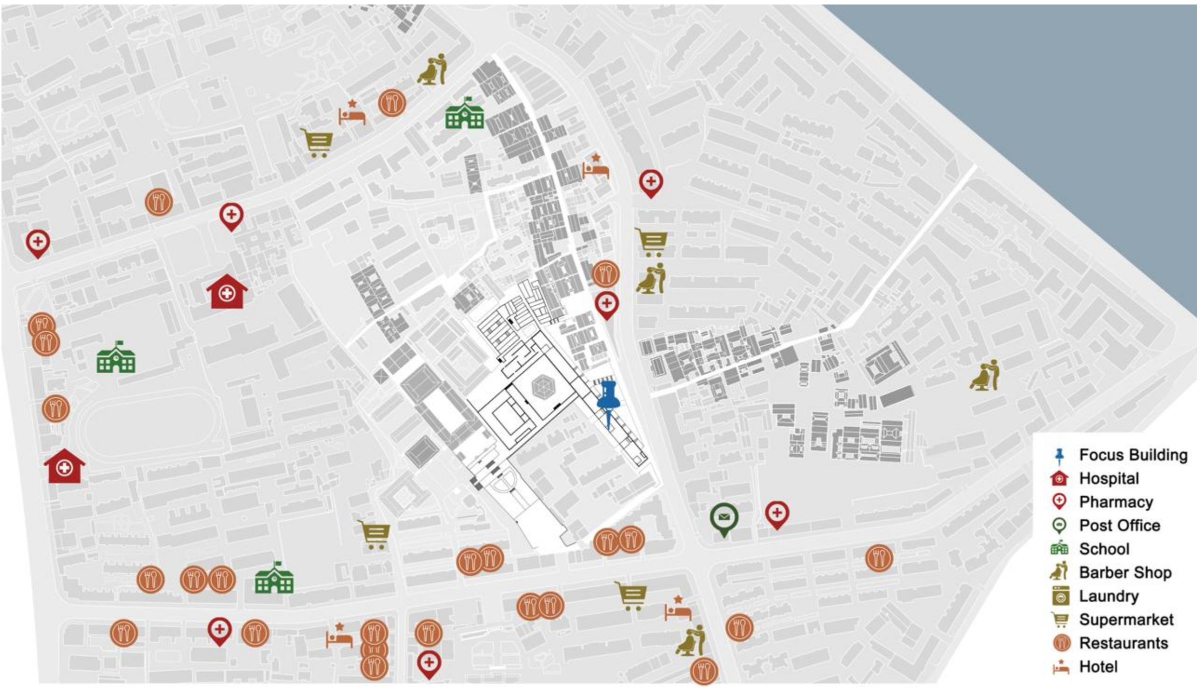

Figure 22 Distribution map of surrounding service points (Source:Elaboration by author)

3.1.2 Access to Quality Transit

The city of Ganzhou is not served by a metro and the main form of public transport is by bus. There is a bus stop on the east side and south side of the site. The bus stop on the south side is located about 40 m from the entrance of the Confucian Temple and the bus stop on the east side is about 150 m from the main entrance of the library. Both bus stops are within walking comfort zones from the project site.

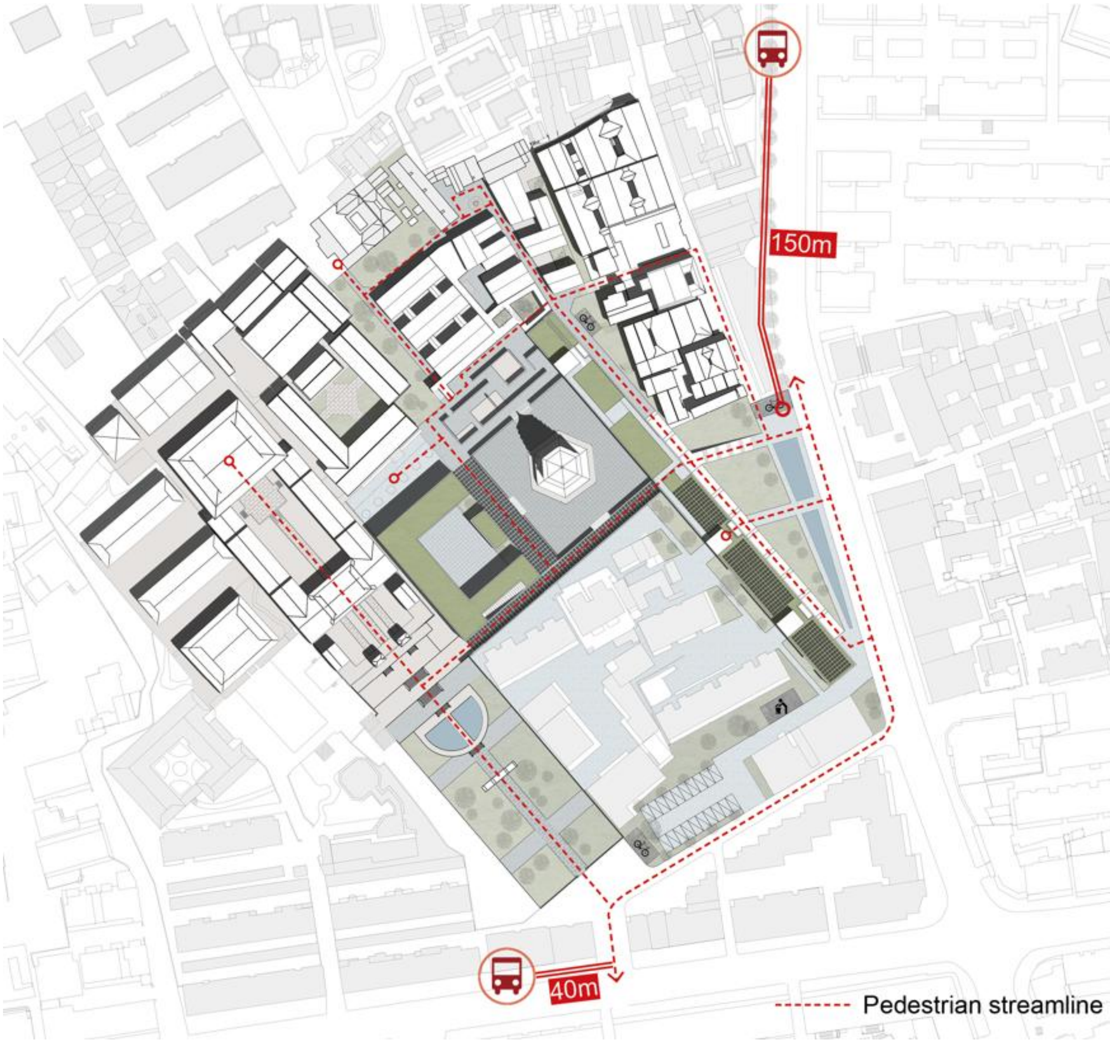

Figure 23 Pedestrian flow diagram (Source:Elaboration by author)

3.1.3 Bicycle Facilities

Bicycle parking areas are located on the main road on the east side and the secondary road on the south side, serving the Temple and the Library respectively. The parking space covers an area of approximately 200 m^2 and has a total parking capacity of approximately 100 vehicles. We have also installed charging units in both areas to serve electric bicycles. The ramp on the east side of the library connects the north and south areas of the site, opening up a previously blocked path from which bicycles can also be pushed to the historic building area on the north side, providing access to the cycle paths within the site.

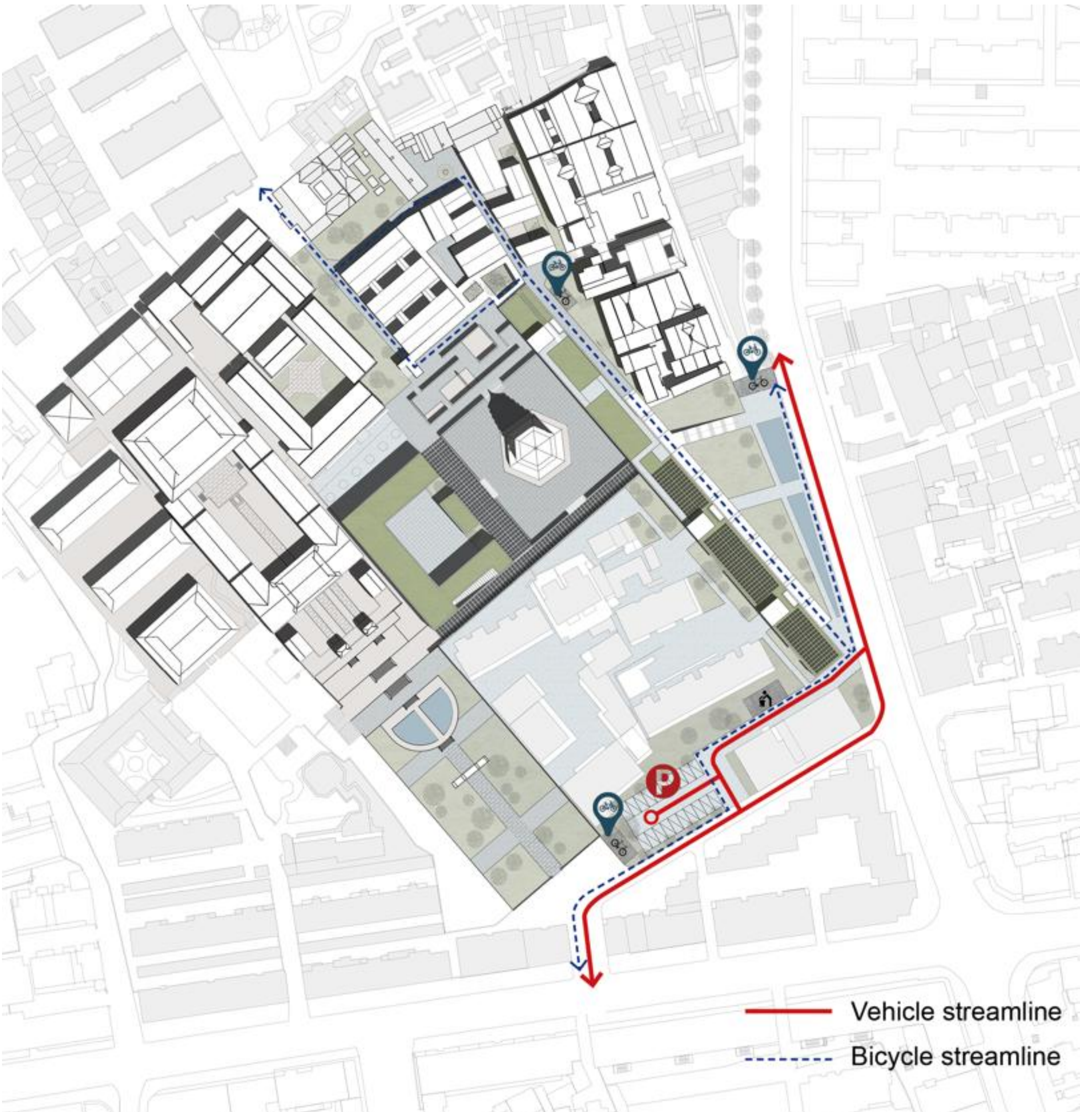

Figure 24 Traffic flow diagram(Source:Elaboration by author)

3.1.4 Green Vehicles

The standard requires that parking areas on the site need to be reserved for at least 5% of the parking spaces for green cars. A total of 20 surface parking spaces are currently provided between the Temple and the Library and we are considering using half of these as green parking spaces.

3.2 Sustainable Sites

3.2.1 Design Objectives

According to the LEED rating criteria, we need to focus on construction activity pollution prevention as a prerequisite for sustainable design in the design. The distribution of the scored items shows that the focus of this section is on the heat island reduction and rainwater management. The following will focus on these three aspects of sustainable site design.

Sustainable Sites		**10**
Prereq	Construction Activity Pollution Prevention	Required
Credit	Site Assessment	1
Credit	Site Development - Protect or Restore Habitat	2
Credit	Open Space	1
Credit	Rainwater Management	3
Credit	Heat Island Reduction	2
Credit	Light Pollution Reduction	1

Table 3 LEED Scorecard (The part of Sustainable Sites)

Source:https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version

3.2.2 Construction Activity Pollution Prevention

Construction projects involve a wide range of upstream and downstream industries in the process, it has a long construction cycles, consume large amounts of resources and inevitably generate pollution. The main sources of pollution come from dust, noise and solid waste emissions[26].

(1) Control of dust pollution

The excavation of the site and the demolition of abandoned buildings should be accompanied by sprinkling or spraying, and operations should be suspended in windy conditions.The road surface at the entrance and exit of vehicles in construction sites should be hardened and vehicle washing facilities should be installed to prevent the dispersal of pollutants onto urban roads. Particulate matter needs to be covered by measures if left in open space. Building should use prefabricated materials as much as possible to reduce the use of sand and gravel on site. This project uses steel structures and precast concrete panels for the main frame and precast terracotta panels for the external facade.

(2) Control of construction noise

Noise generated at construction sites should meet the requirements of *Emission standard of environment noise for boundary of constructionsite (GB 12523 —2011).* The builder shall strictly control the hours of construction operations and prohibit night work. Installation of acoustic insulation around construction equipment that generates strong noise.

(3) Control of solid waste emissions

Waste generated during the construction process needs to be strictly segregated according to recyclable, non-recyclable, toxic and hazardous waste. Some of the masonry from the demolition of abandoned buildings on the project site can be used to construct a landscape partition wall around the Ciyun Pagoda. Due to the large difference in elevation of the topography on site, the excess earth from the excavation process can be used for the landscape ramp on the south side of the library building. Non-recyclable waste needs to be stored in a fixed location and removed regularly.

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[26] Guoan Wei,*Construction Pollution Prevention Measures and Effect Analysis of Engineering Projects,IOP Conf. Series: Earth and Environmental Science*.Vol. 687(2021) 012010,p3-4

Toxic and hazardous wastes need to be stored separately and transferred to a qualified waste disposal unit for environmentally sound treatment.

3.2.3 Heat Island Reduction

Figure 25 Map of original green spaces(Source:Elaboration by author)

The urban heat island effect is one of the common environmental problems faced by metropolitan areas. Rapid urbanisation has created a large number of masonry buildings that have replaced the original agricultural land and water ponds, permanently altering the ecological environment of the urban areas. This has led to higher temperatures in urban areas than in the suburbs. The FIX.X map shows that the project site is currently densely built up, with little greenery and water area. The project site is surrounded by a large number of old buildings with mostly dark tiled roofs, which have low reflectivity and tend to absorb solar radiation. In addition, most of the city centre squares and roads built in the last century are impermeable, which tends to increase the evaporation of rainwater, store heat and exacerbate the heat island effect.

In order to reduce the heat island effect in cities, targeted measures have been taken for different types of urban areas.

(1)New Construction

For new buildings, we use planted roofs and have solar photovoltaic panels in some areas, and tiles with reflective coatings can be used for sloping roofs. Light-coloured terracotta panels are used on external walls to increase reflectivity.

(2)Outdoor ground

The open plaza space uses a highly permeable ground material to absorb moisture and heat. It also regulates the temperature and humidity of the ground space. For example, grass tiles are used around the Ciyun Pagoda Square and parking spaces, coloured permeable concrete can be used for the children's activity area, permeable asphalt concrete can be used for the carriageway, and non-slip permeable floor tiles are used for the pedestrian paths and outdoor entrance space.

(3)Outdoor landscaping

The vacant areas around the buildings can be replaced with greenery instead of the original hard surfaces, such as the entrance square of the Confucian Temple, where the greenery in front of the Pan Pool is extended southwards to the roadside in the new design. Green belts are added between buildings in residential areas. Border tree have been planted around the roadside and car park area to reduce heat reflection.

(4)Water feature

Water feature is placed at the main entrance of the library to store heat and regulate the temperature, while the evaporation of the water can also take away some of the heat.

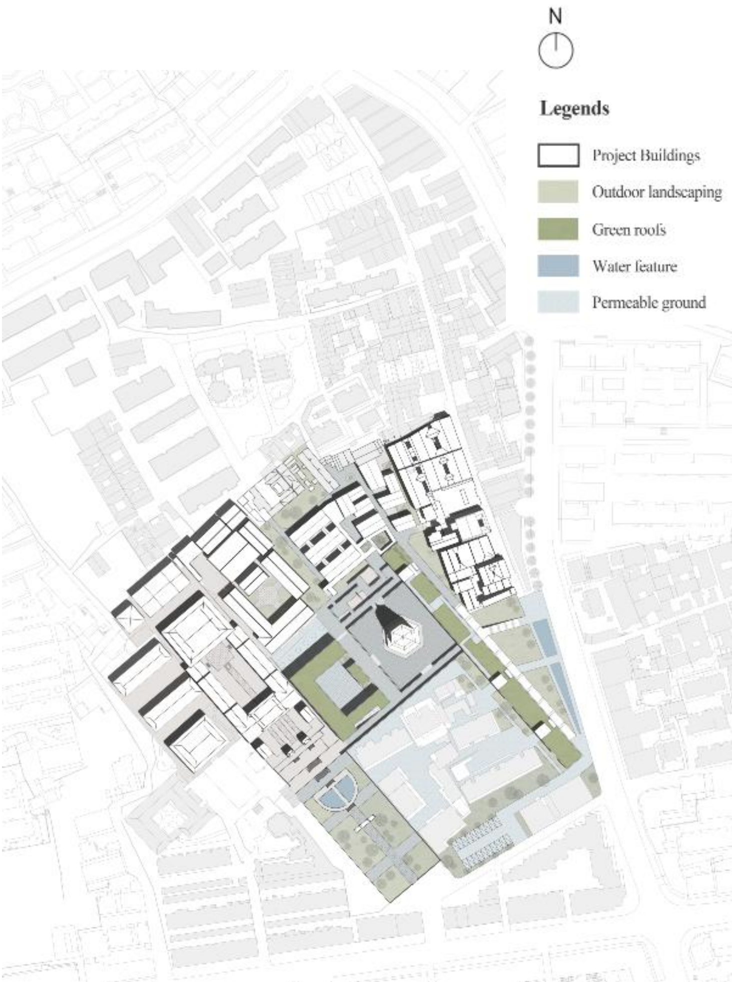


Figure 26 Outdoor landscaping diagram(Source:Elaboration by author)

3.2.4 Rainwater Management

According to the geography and climate analysis in chapter 2.1.1, Ganzhou region is rich in rainfall and the city is surrounded by two rivers, which were often plagued by floods in ancient times. Therefore a good rainwater recycling system in this area will help to relieve water pressure, replenish groundwater resources and reduce the potential threat for urban flooding.

The process of rainwater recycling is divided into three main steps: rainwater collection, filtration and cleaning, and reuse. Green roofs and permeable pavements help to reduce surface runoff, filter and clean the rainwater at the same time. After the initial filtration, the rainwater is collected through pipes, then it can be used for irrigation, flushing and other non-domestic purposes through secondary filtration.

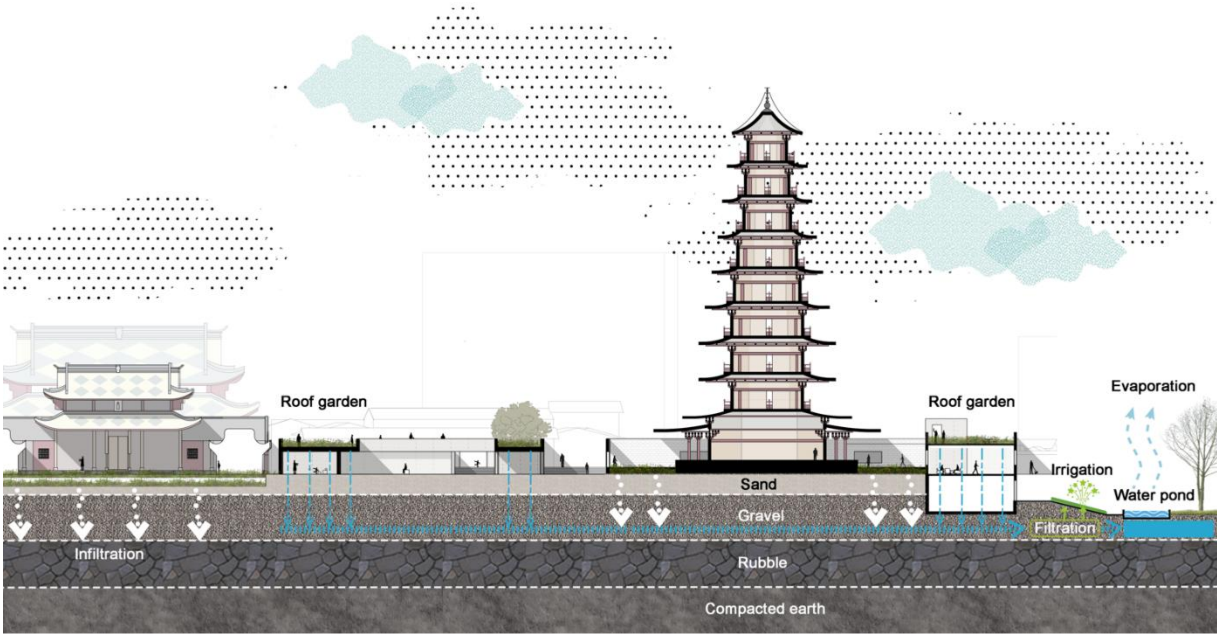


Figure 27 Diagram of rainwater recycling(Source:Elaboration by author)

3.3 Water Efficiency

3.3.1 Design Objectives

Today's water problems have become a common concern worldwide and water scarcity has become a major constraint on economic development.The use of domestic and productive water is an important part of energy consumption in buildings.Strategies for water conservation mainly focus on the rational planning of water use in buildings from both water supply and use perspectives.

In accordance with the requirements of the LEED rating standards, we will analyse the water efficiency of the designed building in terms of Outdoor Water Use Reduction, Indoor Water Use Reduction and Building-Level Water Metering.

Water Efficiency		11
Prereq	Outdoor Water Use Reduction	Required
Prereq	Indoor Water Use Reduction	Required
Prereq	Building-Level Water Metering	Required
Credit	Outdoor Water Use Reduction	2
Credit	Indoor Water Use Reduction	6
Credit	Cooling Tower Water Use	2
Credit	Water Metering	1

Table 4 LEED Scorecard (The part of Water Efficiency)

Source:https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version

3.3.2 Outdoor Water Use Reduction

Outdoor water conservation measures include rainwater recycling, water efficient irrigation and the use of non-traditional water sources. Rainwater recycling has been analysed in chapter 6.3.2 and then we will focusing on water-efficient irrigation measures and the use of non-traditional water sources.

(1) Water-efficient irrigation

At present, in order to achieve the purpose of water-saving irrigation, we mainly start from two aspects. One is to adopt water-saving irrigation technical measures to reduce water loss in the irrigation process, such as drip irrigation, sprinkler irrigation and micro-irrigation. The other is to reduce water consumption at source by changing the planting structure and choosing drought-tolerant and aesthetically pleasing plants instead of those that use a lot of water.

(2) The use of non-traditional water sources

The use of non-traditional water sources in this project includes the rational use of rainwater and water from buildings. The recycling of rainwater is discussed in section 6.3.4. The reuse of water in buildings refers to the treatment of domestic water in buildings. For example, after disinfection and filtration, the domestic water can be used for outdoor car washing, irrigation, filling landscape ponds.

3.3.3 Indoor Water Use Reduction

The main measures to save water in public buildings are the reuse of reclaimed water and the use of water-saving appliances. After filtration, sedimentation and disinfection, reclaimed water can be used for landscape irrigation and toilet flushing and fire-fighting and can reduce the pressure on the municipal sewage system caused by the outflow of sewage. Toilet facilities should use infrared sensor taps as well as choosing aerated spouts to reduce the need for water pressure.

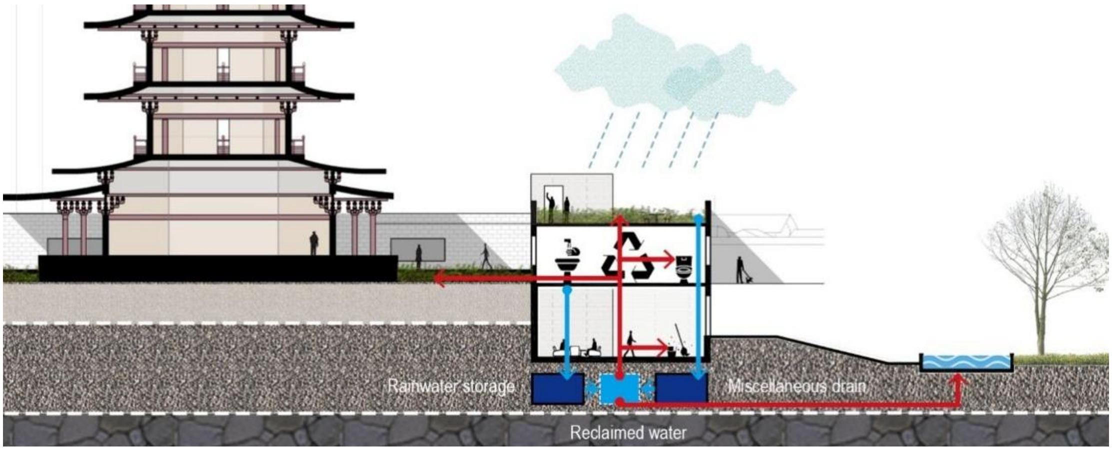


Figure 28 Diagram of indoor water recycling(Source:Elaboration by author)

3.4 Energy and Atmosphere

3.4.1 Design Objectives

The energy and atmosphere part mainly focuses on the energy performance of buildings. It is the highest scoring component of the LEED score board, accounting for 30% of the total score. This shows the importance of energy conservation and control of greenhouse gas emissions in sustainable buildings.

The commissioning, metering, demand response and refrigerant management items in this section are more related to the operation, management, review and maintenance of the building throughout its life cycle. In the architectural design stage, we mainly discuss three parts: Renewable energy production and Green power and carbon offsets.

Energy and Atmosphere		**33**
Prereq	Fundamental Commissioning and Verification	Required
Prereq	Minimum Energy Performance	Required
Prereq	Building-Level Energy Metering	Required
Prereq	Fundamental Refrigerant Management	Required
Credit	Enhanced Commissioning	6
Credit	Optimize Energy Performance	18
Credit	Advanced Energy Metering	1
Credit	Demand Response	2
Credit	Renewable Energy Production	3
Credit	Enhanced Refrigerant Management	1
Credit	Green Power and Carbon Offsets	2

Table 5 LEED Scorecard (The part of Energy and Atmosphere)
https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version

3.4.2 Renewable energy production

The renewable energy related design of the project is a ground source heat pump system, a roof mounted solar photovoltaic facility and a solar hot water system.

The ground source heat pump system has vertical heat and cold exchange piping and has a good energy conversion efficiency with COP and EER values of 5.14 and 4.85 respectively. The electricity used for heating is 22.6 MWh and the electricity used for cooling is 137.1 MWh.

The solar photovoltaic panels are arranged on the south side of the library roof and on top of the connecting corridor around the square. The total area is approximately 1500 square metres.

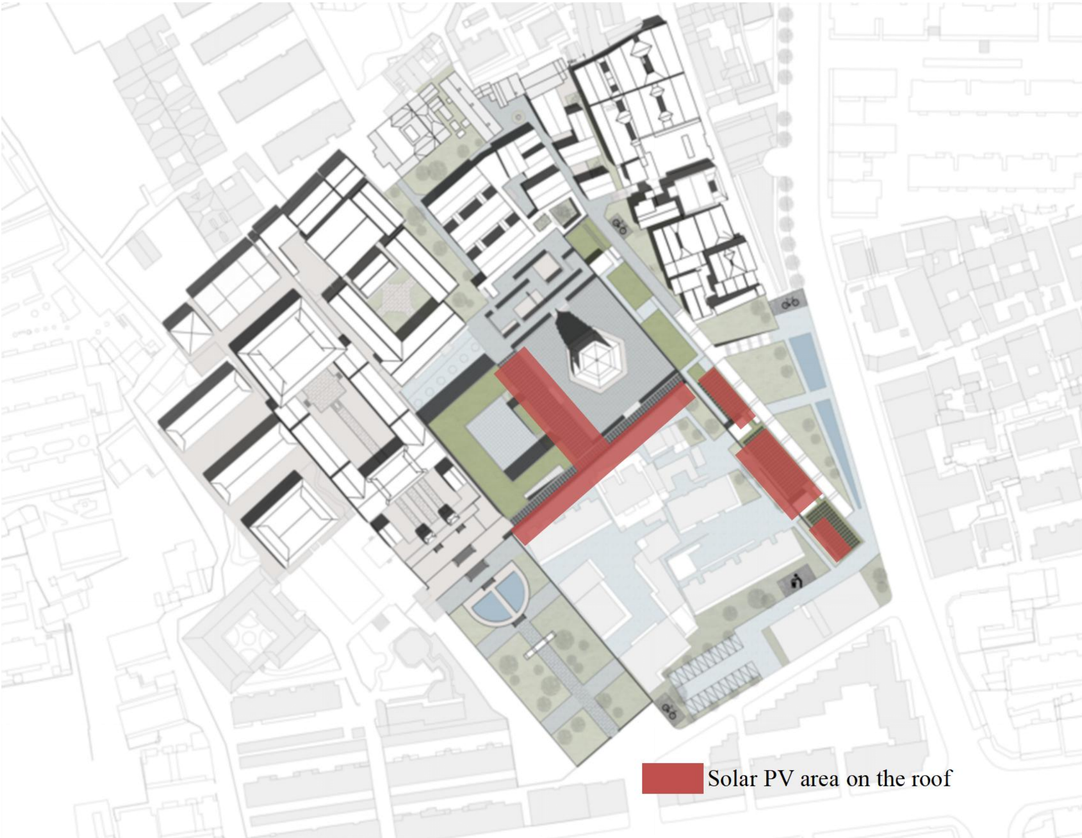


Figure 29 The location of Solar PV area on the roof(Source:Elaboration by author)

The combination of solar panels and green roofs on the library roof improves thermal insulation and avoids wasting space.[27]The solar water heating system is also located on the roof of the building and covers an area of 22 m^2. Hot water usage 1000 L/day, seven days per week at 45°C.

[27] Zhejiang Architectural Science and Design Institute Co., *Insulation system combining green roofs and overhead photovoltaic panels,*Utility model patents,CN201713952U,2006.01

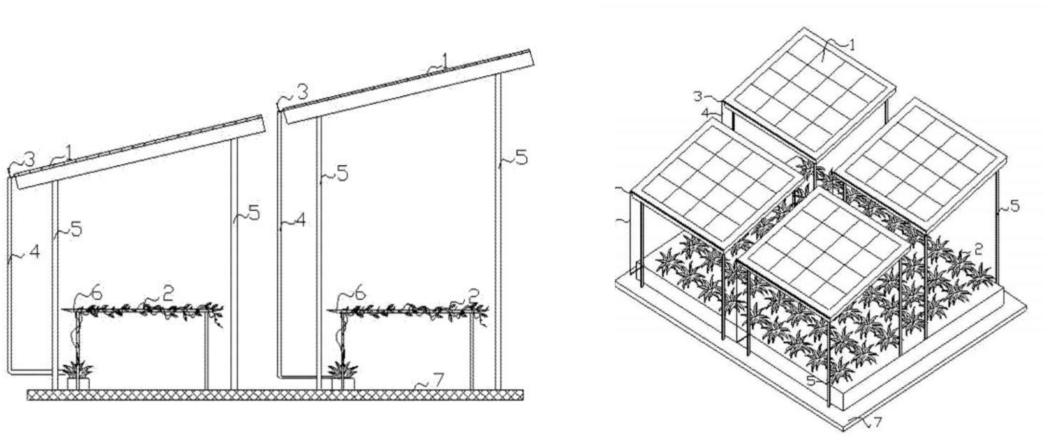


Figure 30 Insulation system combining green roofs and overhead photovoltaic panels
(Source:Utility model patents,CN201713952U)

The solar water heating system is also located on the roof of the building and covers an area of 22 square metres. Hot water usage 1000 L/day, seven days per week at 45°.

3.4.3 Green power and carbon offsets

Based on the calculations presented in section 4.3.4, the ground source heat pumps, solar PV and hot water systems can help reduce greenhouse gas emissions by 240.78(tCO2/year).

3.5 Materials and Resources

Materials and Resources		**13**
Prereq	Storage and Collection of Recyclables	Required
Prereq	Construction and Demolition Waste Management Planning	Required
Credit	Building Life-Cycle Impact Reduction	5
Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
Credit	Building Product Disclosure and Optimization - Material Ingredients	2
Credit	Construction and Demolition Waste Management	2

Table 6 LEED Scorecard (The part of Materials and Resources)
https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version

This section mainly focuses on the use of environmentally friendly materials in buildings and the recycling of materials. As an architect, the main consideration in this section is the need to design the site with a dedicated area for the collection and storage of recyclable materials, which is easily accessible to both building users and waste collectors.

For this project, we have considered locating the collection point on the south side of the site, near the outdoor parking area. It is located between the Temple and the Library, making it easy for staff to dispose the waste. The proximity to the carriageway and parking area also makes it easier for refuse collection vehicles to park and access the site.

3.6 Indoor Environmental Quality

This section focuses on how to improve the environmental quality building interiors. The scoring and control items here are mainly concerned with ventilation, lighting and sound insulation. The most relevant elements of pre-construction programming are Environmental Tobacco Smoke Control, Indoor Air Quality Assessment, Daylight，Quality Views. Due to the proximity of our site to a school and historic building conservation area, the public areas are completely non-smoking and no outdoor smoking areas are being considered. We will address three other aspects of the design in relation to sustainable measures.

Indoor Environmental Quality		**16**
Prereq	Minimum Indoor Air Quality Performance	Required
Prereq	Environmental Tobacco Smoke Control	Required
Credit	Enhanced Indoor Air Quality Strategies	2
Credit	Low-Emitting Materials	3
Credit	Construction Indoor Air Quality Management Plan	1
Credit	Indoor Air Quality Assessment	2
Credit	Thermal Comfort	1
Credit	Interior Lighting	2
Credit	Daylight	3
Credit	Quality Views	1
Credit	Acoustic Performance	1

Table 7 LEED Scorecard (The part of Indoor Environmental Quality)
https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version

3.6.1 Indoor Air Quality Assessment

To achieve the comfort and healthy of the occupants of the new building, minimum indoor air quality (IAQ) should be established according to the environment and the requirements. There are two aspects need to be fulfilled: Ventilation and monitoring.

(1) Ventilation

In this project we follow the ASHRAE Standard 62.1–2010 and Green Building Evaluation Criteria GB/T 50378-2019 revised by China Academy of Building Research Co., Ltd for determining the acceptable indoor air quality of Mechanical ventilated space and naturally ventilated spaces. For naturally ventilated space or mixed-mode system the effectiveness and validation also need to be confirmed by those two procedures.

(2) Monitoring

For mechanical ventilated spaces, as instructed in the LEED reference, the minimum outdoor air intake should be measured with an accuracy of 10% of the design minimum outdoor airflow rate. Also, the alarm should be indicated when the outdoor airflow value varies by from the open-air situation.

For natural ventilated space, exhausted airflow is the indicator of monitoring the ventilated space with +/–10% of the design minimum exhaust airflow rate as while as putting alarms when the airflow values vary by 15% of the setpoint of the exhaust airflow. Devices should be equipped on all natural ventilation openings intended to meet base opening prerequisites. An alert should show when any of the openings is shut during involved hours.

In addition, carbon dioxide monitor should be installed at every 0.9 meters to 1.8 meters to monitoring the concentration of CO^2 within the thermal zone, the value should not exceed 10% of the setpoint (where as indicated in ASHRAE 62.1-2010, to maintain a steady CO^2 concentration, the indoor value should not greater than 700ppm above outdoor level). CO^2 fixations in satisfactory open air commonly range from 300 to 500 ppm. High CO^2 fixations in the open air can be a sign of ignition as well as other pollutant sources.[28]

Guidance steps

- Step one, evaluate outdoor air quality.

As the site is located in a humid and hot climate zone, ventilation is a very important strategy to solve the problem of the uncomfortable indoor somatosensory. From the climate analysis (Software: Climate Consultant), which is showed in figure 42, there are two prevailing wind directions which are east and southwest with an average wind velocity of 1m/s. The result of the analysis is used to inform ventilation strategy selection and system design for the next steps. As the site is in a quite historical city district with vegetation and a river nearby, there is potential to maximize the strategy of natural ventilation and less filtration system.

- Step two, select ventilation strategy.

The consideration of the building’s form location, orientation, programming and depth of the floor could generate opportunities for low-energy and high-quality natural ventilation or mix-mode system. In our case, the building’s configuration is presenting a longitudinal form with all the rooms in one side and the longest façade is orthogonal to the southwest direction which is one of the prevailing wind in summer. Under this premise, there are four permanent openings are designed on the south

[28] USGBC, LEED rating system, https://www.usgbc.org/leed

façade. On the roof and east façade there are another series of openings with close or open state depends on the weather and month of the year. According to ASHRAE Standard 62.1–2010 (-Section 6.4), the maximum distance from the operable openings for double side opening is 5H, where H is the ceiling height in our case is 7.5 m. While for the case of corner openings (on the south façade and roof), the maximum distance is also 5H along a line drawn between the two openings which are farthest apart. For naturally ventilated space the permanently openings operable directly to outdoor space should have a minimum 4% of net occupiable floor area with unobstructed space, while for interior the minimum openings should no less than 8% of the room.

Based on this premise, we run two stimulations on the circumstances that the outdoor wind velocity is in 1m/s which is the average value thought the year and consider the building ventilated in completely natural wind. The first scheme considers that the prevailing wind coming from south-west direction, the openings are fixed on ground floor and first floor as inlet allow the warm airflow coming out from the openings on the roof. Two small permanent openings are also design at the gate of the passageway.

The result of the stimulation (see figure 32) shows that most of the space of interior has an airflow from 0 to 1.5m/s which show that this strategy is affective. What need to be paid attention is that the entrance area has a relatively strong stream, the space is more suitable for activities need high ventilation rate.

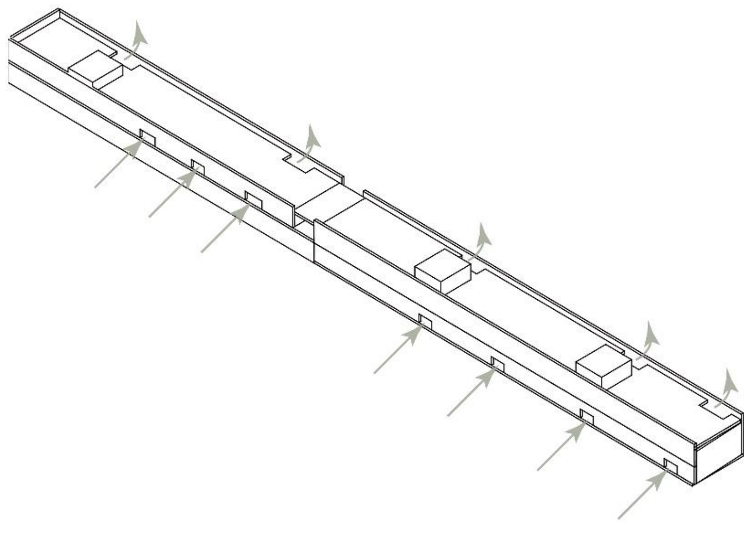


Figure 31 South-west prevailing wind opening strategy (Source: elaborate by author)

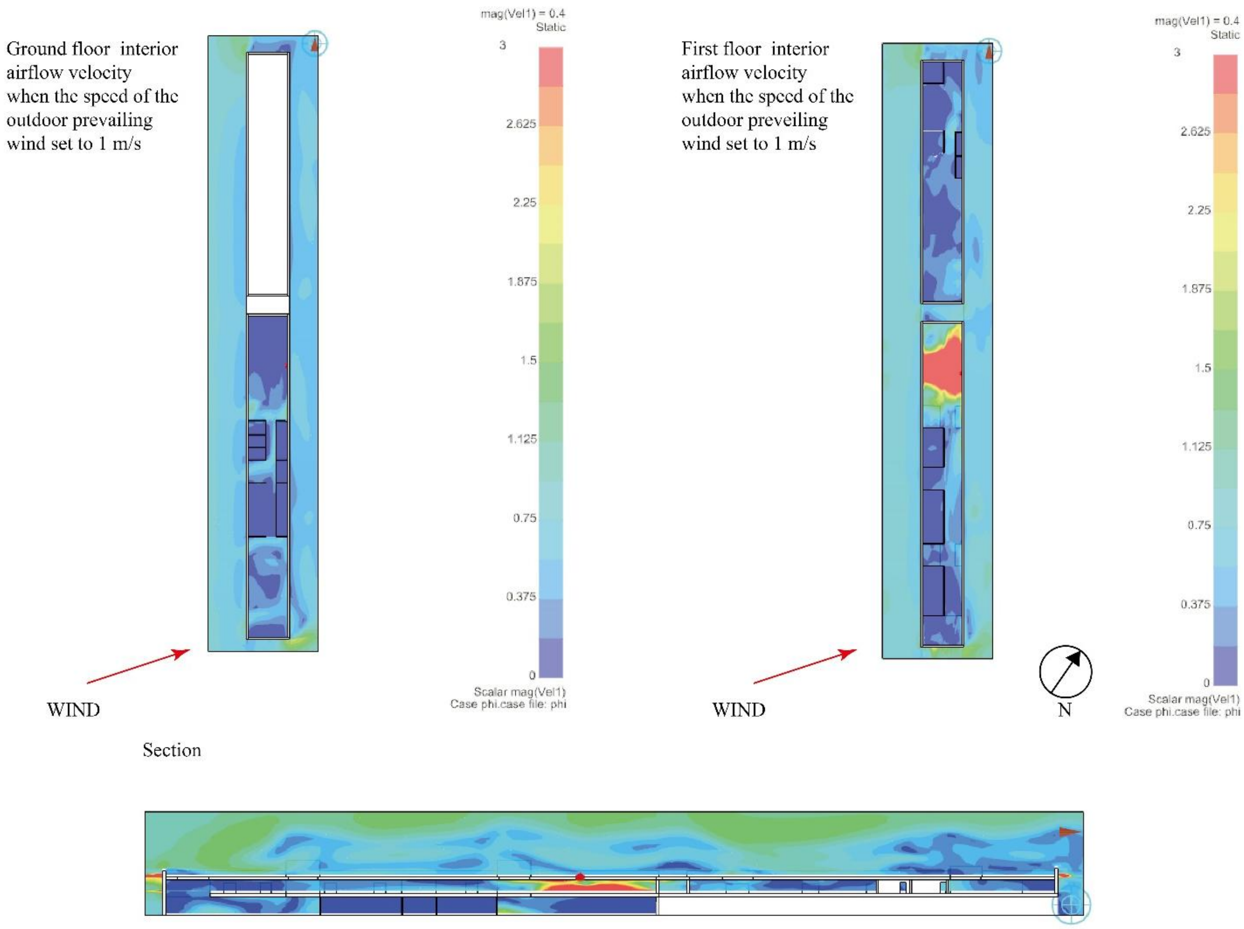


Figure 32 South-west prevailing wind CFD stimulation of internal wind velocity (Source: elaborate by author)

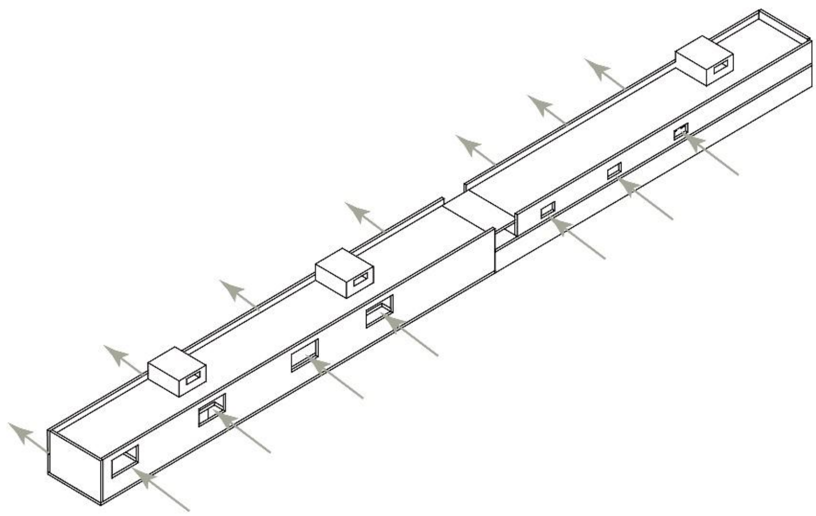


Figure 33 East prevailing wind opening strategy (Source: elaborate by author)

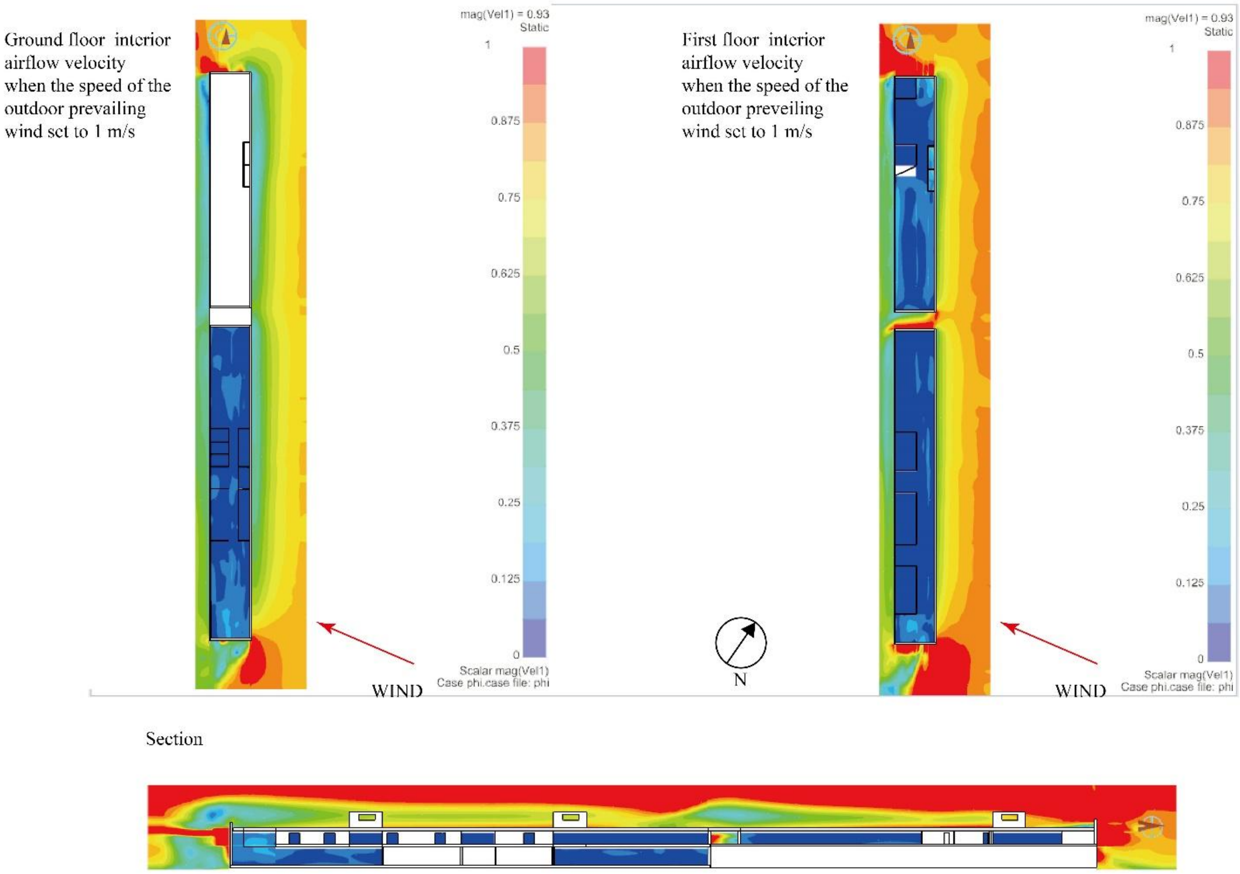


Figure 34 East prevailing wind CFD stimulation of internal wind velocity

(Source: elaborate by author)

The second scheme considers that the prevailing wind coming from east direction, the openings are fixed on both sides of the building to create a cross ventilation. However, the result of the south portion of the building has nearly no airflow inside except the end of the building where is the atrium. Therefore, the openings on the first floor (-south side) needed to be open wider to generate more airflow or use mechanical device to control some part of the space using mix mode.

- Step three, categorize spaces

Create a table of all rooms and spaces in the project and identify the following for each:

· **Ventilation strategy**

The ventilation strategy is based on the function of the room and the airflow condition. On the ground floor there are rooms for book storage which require certain humidity and temperature needed to be controlled and monitored by electrical device. On the upper floors the mix mode is adopted in the workshop space with permanent openings more than 8% of the room space and mechanical equipment to monitor.

· Net occupiable space, as defined in ASHRAE Standard 62.1–2010, page 4

· Occupancy category, as listed in ASHRAE Standard 62.1–2010, Table 6-1

Figure 35 Ventilation strategy (Source: elaborate by author)

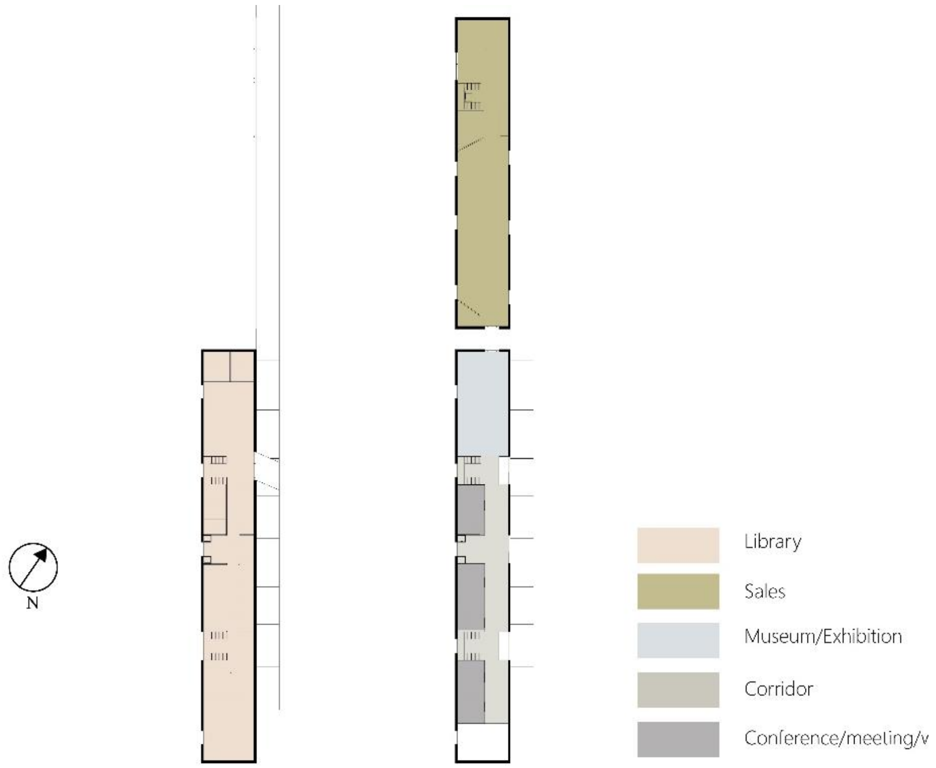


Figure 36 Function map (Source: elaborate by author)

MINIMUM VENTILATION RATES IN BREATHING ZONE		
Occupancy Category	People Outdoor Air Rate Rp	Area Outdoor Air Rate Ra
	L/s·person	L/s·m2
Libraries	2.5	0.6
Sales	3.8	0.6
Museums/galleries	3.8	0.3
Corridor	–	0.3
Conference/ workshop	2.5	0.3

Table 8 Minimum ventilation rates in breathing zone
(source: ASHRAE Standard 62.1–2010, Table 6-1)

According to ASHRAE Standard 62.1–2010, Table 6-1, the spaces are designed as follow in line with its natural ventilation airflow situation. The whole building is cataloged into three main part, the north part has good performance of natural ventilation, therefore, is defined as sale space which require relative high ventilation rate. The south portion of the first floor is defined into three different functions, the entrance space where has higher nature ventilation rate is forth put into an exhibition space, while the space covered by glass partitions is applied for activities like workshop or conference.

· If applicable, identify whether the building is very low polluting, low polluting, or not low polluting (see CEN Standard 15251, Annex C).

· Design occupancy (see Getting Started, Occupancy)

It may be appropriate to group rooms or spaces into ventilation zones (see Further Explanation, Types of Mechanical Ventilation Systems).

- Step 4, identify appropriate prerequisite requirements

Follow the means underneath for mechanical ventilation or regular ventilation, contingent upon the ventilation procedure utilized in each space.

For blended mode frameworks, projects should follow mechanical ventilation necessities when the mechanical framework is dynamic, and regular ventilation prerequisites when the mechanical ventilation framework is inert.

3.6.2 Daylight

The external windows are made of sun-shading Low insulating glass with a heat transfer coefficient of 1.3 and a solar heat gain coefficient (SHGC) of 0.35, which meets the relevant standard of the *Energy Conservation Standard for Public Buildings*.

The public areas of the library are all set with direct external lighting windows, and natural light is the main way for lighting. The dense buildings in the old city center, especially the area in the south of the Ciyun Pagoda, have more residential buildings of about 6 stories, which have a certain impact on the lighting of the library. We have therefore raised the roof over the stairwell and installed top windows to increase light intake. The roof on the north side of the stairwell is installed with light skylights and light wells, so that the light entering the library is reflected several times into the reading area enclosed by glass partitions, which prevents glare.

Considering that Ganzhou is a hot-summer and cold-winter region, it is necessary to focus on heat protection in summer and proper heat preservation in winter. The external windows on the south side of the library and the area of the roof skylight are installed with movable sun-shading louvers, which can be manually adjusted according to the position of the sun in summer to prevent overheating and save energy consumption.

3.6.3 Quality Views

The library has exterior windows with good views from the north and south sides, with the south side offering views around the Ciyun Tower, and the obstructions are all outside the 7.5m range from the building facade. The main street and some of the old buildings can be seen on the north side. Most area on the first floor of the library is an open exhibition and activity area, and most of the interior furniture is tables and chairs, allowing unobstructed views to the windows from all angles. In addition, an open roof walkway is provided on the north side of the roof, allowing views of the Ciyun Pagoda and part of the ancient roof of the buildings.

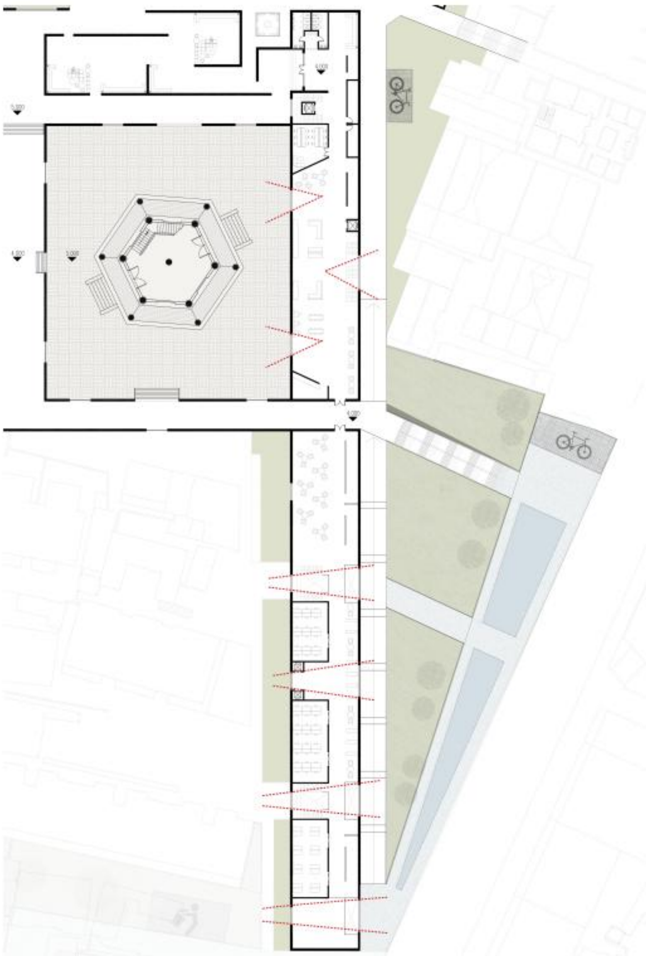


Figure 37 Diagram showing the location of exterior windows (Source: elaborate by author)

Figure 38 Rooftop tour view diagram (Source: elaborate by author)

4. ENVIRONMENT AND ENERGY ASSESSMENT OF CURRENT SITE AND NEW PROPOSAL

4.1 Climate and Environment assessment

4.1.1 Climate description of Ganzhou

Ganzhou is located at the intersection of Wuyi Mountains, Nanling Mountains and Luoxiao Mountains, with time zone of Greenwich of +8, is a typical humid subtropical monsoon climate.

The temperature range of yearly data is from 16℃ to 24℃, the highest temperature could reach above 35 ℃ in July and in January the temperature could fall to below 0℃. According to ASHRAE 2005 criteria, only May and October have a good average comfort performance.

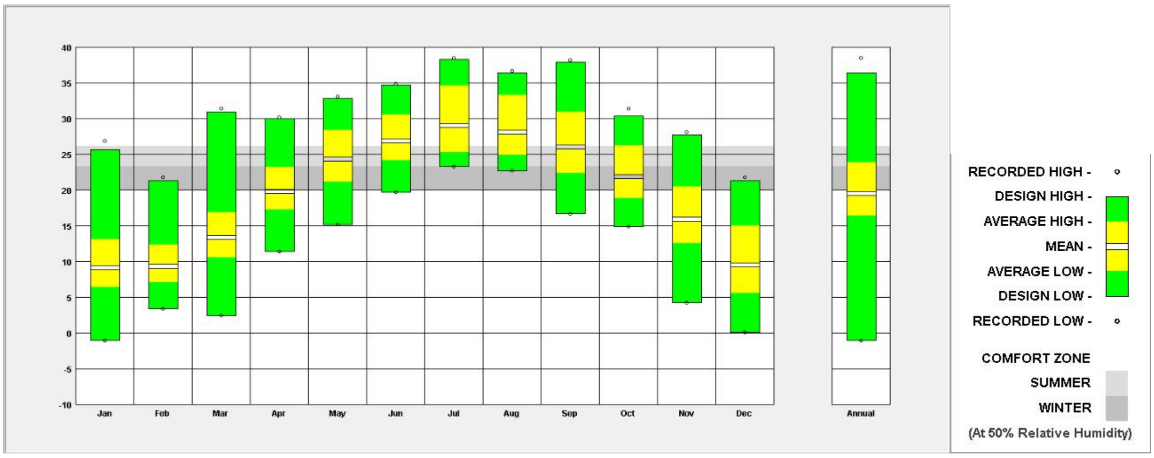


Figure 39 Monthly average temperature (Source: Climate consultant 6.0)

From the monthly diurnal average, the difference between the dry bulb temperature and the wet bulb temperature increases from June to December, which means that the humidity in Ganzhou begins to increase from June. For summer, the increased humidity and the higher solar radiation create uncomfortable thermal conditions and will require active or passive cooling strategies. At the same time, the figure also points out that the temperature difference between day and night is large from January to March. In general, Ganzhou belongs to the hot zone in summer (people's somatosensory temperature is also very high.) and mild cold climate in winter. The higher solar radiation in summer makes the temperature rise. From the perspective of architectural composition, we should focus on shading and avoid direct radiation, ventilation and heat dissipation in summer, and then consider the problem of insulation in winter in terms of materials.

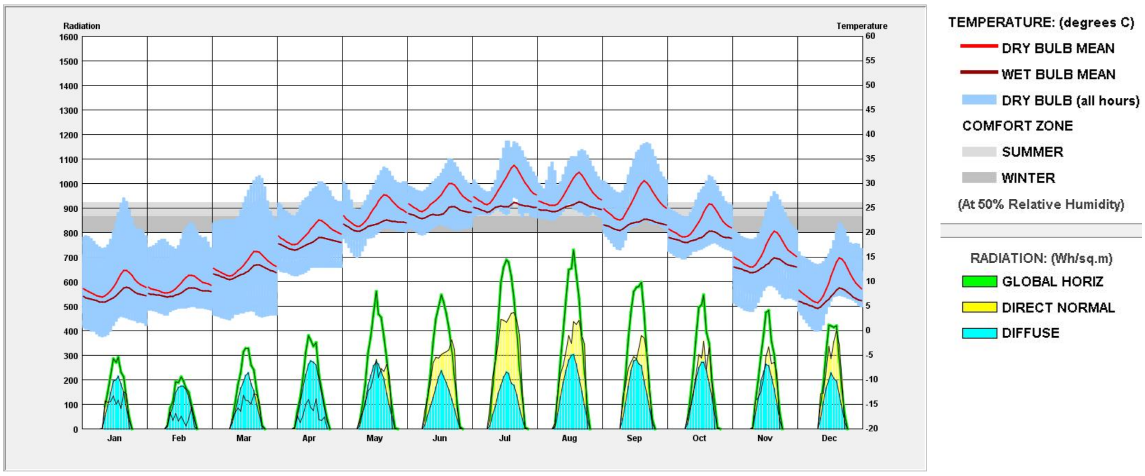


Figure 40 Monthly diurnal average chart (Source: Climate consultant 6.0)

The psychrometric chart indicates that only 8.8% of the hours in the year meet the comfort criteria while almost 1/3 of the time needs active cooling and dehumidification. In winter which is 22% hours of the year, there is a need of active heating. It also indicates that for about 40% of the hours, the comfort conditions can be improved using bio-climatic design strategies.

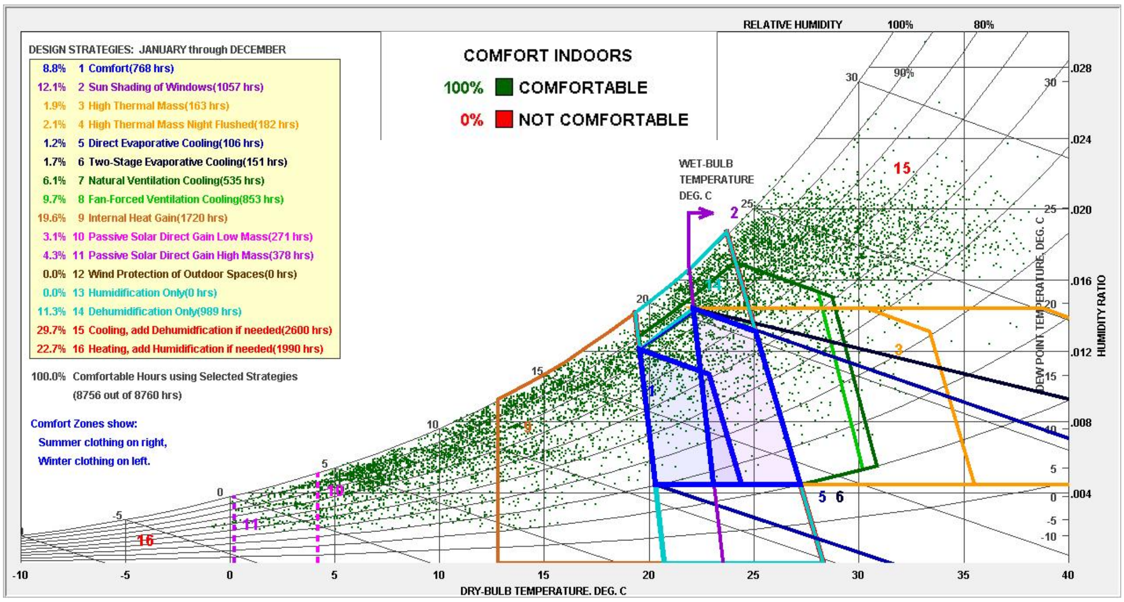


Figure 41 Psychrometric chart and corresponding strategy
(Source: Climate consultant 6.0)

In summary, Ganzhou has hot, oppressive, humid, and cloudy summers and short, cold, and mostly clear winters. Outdoor venues need to strengthen shading, and indoor environment should pay attention to shading and ventilation on the basis of paying attention to sunlight.

4.1.2 Wind analysis and CFD distribution parameter calculation of the building clusters

From the climatic data in energy plus of Jiangxi province, Ganzhou, more than half of year the average wind velocity is lower than 2m/s, and the speed does not exceed 9m/s. In spring and autumn, the wind is mild and shows a uniformed air pressure, while in summer there are strong ones performed in south-west and east reach over 6m/s. Therefore, we could have the conclusion that nature ventilation could meet the comfort need thought out a year, especially in summer the wind velocity shows a good performance in terms of outdoor ventilation.

According to the Standard for green performance calculation of civil buildings JGJT 449-2018, summer prevailing wind in Ganzhou is south-west in 2.5m/s, and winter prevailing wind is in north-east in the speed of 2.4m/s.

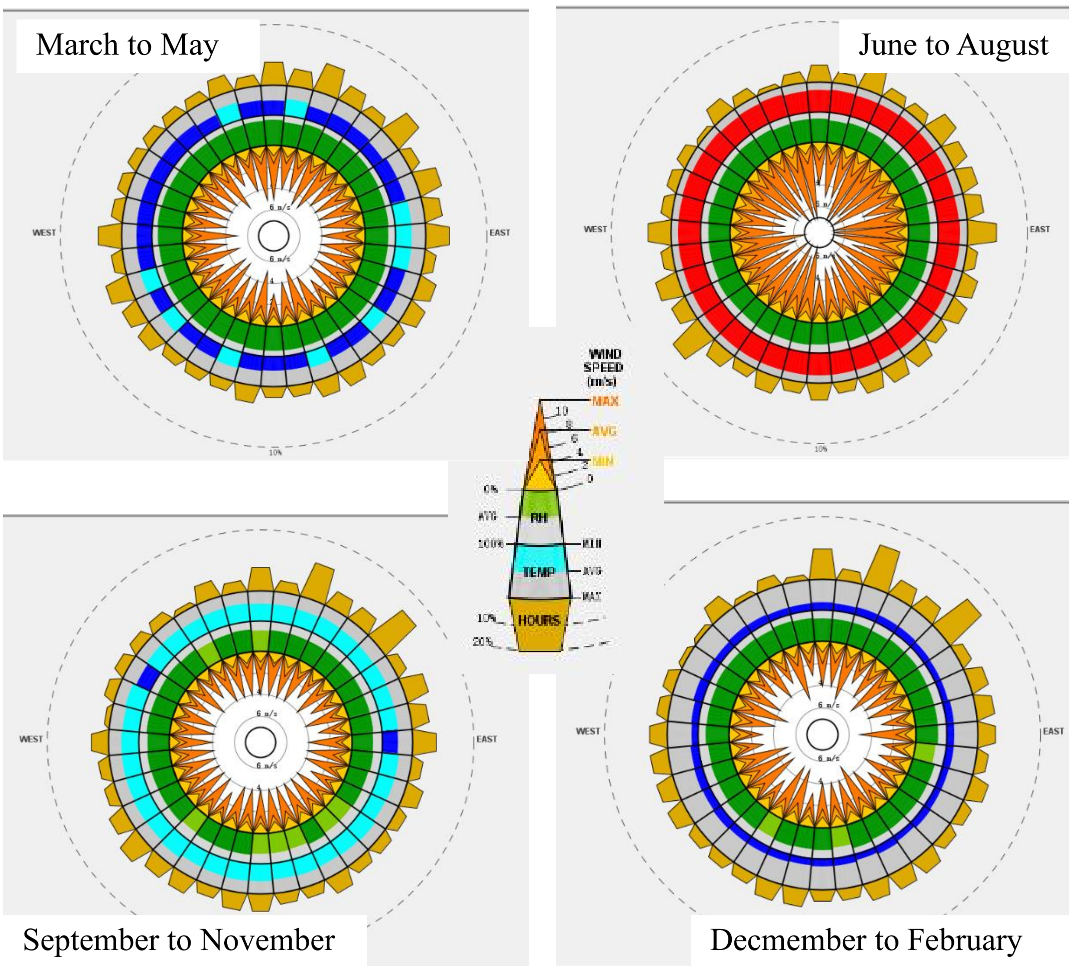


Figure 42 Wind wheel (Source: Climate consultant 6.0)

For determining the prevailing wind in summer, we use southwest and east direction as the inlet. The stimulation program Rhino CFD helps us understand how the airflow is in the specific terrain and the scale of the velocity and the directions. From the stimulation results, we have the conclusion that when the prevailing wind is in southwest direction, the inlet side of the library has affected by the surrounding buildings and Pagoda to velocity around 3.3 m/s while the leeward side almost no wind. While for east prevailing wind, the inlet side which is the elevation of the façade, the wind velocity increases a bit and showing an upward trend, there is a slight influence in the north where there are two higher buildings block the wind. Therefore, the ventilation outdoor of the library shows a good condition, the openings are almost orthogonal to the two prevailing wind direction and have little effect by the surrounding.

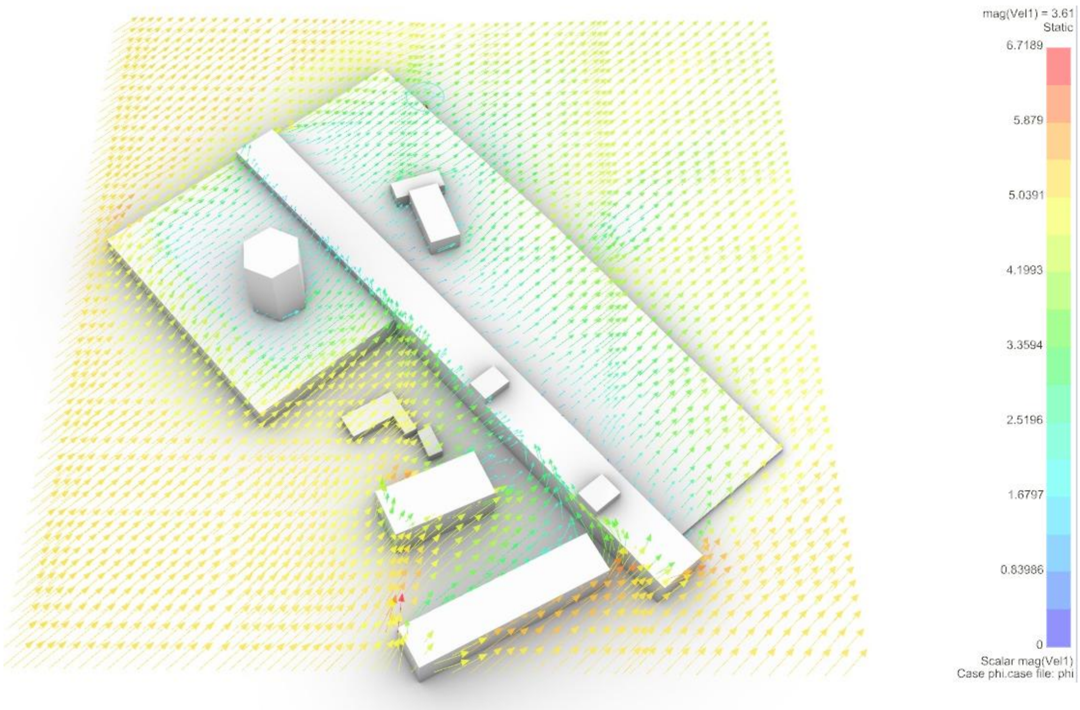


Figure 43 CFD Simulation-southwest prevailing wind in summer (Elaboration by author)

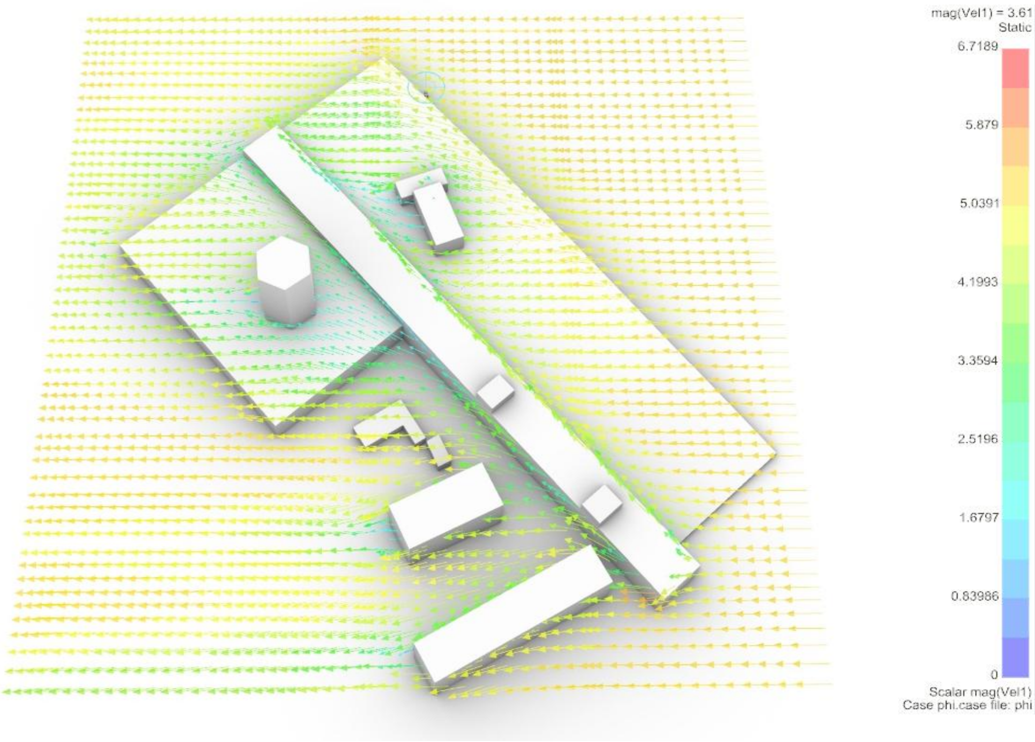


Figure 44 CFD Simulation-east prevailing wind in summer (Elaboration by author)

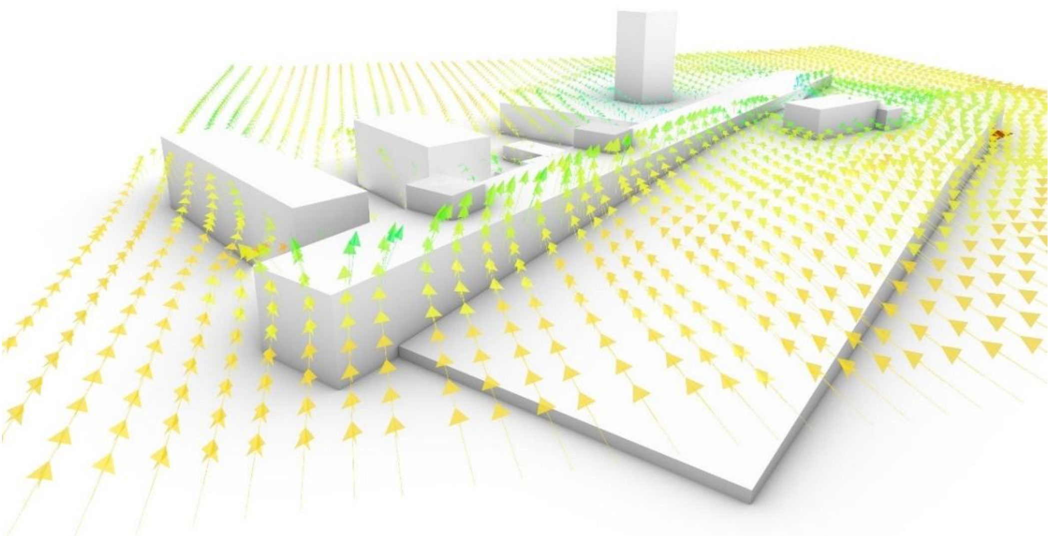


Figure 45 Simulation-southwest prevailing wind in summer (Elaboration by author)

4.1.3 Shading analysis of the site and after intervention

Ganzhou is located in a mountainous area. The terrain of the site is relatively undulating and can reach a height difference of about 6 m. The Ciyun pagoda with the old building areas to the north are 5 m higher than the buildings of Houde Road and the government family residential buildings to the south. The Confucian Temple complex is also on a higher level.

Through the simulations (Software: Ecotect), we analyzed the shading during the effective illumination time of the sun on the day 21st of the four seasons and made a comparison before and after the refurbishment. On the whole, the shadow projections in spring and autumn is east-west, slightly leaning to south in summer, and relatively north in winter. The crowded courtyard housing provides shading in summer, and the shadows cast by the high-rise areas in the north have not much effect on the site, but it casts shadows on the facade buildings along Houde Road. In summer, because the tower provides a certain level of shading for the school in the square of Ciyun pagoda, the north façade of the school does not receive sufficient sunlight due to the reduction of solar radiation in winter. After the reorganization and use of the site, the school was opened and provide more distance between the buildings. Solar panels will be installed at the south half of the newly added library roof top to provide green energy for the building. The maze as the transitional area in the north also undergoes no direct sunlight which is suitable as an outdoor resting area.

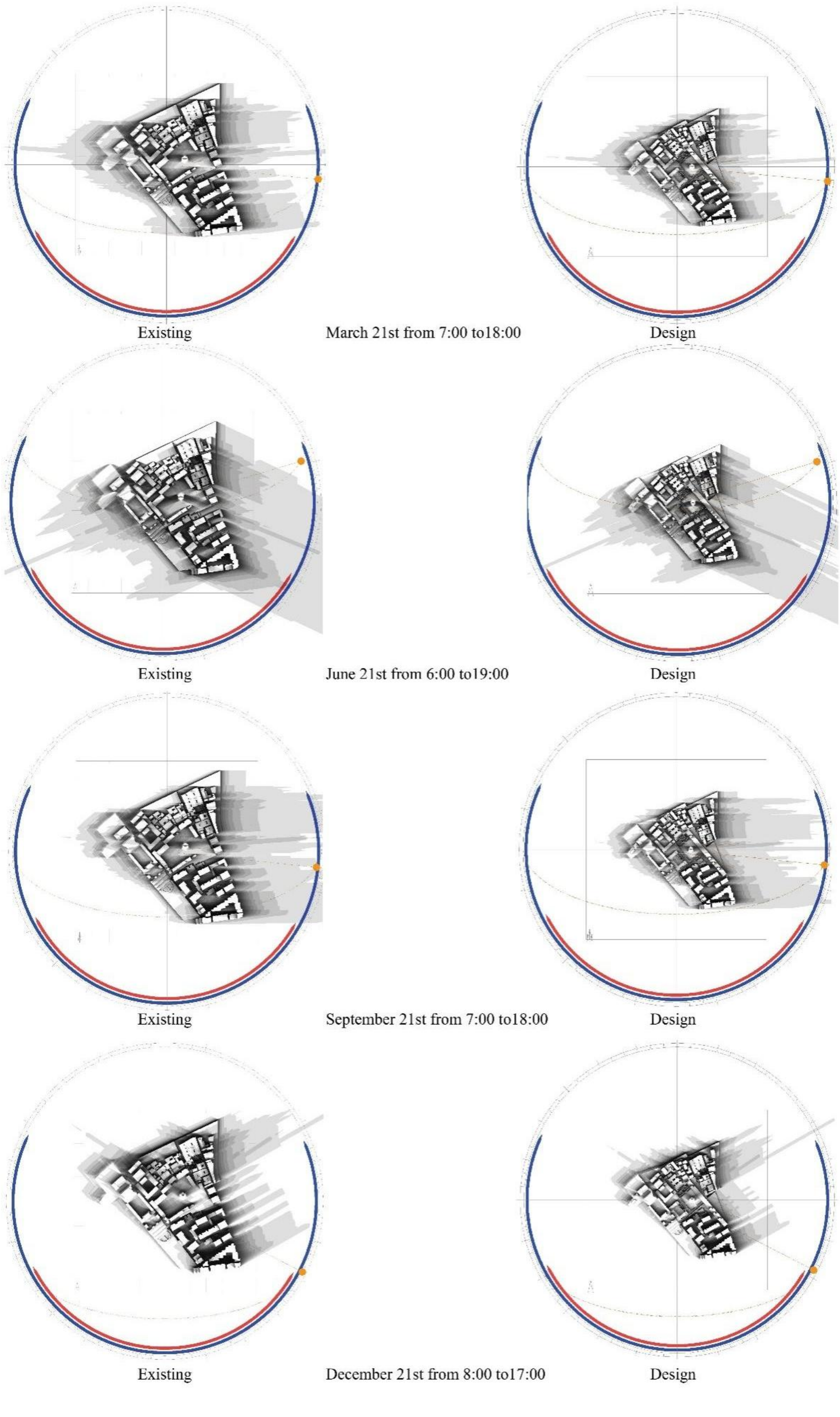


Figure 46 Comparison of sunlight on the current and the design site (Elaboration by author)

Then, in order to understand more focusing point shading situation, few points in the square of Ciyun pagoda and on the façade of the existing buildings and new library, are studied and reflected by stereographic diagram where we could see the direction and time period of the shading. Also, another diagram is for understanding the solar stress with the distribution of direct radiation.

Firstly, we exam 7 points in the piazza of pagoda because as the open public space of most essential historical element, analyzing the shading situation helps defining new outdoor activities. Point 1-4 are where the new library will be, they were in the range of the shadow of pagoda, therefore is shaded in spring and autumn afternoon and the also solar stress diagram shows that there is no direct sunlight. Point 5 is the current gate to the square from Wen temple and this area is largely effects by surround buildings in the morning and late afternoon. Point 6 and 7 as the representative of the west half of the square, there is not much shading effected by the pagoda.

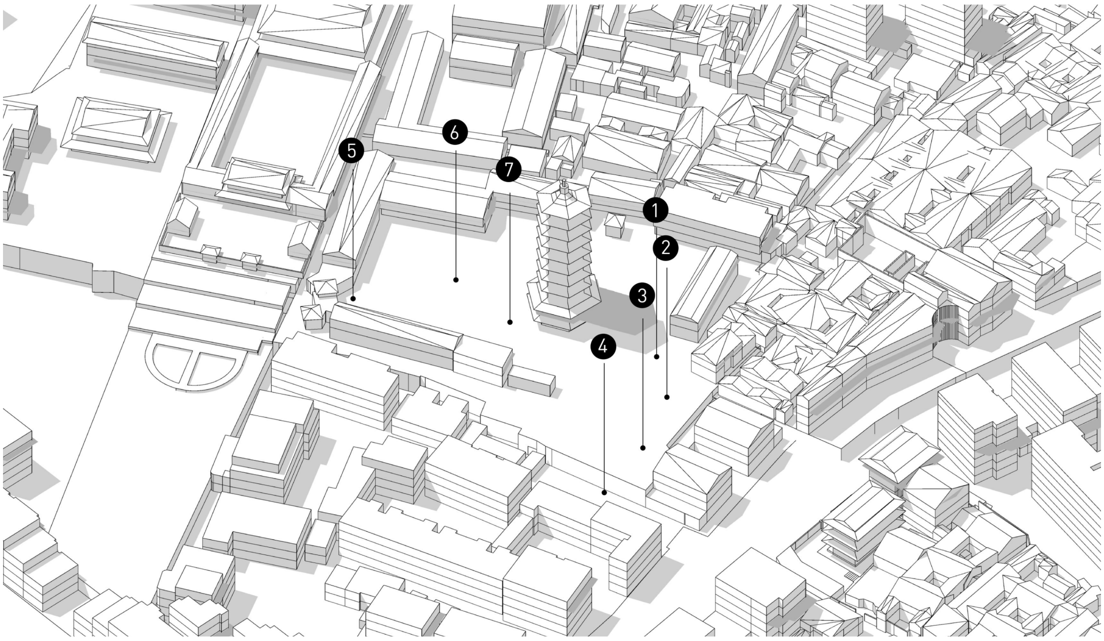
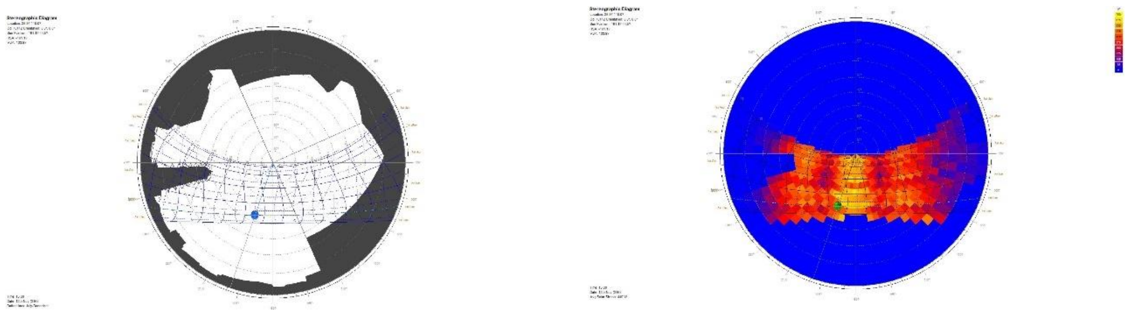
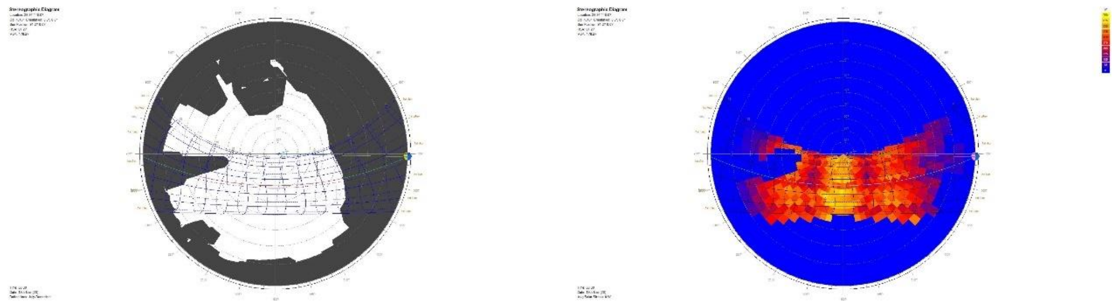


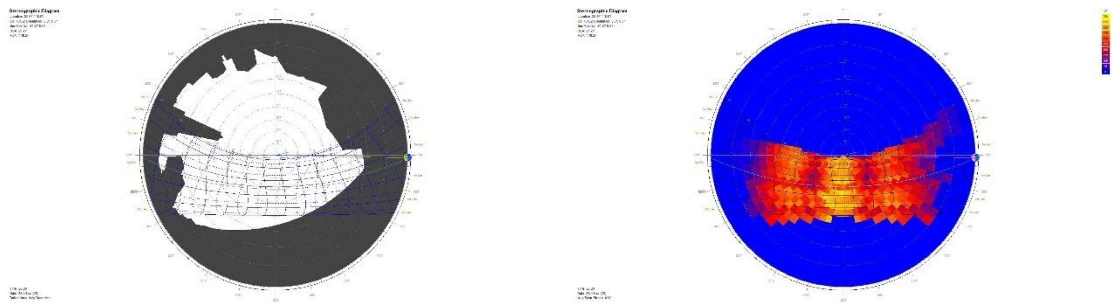
Figure 47 Key map of the shading mask of the points in the square (Elaboration by author)



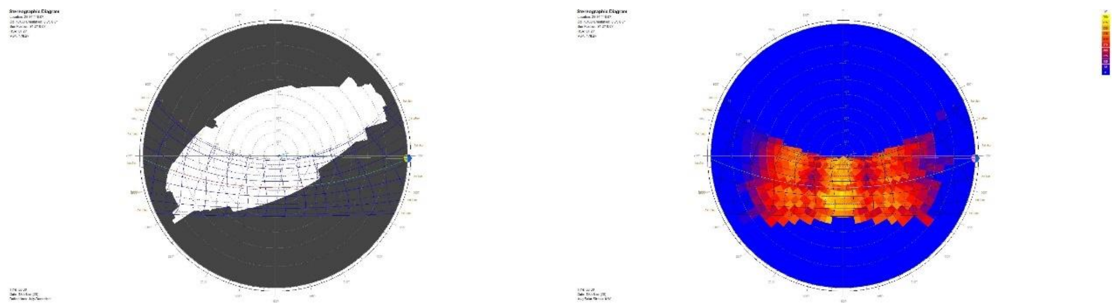
Point one



Point two

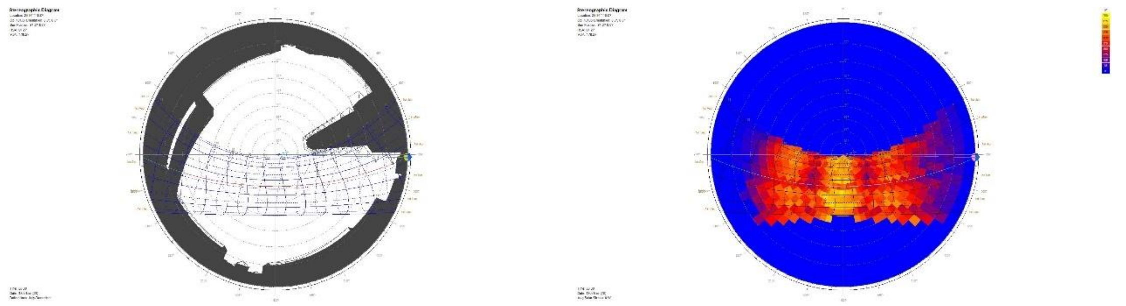


Point three

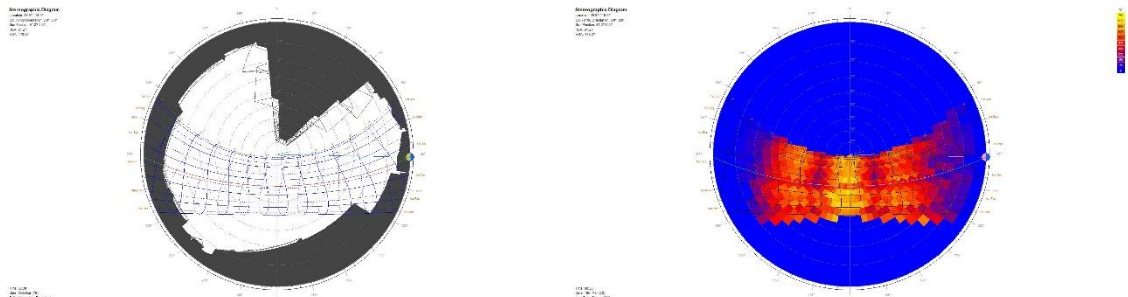


Point four

Point five



Point six



Point Seven

Figure 48 Shading and solar stress mask of seven points (Elaboration by author)

Secondly, the façade of the classrooms is stimulated for the south sides shaded due to the presence of the cantilever upper floor. Pagoda has a great effect on point 2 and 4. On the other side, the point number 5 does receive much effect from pagoda, point 6 is highly shaded in the afternoon.

The façades along the Houde road are toward north-east side, from the stereographic diagram, there is shading during the afternoon and noon in the winter and before 8:00 is mostly shaded. The situation grows better toward south buildings.

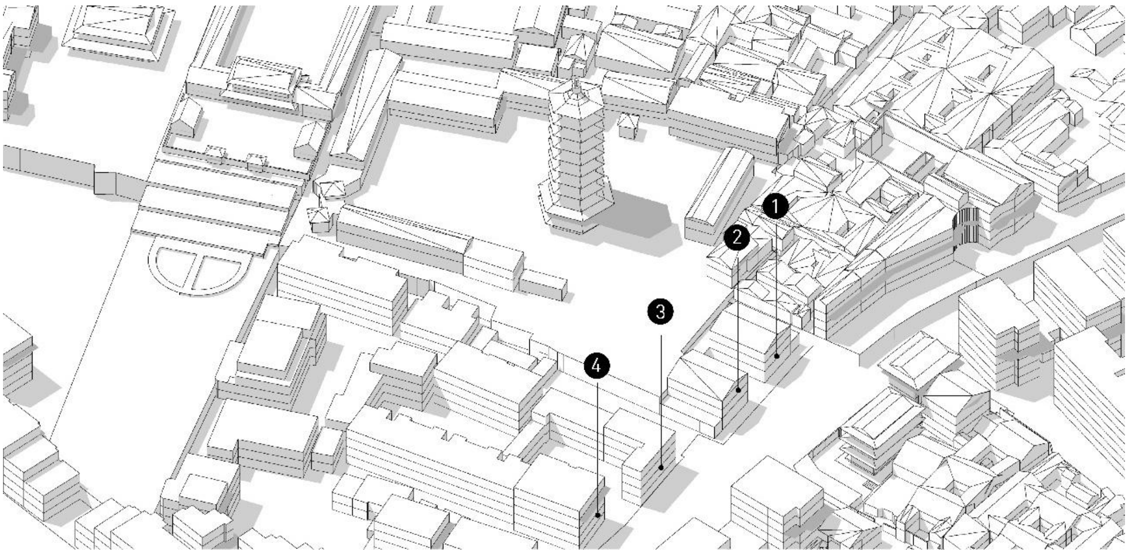
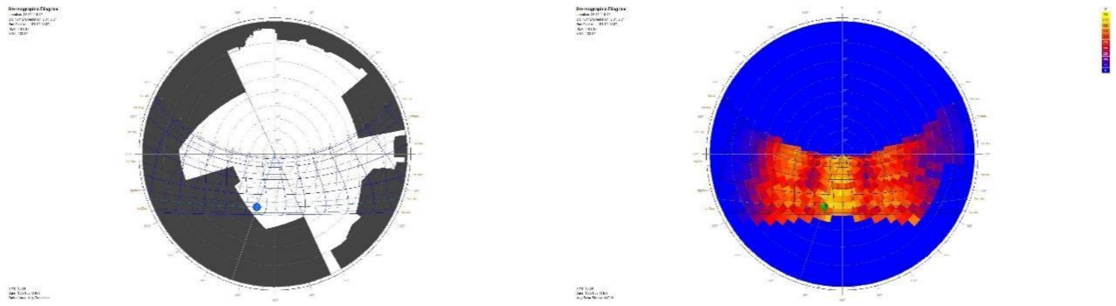


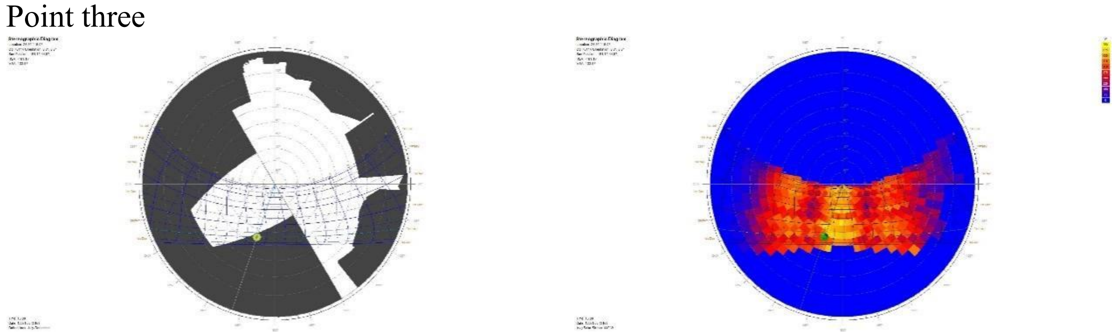
Figure 49 Shading and solar stress mask of six points on school façade (Elaboration by author)

Point one



Point two

Point three



Point four

Figure 50 Shading and solar stress mask of six points on building façade of Houde street (Elaboration by author)

Based on the research of the above three groups, as well as the analysis of the site and history, we have transformed and reorganized the place. The school has changed from being scattered around the Ciyun Pagoda to being concentrated at the west end, and the public passage has been opened, the old building complex in the north has also been reorganized.

First, we tested the southwest façade of the library. There are four floor-to-ceiling windows in the south section corresponding to the stairwell, bringing sunlight into the interior. According to the diagram, from March to October from 8:00 to 11:00, there are shadows from the surrounding buildings from 13:00-15:00. In addition, there is direct sunlight. The time with the most radiation is around 11:00 in October. The highest average amount could exceed 750 W, and the lower the floor, the shorter the direct exposure time. Point 4 is more affected by shadows. In winter, there are shadows at 10:00, and in summer, there is no direct sunlight after 17:00. The main influence of points 5-8 comes from Ciyun Pagoda. The farther north, the less shadow and the tendency to move from afternoon to noon. As shown in solar stress figure, the position of point 8 is sometimes without direct sunlight. Therefore, a natural shading is formed for the interior. The location of point 9 is where the labyrinth and the exit of the library meet. The sunshine time is relatively short, so the surface temperature will be cooler than other points on the facade.

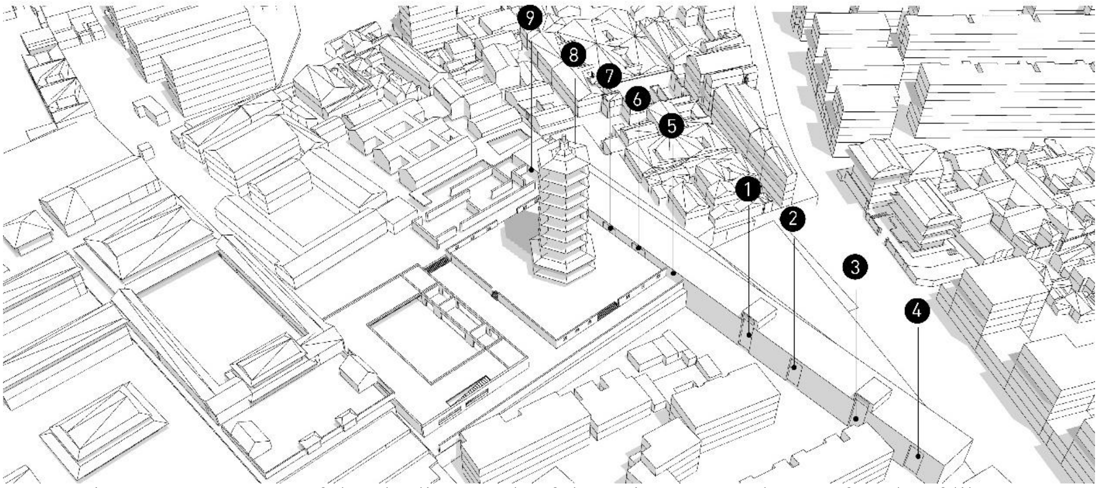
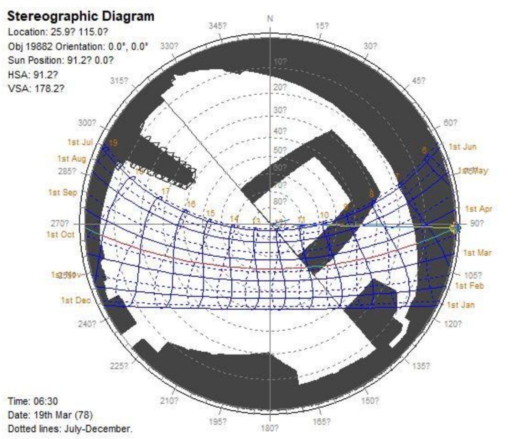
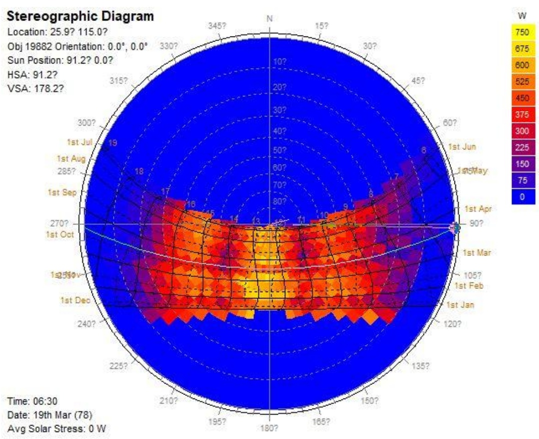
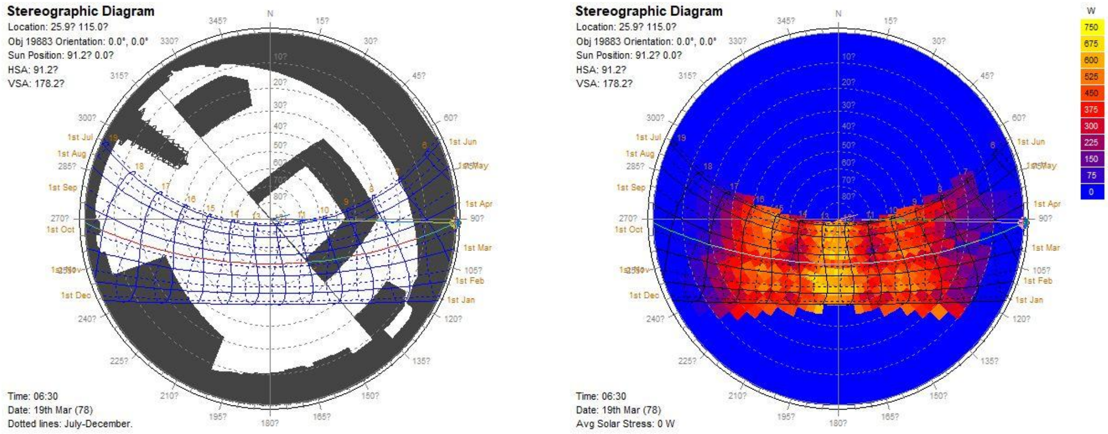


Figure 51 Key map of the shading mask of the points on south west façade of library
(Elaboration by author)

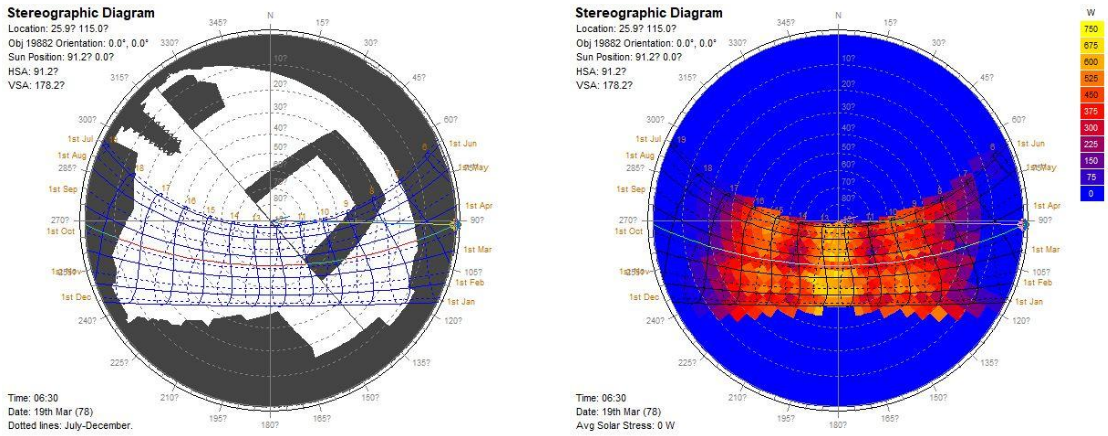




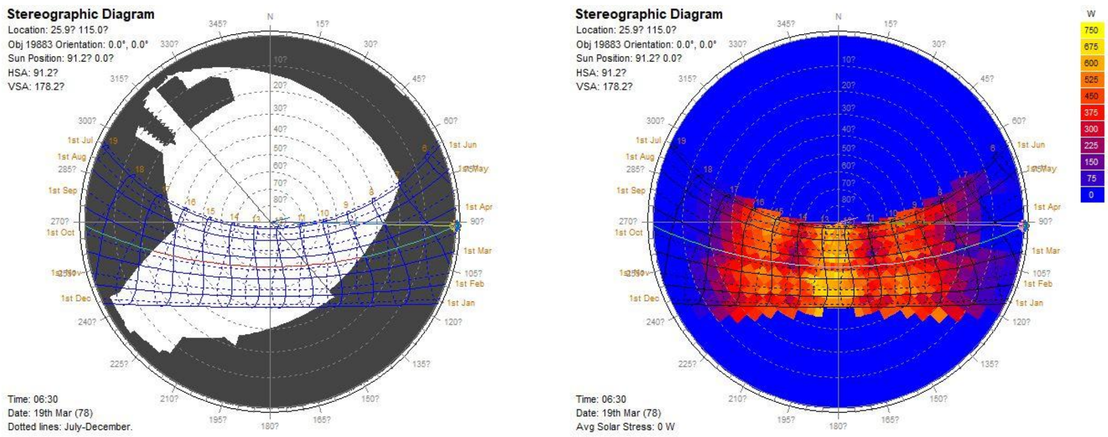
Point one



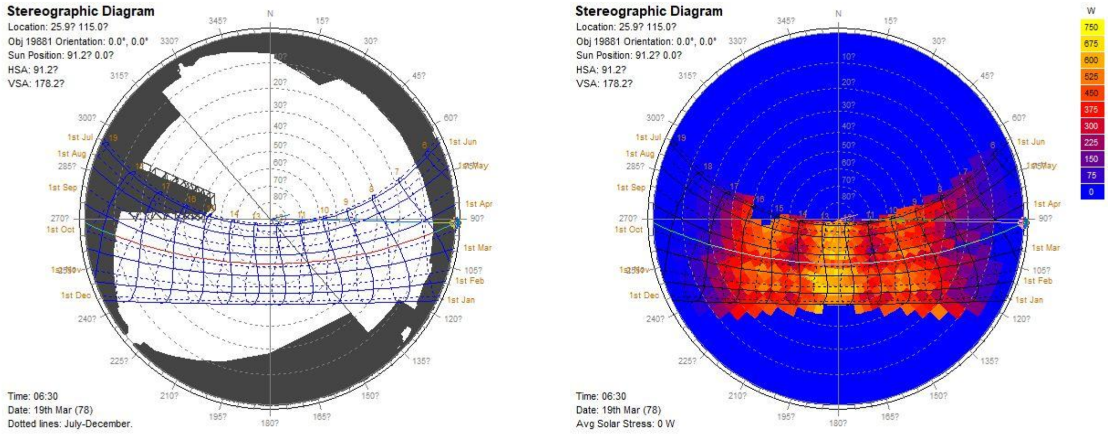
Point two



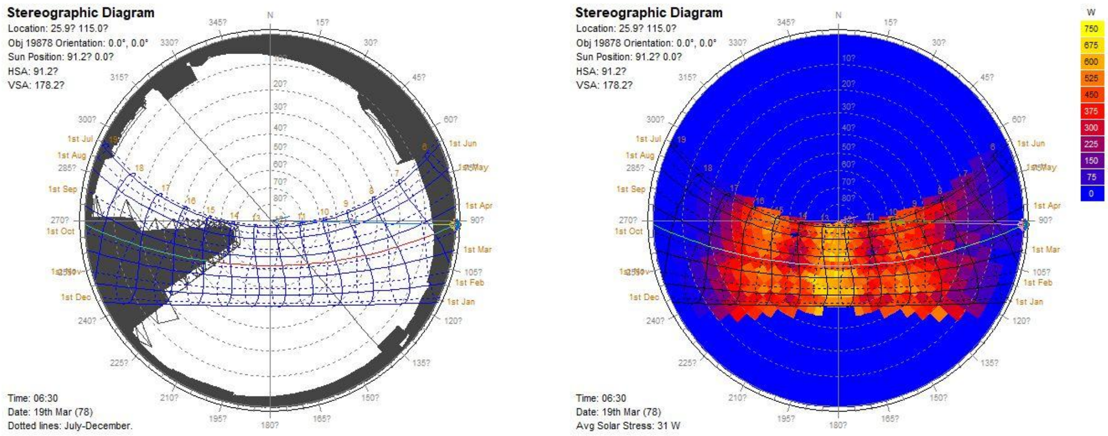
Point three



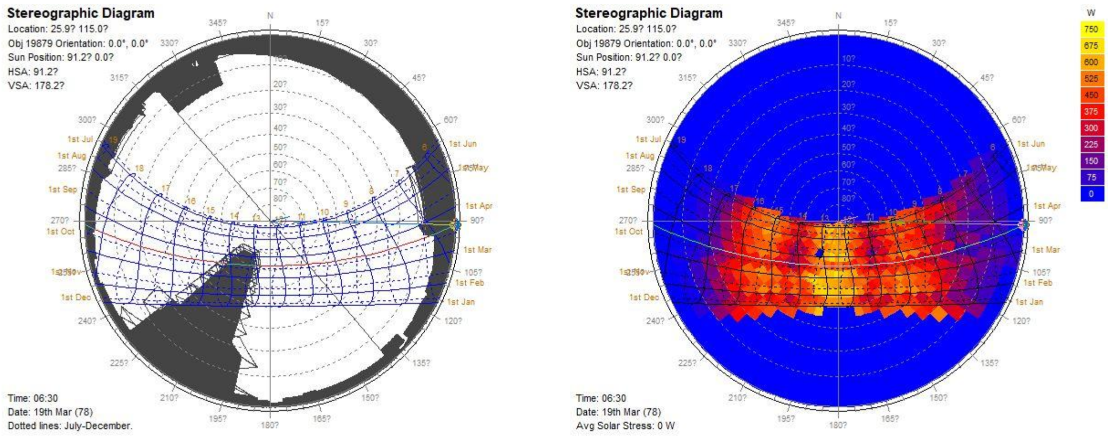
Point four



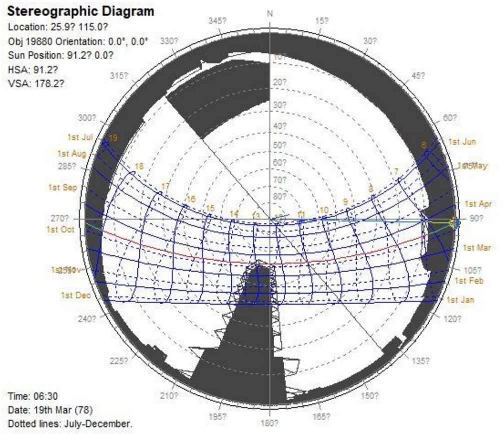
Point five

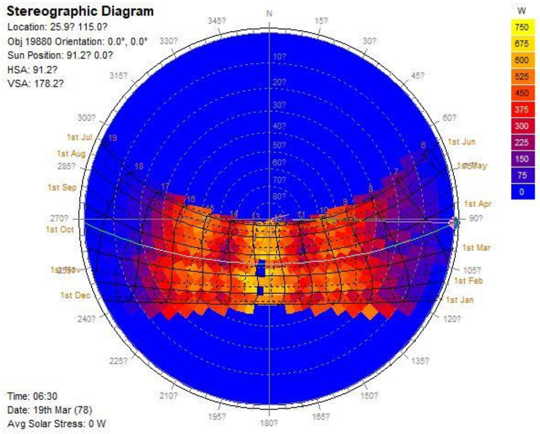


Point six

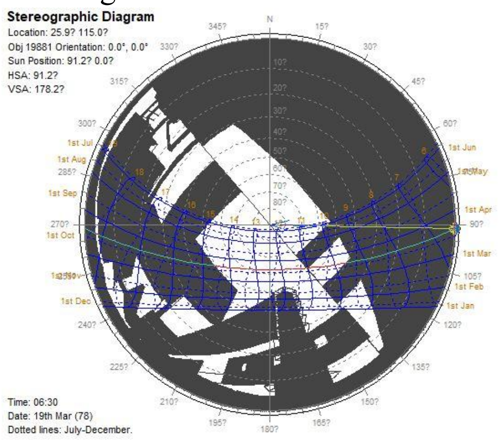


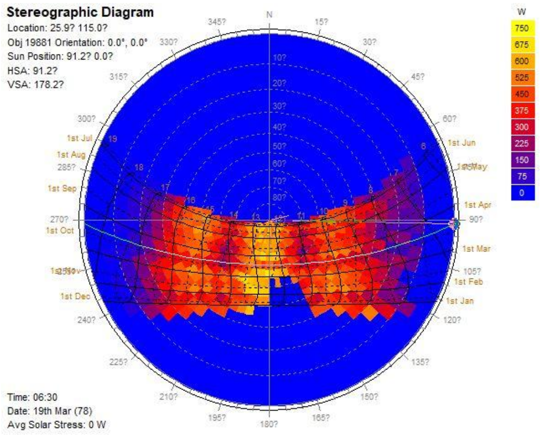
Point seven





Point eight





Point nin

Figure 52 Shading and solar stress mask of six points on building façade of Houde street (Elaboration by author)

The new school adopts a semi-enclosed configuration, due to the presence of the protruding walkable roof, the inner façades on the west and south sides generate shading in the morning at around 8:00 and 9:00, respectively. At 13:00 in the afternoon in winter, the amount of direct sunlight is also reduced. The exterior facades to the north and south of the new school have adequate daylight hours.

4.2 Building envelope material and thermal performance

4.2.1 Principles of building material selection

The production and utilisation of building materials is an important aspect of energy consumption in the construction process. Green building materials should have the following characteristics: for the production of raw materials, the waste should be used instead of non-renewable natural resources as far as possible; low energy consumption manufacturing process; recyclable; excellent durability to extend the life of the building.

Ganzhou is located in a subtropical monsoon climate zone with hot and humid summers, so in addition to energy efficiency and environmental protection, the choice of building materials should also take into account thermal insulation and ventilation.

The main support structure (foundations, beams and columns) of the new library is steel structure. Compared to concrete structures, steel is more energy-saving and environmentally friendly. As the steel structure can be prefabricated in the factory and assembled on site, the construction period is saved, as the construction is less affected by the weather environment. During construction, the amount of sand, stone and ash can be greatly reduced. After the building is abandoned, the recycling rate of steel is much higher than that of concrete.

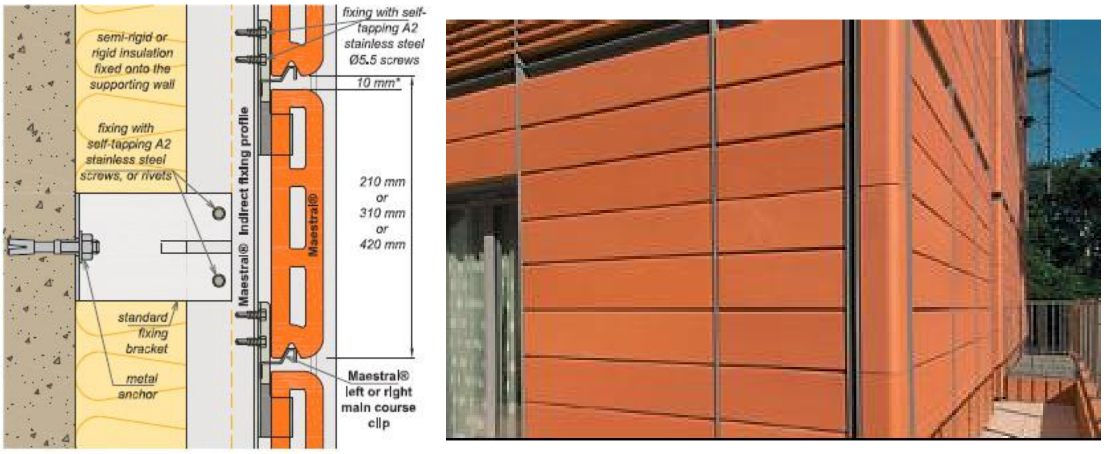


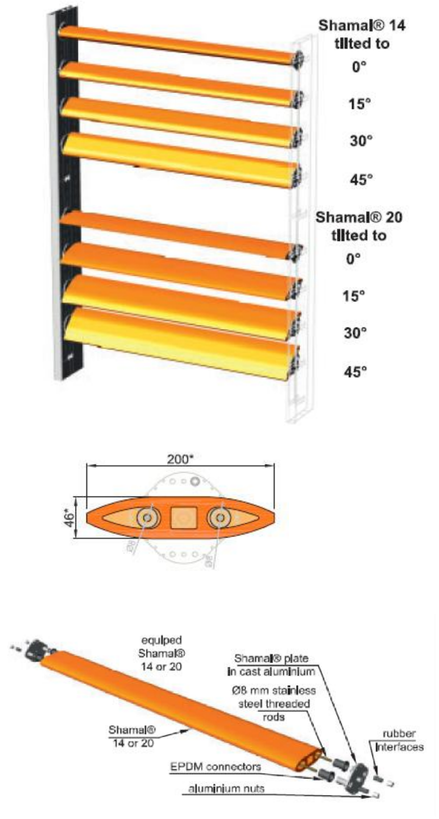
Figure 53 Terracotta panel facade style (Source:www.terreal.com)

The external wall is made up of a double-layered terracotta panel curtain wall system.It has an internal cavity which provides better thermal and acoustic insulation and is lighter in weight than traditional façade materials. The open curtain wall system also contributes to ventilation and drainage.Flame retardancy can reach class A.The internal wall materials are ALC precast concrete panels and EPS insulation.

A large green roof has been installed on the roof of the library. With the high rainfall in Ganzhou, the green roof will filter rainwater, alleviate urban flooding and reduce the urban heat island effect.To reduce the building load, the roof is mainly considered to be planted with low shrubs and lawns, keeping the soil thickness of the roof to 450 mm or less.

The interior floor and ceiling are supported by steel and timber surfaces, seeking to reduce the use of concrete materials. EPS insulation is provided internally. The interior decorative surfaces are in light coloured timber and metal.

To increase natural ventilation and lighting, a large number of windows have been provided on the external walls and roof of the library. To reduce energy consumption for air conditioning and cooling in summer, Triple insulated LOW-E glass was chosen for the external window. The west-facing exterior windows are equipped with rotatable terracotta panel shading louvers on the outside to reduce heat radiation in summer.



		Centres between sunscreen	100 mm	200 mm	300 mm	500 mm
Shaded area in % of the area of the bay (other than that masked by lintels and reveals)	Sunscreen inclined at 0°	Sun at 0° Height of shade 46 mm	46 %	23 %	15 %	9 %
		Sun at 45° Height of shade 150 mm	100 %	75 %	50 %	30 %
	Sunscreen inclined at 15°	Sun at 0° Height of shade 64 mm	64 %	32 %	21 %	13 %
		Sun at 45° Height of shade 179 mm	100 %	90 %	60 %	36 %
	Sunscreen inclined at 30°	Sun at 0° Height of shade 84 mm	84 %	42 %	28 %	17 %
		Sun at 45° Height of shade 195 mm	100 %	98 %	65 %	39 %
	Sunscreen inclined at 45°	Sun at 0° Height of shade 106 mm	100 %	53 %	35 %	21 %
		Sun at 45° Height of shade 198 mm	100 %	99 %	66 %	40 %

Figure 54 Reference of rotatable terracotta panel blackout louvres(Source:www.terreal.com)

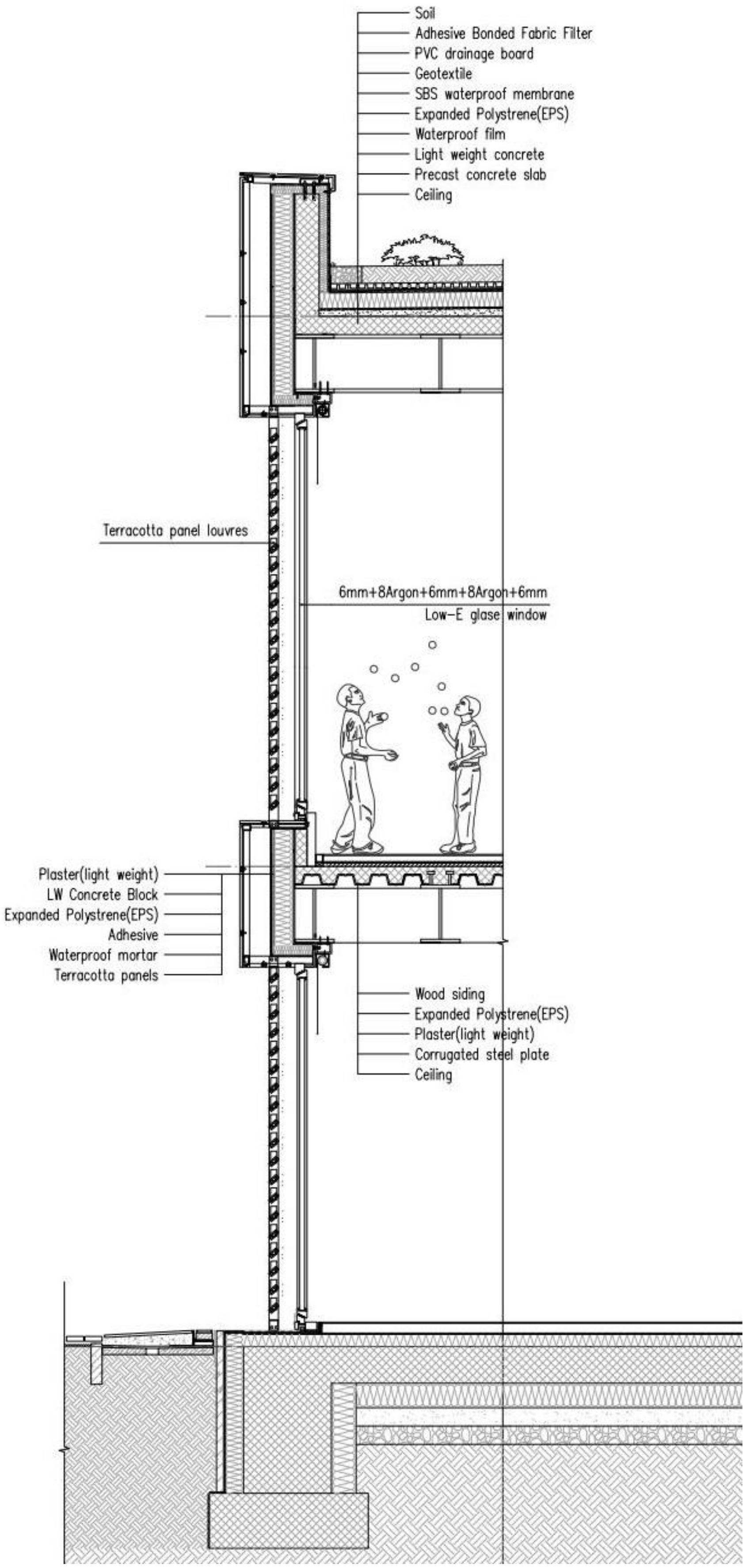


Figure 55 Detail of the wall on the west side of the building（Scale 1:50）(Elaboration by author)

4.2.2 Thermal performance of building envelope structures

Ganzhou is located in Jiangxi Province, China. It has a subtropical monsoon climate. The thermos-climatic zoning is hot in summer and cold in winter (zone B). The climate of this region is characterised by hot and muggy summers, wet and cold winters and high annual rainfall.

Buildings in this zone must meet the requirements for heat protection and ventilation and cooling in summer, with appropriate consideration given to cold protection in winter. Buildings should be designed to facilitate good natural ventilation and to avoid western sunlight.

China's national standard,*Design standard for energy efficiency of public buildings (GB50189-2015)*,specifies the heat transfer coefficients for each part of the building, as detailed in the table below.[29]

Envelope structures		Heat transfer coefficient K [W/(m^2·K)]	Solar heat gain coefficient SHGC (East, South, West/North)
Roof	Thermal inertia indicators D≤2.5	≤0.4	
	Thermal inertia indicators D＞2.5	≤0.5	
External wall	Thermal inertia indicators D≤2.5	≤0.6	
	Thermal inertia indicators D＞2.5	≤0.8	
Elevated floor slabs		≤0.7	
Exterior window	Window/wall≤0.2	≤3.5	
	0.2＜Window/wall≤0.3	≤3.0	≤0.44/0.48
	0.3＜Window/wall≤0.4	≤2.6	≤0.40/0.44
	0.4＜Window/wall≤0.5	≤2.4	≤0.35/0.40
	0.5＜Window/wall≤0.6	≤2.2	≤0.35/0.40
	0.6＜Window/wall≤0.7	≤2.2	≤0.30/0.35
	0.7＜Window/wall≤0.8	≤2.0	≤0.26/0.35
	Window/wall＞0.8	≤1.8	≤0.24/0.30
Skylight		≤2.6	≤0.30

Table 9 Heat transfer coefficient limits for building envelope under different conditions
Source:Design standard for energy efficiency of public buildings (GB50189-2015)

(1) External wall

The external wall is a vitrified clay panel curtain wall system lined with 150mm thick EPS insulation panels and the main infill structure is concrete block.The final calculated heat transfer coefficient U= 0.214,meets the standard value≤0.6.

[29] Ministry of Housing and Urban-Rural Development of the people’s republic of China, Design standard for energy efficiency of public buildings

U Value Calculation (d_{wall}=0.43m)							
External wall	LAYER DESCRIPTION (from inside to outside)		d		C	R	U_K
			m	W/mK	W/m^{2}K	m^{2}K/W	W/m^{2}K
	Internal thermal resistance ($1/h_i$)						
1	Inside surface	Plaster(light weight)	0.02	0.18	9	0.11	
2	Structure	LW Concrete Block	0.2	0.5	2.5	0.40	
3	Screed coat	Plaster(light weight)	0.01	0.18	18	0.06	
4	Thermal insulation layer	Expanded Polystyrene(EPS)	0.15	0.04	0.27	3.75	
		Adhesive	0.0005				
5	Waterproof layer	Waterproof mortar	0.02	0.93	46.50	0.02	
6	Finishing layer	Terracotta panels	0.03	0.087	2.9	0.34	
	External thermal resistance ($1/h_e$)					0.04(W)/0.05(S)	
	Gross layer and U_K		**0.43**			**4.68**	**0.214**

Table 10 External wall heat transfer coefficient calculations (Elaboration by author)

(2) External roof(Garden roof)

The roof is a green roof with a planting soil thickness of 300mm, a drainage layer at the bottom, a filter layer, a waterproofing layer, EPS insulation panels with a thickness of 100mm and a prefabricated concrete slab as the main body of the structure.The final calculated heat transfer coefficient U= 0.229,meets the standard value≤0.4.

U Value Calculation (d_{roof}=0.70m)							
Roof Garden	LAYER DESCRIPTION (from inside to outside)		*d*		*C*	*R*	U_K
			m	W/mK	W/m²K	m²K/W	W/m² K
	Internal thermal resistance ($1/h_i$)					0.11	
1	Inside surface	Ceiling	0.001				
2	Structure	Precast concrete slab	0.2	1.4	7	0.14	
3	Slope layer	Light weight concrete	0.02	0.53	26.5	0.04	
4	Vapour barrier	Waterproof film	0.001				
5	Thermal insulation layer	Expanded Polystrene(EPS)	0.1	0.04	0.40	2.50	
6	Waterproof layer	SBS waterproof membrane	0.004	0.32	80.00	0.01	
7	Protective layer	Geotextile	0.001				
8	Drainage	PVC drainage board	0.05	0.048	0.96	1.04	
9	Filter	Adhesive Bonded Fabric Filter	0.004				
10	Vegetation & soil layer	Soil	0.3	0.47	1.57	0.64	
	External thermal resistance ($1/h_e$)					0.04(W)/0.05(S)	
	Gross layer and U_K		**0.68**			**4.37**	**0.229**

Table 11 Roof Garden heat transfer coefficient calculations (Elaboration by author)

(3) Internal floor

The interior floor slabs are mainly made of wood with insulation and Corrugated steel plate at the bottom.

U Value Calculation (d_{roof}=0.11m)							
Internal Floor	LAYER DESCRIPTION (from inside to outside)		*d*		*C*	*R*	U_K
			m	W/mK	W/m²K	m²K/W	W/m²K
	Internal thermal resistance ($1/h_i$)					0.11	
1	Inside surface	Wood siding	0.03	0.09	3	0.33	
2	Sound insulation layer	Expanded Polystrene(EPS)	0.03	0.04	1.33	0.75	
3	Screed coat	Plaster(light weight)	0.03	0.18	6	0.17	
4	Structure	Corrugated steel plate	0.01				
5	Surface layer	Ceiling	0.01				
	External thermal resistance ($1/h_e$)					0.04(W)/0.05(S)	
	Gross layer and U_K		**0.11**			**1.25**	**0.800**

Table 12 Internal Floor heat transfer coefficient calculations (Elaboration by author)

(4)Exterior window

To ensure thermal insulation in summer, Triple insulated LOW-E glass was chosen for the exterior window.To prevent excessive absorption of solar radiation, SHGC values≤0.35,U≤1.3.

Thickness	Solar energy		SHGC	*U*
6mm+8Argon+6mm+8Argon+6mm	Reflectance	UV-Transmitance	**0.35**	**1.3**
	22%	19		

Table 13 Heat transfer coefficients and solar heat gain coefficients for external windows (Elaboration by author)

4.3 Evaluation of the building energy performance

4.3.1 Main information of the focus building

The building is located on the east side of the site and is arranged along a north-south orientation. The angle with the north-facing axis is 41°. The building is 9 m in height and has a total of two floors. The floor area is 2994 ㎡ and volume is 14,500 m^3, total building surface area is 4539 ㎡. Therefore, the shape factor S/V is 0.32.

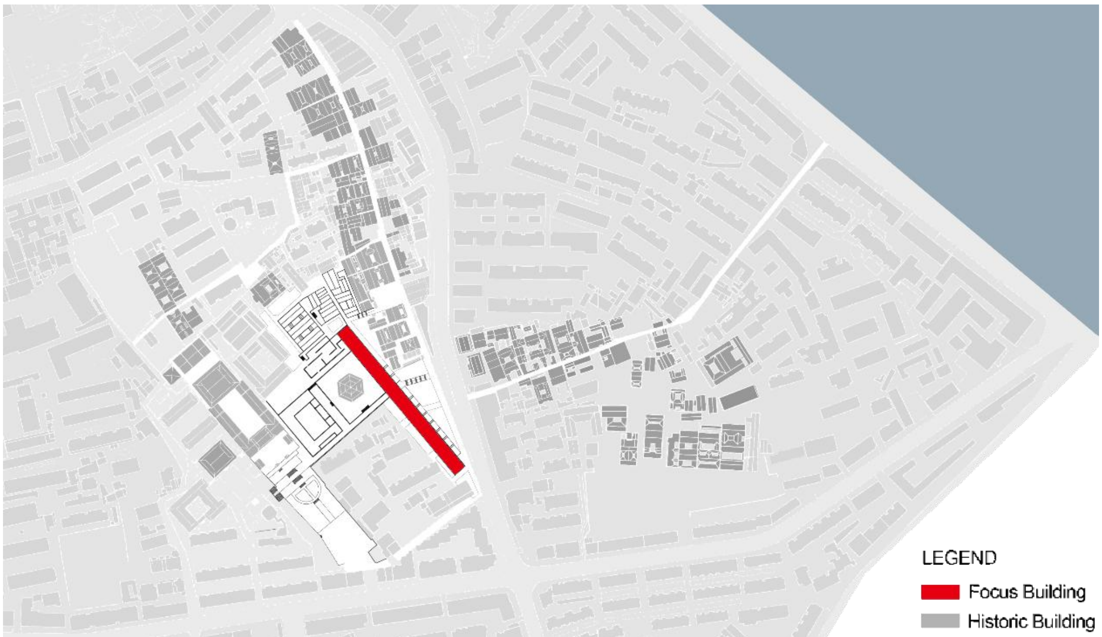


Figure 56 The location diagram of focus building(Elaboration by author)

The main functions of the building are the library and the exhibition. We have divided the building into two thermal divisions according to function, with a reading area on the ground floor and an exhibition area on the first floor.

4.3.2Building Energy Consumption Simulation for heating and cooling

After the thermal zoning had been defined, the energy consumption of the building was calculated using BESTenergy software. Materials and heat transfer coefficients for building envelope structures refer to the calculations in section 4.1.2.

External wall U-value = 0.214W/(m^2 K);

Interior floor U-value = 0.80 W/(m^2 K);

Roof U-value = 0.229 W/(m^2 K);

Exterior window U-value = 0.13 W/(m^2 K);

Exterior window Solar Heat Gain Coefficient = 0.35

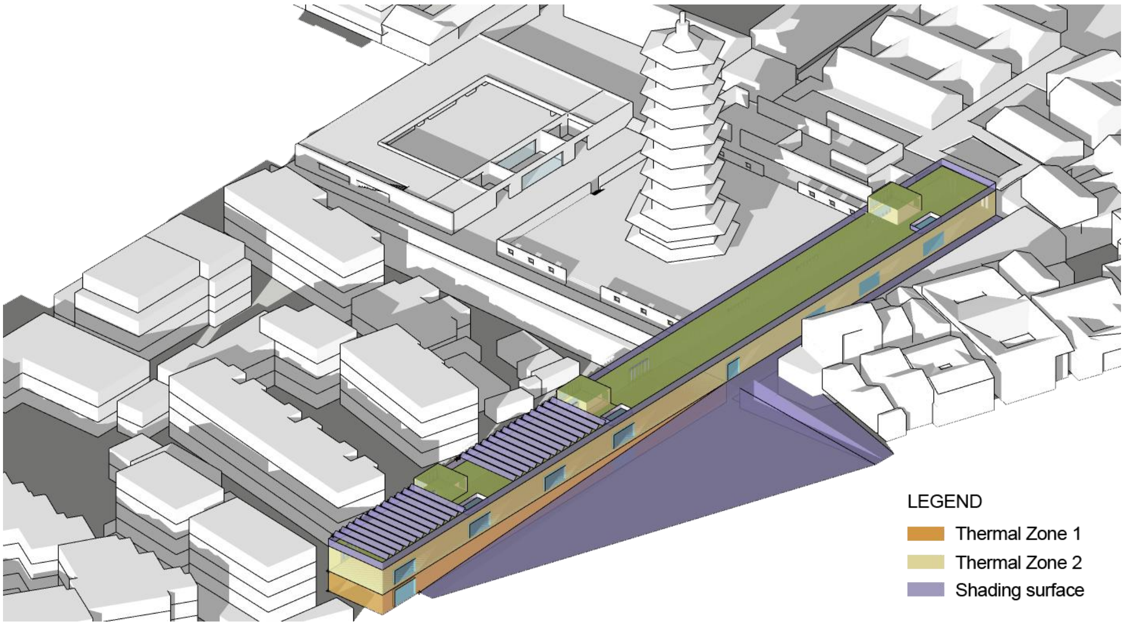


Figure 57 Diagram of building thermal zoning(Elaboration by author)

For the ground floor, we define it as reading space, it has a usable area of approximately 700 m^2 and, based on the seating capacity, the number of people is approximately 65, so the people occupancy rate is approximately 0.1, the electric equipment thermal load is 14.0 W/m^2 (according to Table 17 Electricity loads). For the first floor, we define it as commercial and exhibition space, the people occupancy rate is 0.1, the electric equipment thermal load is 4.6 W/m^2 (according to Table 17 Electricity loads). The ventilation airflow rate is 0.8 V/h. The heating point temperature schedule is 20 °C, and the cooling setting schedule is 26 °C.[30]

[30] General Office of the State Council,*"General Office of the State Council on Strict Enforcement of Notice on the Standard of Air Conditioning Temperature Control in Public Buildings", June 01,2007.*

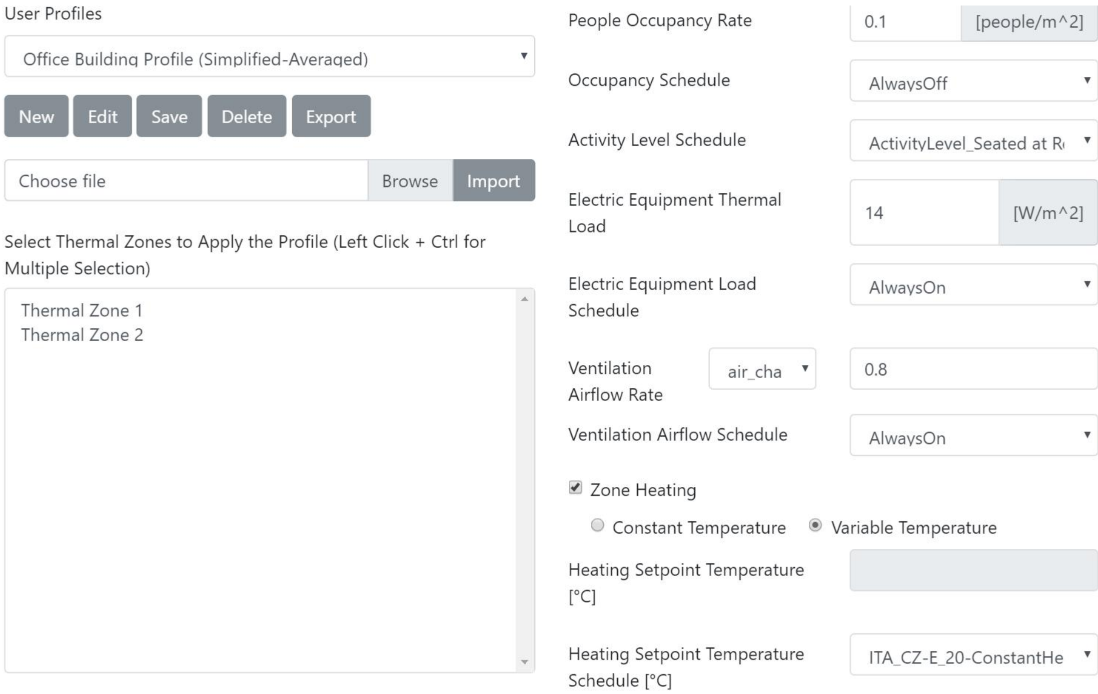


Figure 58 Thermal zone 1 conditioning parameter setting chart(Reading and office areas) (Elaboration by author)

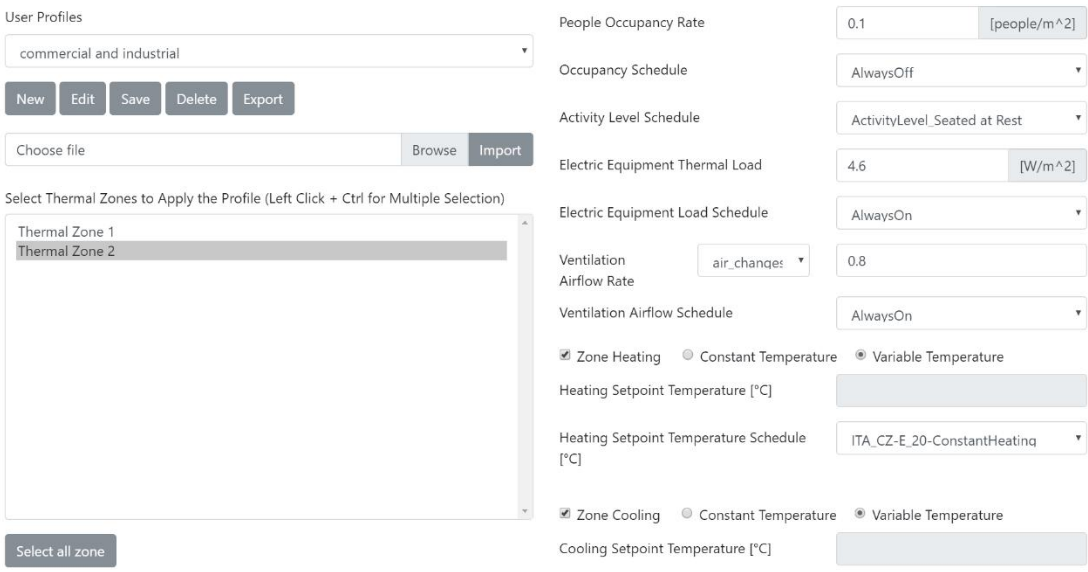


Figure 59 Thermal zone 2 air conditioning parameter setting chart (Exhibition and commercial area)(Elaboration by author)

As Ganzhou is located in a hot summer and cold winter climate zoning, it is necessary to focus on heat insulation and ventilation in summer and proper insulation in winter. Therefore, we proposed 40 mm thick EPS insulation panels on the external walls and roof of the building and shading elements to the external windows on the west side and roof. Low emissivity transmission coated glazing was then considered to reduce the SHGC values and ultimately the thermal radiation in summer. The energy consumption of the building before and after the proposed interventions were estimated separately and the results are as follows.

Firstly, we chose the initial state of the building, without insulation and shading system, with ordinary double glazed LOW-E windows with a heat transfer coefficient of 2.6 W/(m^2 K) and a solar heat gain coefficient of 0.55. The results of this calculation are as follows:

Heating System		
Net Sensible Heating Energy Demand	5.1	kWh/m³
Peak Sensible Heating Power	95.8	kW
Annual heating energy demand	73.9	MWh
Cooling System		
Net Sensible Cooling Energy Demand	16	kWh/m³
Peak Sensible Cooling Power	128.8	kW
Annual cooling energy demand	232	MWh

Table 14 Energy demand calculations (without insulation or shade)(Elaboration by author)

From the above results, it can be seen that the cooling energy demand of this project is much higher than the heating, so the first focus needed to be on reducing the cooling energy demand in summer. We then first optimised the external façade of the building by adding a 40 mm thick insulation layer and adjusting the external windows to triple LOW-E glazing with a heat transfer coefficient of 1.3 W/(m^2 K) and a solar heat gain coefficient of 0.35.

.

Heating System		
Net Sensible Heating Energy Demand	4.34	kWh/m³
Peak Sensible Heating Power	80.3	kW
Annual heating energy demand	62.9	MWh
Cooling System		
Net Sensible Cooling Energy Demand	13.2	kWh/m³
Peak Sensible Cooling Power	191.4	kW
Annual cooling energy demand	140.3	MWh

Table 15 Energy demand calculations (without shading)(Elaboration by author)

This is a significant reduction in energy demand for both heating and cooling, especially for cooling. However, the latter is still much higher than the former, so we consider a reduction in solar radiation in summer.

Finally we have added movable sunshade louvers to all external windows which can be opened in summer and closed in winter to reduce the intake of summer sun. After adding insulation, providing shading and adjusting the solar heat gain coefficient, we get the following final results:

Heating System		
Net Sensible Heating Energy Demand	4.8	kWh/m³
Peak Sensible Heating Power	83.1	kW
Annual heating energy demand	69.6	MWh
Cooling System		
Net Sensible Cooling Energy Demand	10.4	kWh/m³
Peak Sensible Cooling Power	93.2	kW
Annual cooling energy demand	150.8	MWh

Table 16 Energy demand calculations (with insulation and shading)(Elaboration by author)

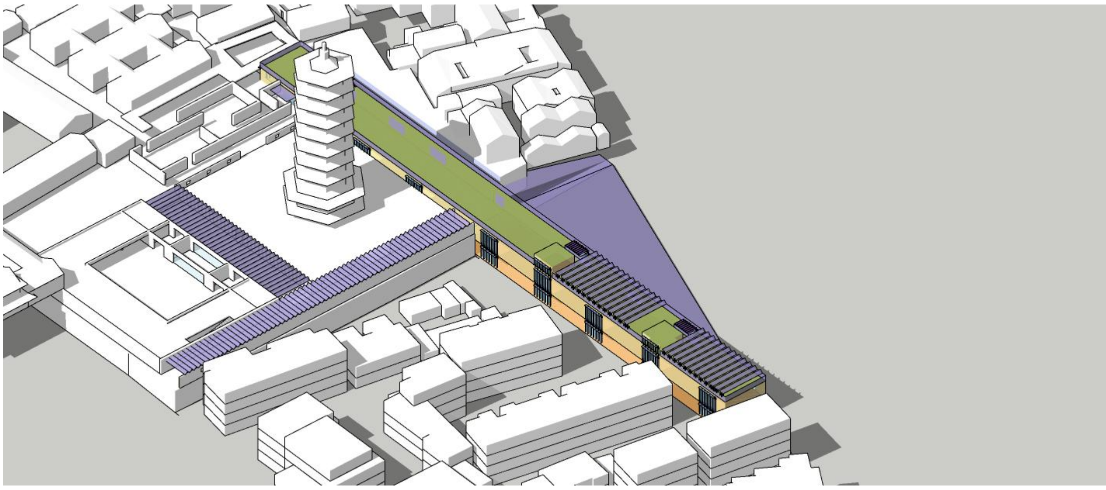


Figure 60 Perspective view of the south side of the library (with external window shading) (Elaboration by author)

By adding shading measures, we found a slight increase in heating energy consumption, but a higher reduction in cooling energy consumption in comparison, so we adopted this version of the scheme.

After comparison, the average annual energy demand for heating was reduced from 73.9 MWh to 69.6 MWh, saving of 6%, and the average annual energy demand for cooling in summer was reduced from 232 MWh to 150.8 MWh, saving of 35%. This shows that the above energy saving measures can significantly help to save energy in summer cooling.

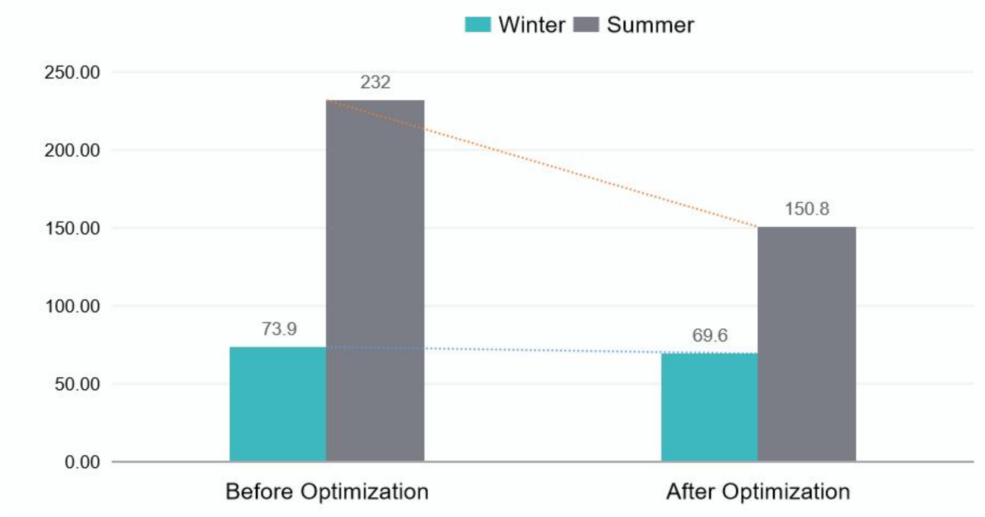


Figure 61 Graph of average annual energy consumption for air conditioning
(Elaboration by author)

4.3.3 Electricity demand in focus building

This part is to calculate the energy required for artificial lightening, electricity equipment and hot water in our selected building.As the length of daylight and the power of the equipment systems differ between winter and summer, we calculate the energy requirements separately for winter and summer.

Building function	Lighting loads [W/m²]	Electrical equipment loads [W/m²]
Auditorium	15.2	10.8
Commercial and industrial	6.5	4.6
Convention centre	12.9	10.3
Financial Institution	11.8	16.2
General commercial and industrial work	10.8	10.7
Grocery store	16.2	9.8
Library	14.0	16.2
Hospital and clinic	11.8	12.7
Office	9.2	14.4
Religious	17.2	10.3
Restaurant	12.9	8.5
School	10.8	10.8
Theatre	14.0	5.8
Residential	1.7	9.0

Table 17 Electricity loads (Artifical lighting and equipments)
Source:Thematic Studio

(1) Electricity demand for lighting

L=14W/㎡

14×20%×2h×365/2=1022Wh/㎡

14×40%×10h×365/2=10220Wh/㎡

14×60%×10h×365/2=15330Wh/㎡

14×80%×2h×365/2=4088Wh/㎡

(1022+10220+15330+4088)/1000×2994 ㎡=91796kWh

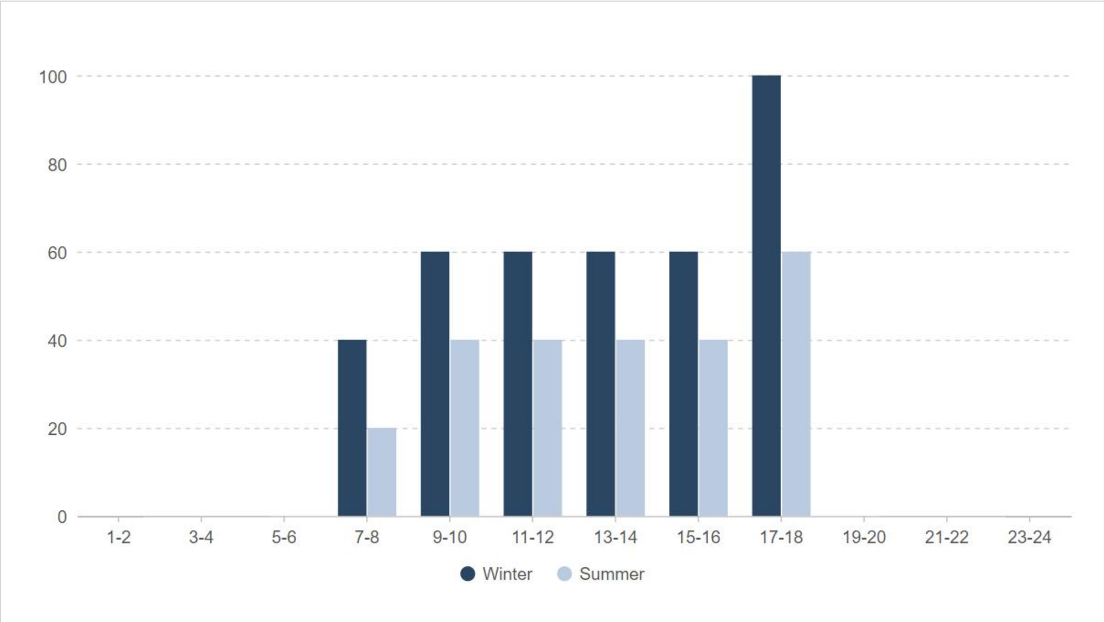


Figure 62 Winter and summer lighting schedules(Elaboration by author)

(2) Electricity demand for equipment

L=16.2W/㎡

16.2×10%×20h×365=11826Wh/㎡

16.2×40%×8h×365=18922Wh/㎡

16.2×80%×10h×365/2=23652Wh/㎡

16.2×100%×10h×365/2=29565Wh/㎡

(11826+18922+23652+29565)/1000×2994 ㎡=251391.21kWh

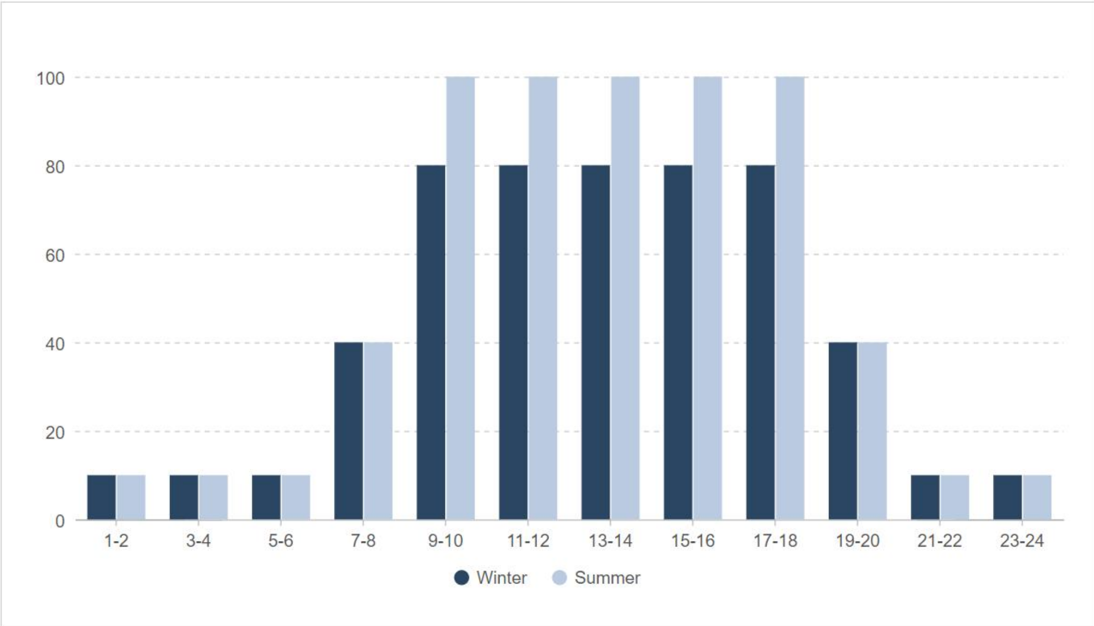


Figure 63 Winter and summer equipment usage schedule(Elaboration by author)

(3) Thermal Energy Demand for hot water

Building demand for domestic hot water: 280 Wh/person/day

Estimate the number of people based on the number of seats and the area of the exhibition space:75 person

75×280×365/1000=7665 kWh

(4) Electricity consumption for ground source heat pump

A ground source heat pump is a heating and cooling system that utilises shallow geothermal resources on the earth's surface. In winter, the heat is extracted from the soil, raised to a higher temperature and supplied to the room for heating; in summer, the heat from the room is released into the soil. Due to the tight land resources around the project site, we opted for a vertical heat and cold exchanger. The heat pump machines (MG-06SFXLRS) form the market (Figure 63) were chosen to have a high COP value of 5.14 and EER value of 4.85.

High COP underfloor heating and cooling geothermal source heat pump

Model			MG-03SFXLRS	MG-03SFXLRS/380	MG-05SFXLRS	MG-06SFXLRS	MG-10SFXLRS
Heating input power	Heating mode	KW	2.1	2.35	4.15	4.9	8.35
Heating capacity		KW	10.5	11.8	21.3	25.2	42.6
COP			5.00	5.02	5.13	5.14	5.10
cooling input power	Cooling mode	KW	1.5	1.7	3	3.4	6
Cooling capacity		KW	6.8	7.8	14	16.5	28
EER			4.53	4.59	4.67	4.85	4.67
pipe size		mm	25	25	25	25	32
noise		db	50	50	50	50	50

Figure 64 Ground source heat pump parameters

Source:https://www.mangoheatpumpcn.com/High-Cop-Underfloor-Heating-and-Cooli

As calculated by RETScreen software,the electricity used for heating is 15.6MWh and the electricity used for cooling is 38.2MWh.

Site Conditions		Estimate	Notes/Range
Nearest location for weather data		Ganzhou	See Weather Database
Heating design temperature	°C	2.0	-40.0 to 15.0
Cooling design temperature	°C	34.8	10.0 to 40.0
Average summer daily temperature range	°C	5.7	5.0 to 15.0
Cooling humidity level	-	High	
Latitude of project location	°N	25.9	-90.0 to 90.0
Mean earth temperature	°C	18.4	Visit NASA satellite data site
Annual earth temperature amplitude	°C	15.1	5.0 to 20.0
Depth of measurement of earth temperature	m	0.0	0.0 to 3.0

Building Heating and Cooling Load		Estimate	Notes/Range
Type of building	-	Commercial	
Available information	-	Energy use data	
Design heating load	kW	83.1	
	million Btu/h	0.284	
Annual heating energy demand	MWh	69.6	
	million Btu	237.5	
Design cooling load	kW	93.2	
	ton (cooling)	26.5	
Annual cooling energy demand	MWh	150.8	
	million Btu	514.5	Return to Energy Model sheet

Site Conditions		Estimate	Notes/Range
Project name		**Renovate building**	See Online Manual
Project location		**Ganzhou, China**	
Available land area	m²	1,500	
Soil type	-	Heavy soil - damp	
Design heating load	kW	83.1	Complete H&CLC sheet
Design cooling load	kW	93.2	

System Characteristics		Estimate	Notes/Range
Base Case HVAC System			
Building has air-conditioning?	yes/no	Yes	
Heating fuel type	-	**Electricity**	
Heating system seasonal efficiency	%	100%	55% to 350%
Air-conditioner seasonal COP	-	5.0	2.4 to 5.0
Ground Heat Exchanger System			
System type	-	Vertical closed-loop	
Design criteria	-	Heating	
Typical land area required	m²	525	
Ground heat exchanger layout	-	Standard	
Total borehole length	m	1,847	
Heat Pump System			
Average heat pump efficiency	-	User-defined	See Product Database
Heat pump manufacturer		ABC S.A.	
Heat pump model		model XYZ	
Standard cooling COP	-	4.85	
Standard heating COP	-	5.14	
Total standard heating capacity	kW	63.6	
	million Btu/h	0.217	
Total standard cooling capacity	kW	96.8	
	ton (cooling)	27.5	
Supplemental Heating and Heat Rejection System			
Suggested supplemental heating capacity	kW	0.0	
	million Btu/h	0.000	
Suggested supplemental heat rejection	kW	41.2	
	million Btu/h	0.140	

Annual Energy Production		Estimate	Notes/Range
Heating			
Electricity used	MWh	15.6	
Supplemental energy delivered	MWh	0.0	
GSHP heating energy delivered	MWh	**69.8**	
	million Btu	238.1	
Seasonal heating COP	-	4.5	2.0 to 5.0
Cooling			
Electricity used	MWh	38.2	
GSHP cooling energy delivered	MWh	**150.8**	
	million Btu	514.5	
Seasonal cooling COP	-	4.0	2.0 to 5.5
Seasonal cooling EER	(Btu/h)/W	13.5	7.0 to 19.0
			Complete Cost Analysis sheet

Figure 65 Ground source heat pump energy consumption calculation table(Elaboration by author)

(5) Conclusion

Total electricity energy demand:

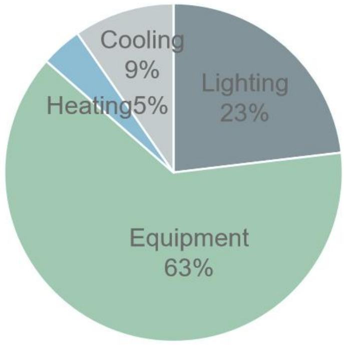
E1=Lighting=91.8MWh

E2=Equipment=251.4MWh

E3=Heating=15.6MWh

E4=Cooling=38.2MWh

Total=E1+E2+E3+E4=397 MWh



4.3.4 Energy consumption and greenhouses gases (CO_2) emission reduction

(1) Renewable energy generated by solar water heating collectors

The solar water heating unit of choice is the Apricus brand ETC-30 series. The equipment dimensions is 2005 x 2196 x 136 mm. Aperture area is 2.84 ㎡ and cross area is 4.4 ㎡. Hot water usage 1000 L/d, seven days per week at 45°C. As calculated by RETScreen software, we could conclude that 5 collector could meet the need of hot water. The system occupies a total of 22 m^2 of roof area.

Site Conditions		Estimate	Notes/Range
Project name		**Renovate building**	*See Online Manual*
Project location		**Ganzhou, China**	
Nearest location for weather data		Ganzhou	*Complete SR&HL sheet*
Annual solar radiation (tilted surface)	MWh/m²	1.35	
Annual average temperature	°C	19.6	-20.0 to 30.0
Annual average wind speed	m/s	1.5	
Desired load temperature	°C	45	
Hot water use	L/d	1,000	
Number of months analysed	month	12.00	
Energy demand for months analysed	MWh	10.81	

System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	**Natural gas - m³**	
Water heating system seasonal efficiency	%	90%	50% to 190%
Solar Collector			
Collector type	-	Glazed	*See Technical Note 1*
Solar water heating collector manufacturer		Apricus	*See Product Database*
Solar water heating collector model		ETC-30	
Gross area of one collector	m²	4.40	1.00 to 5.00
Aperture area of one collector	m²	2.84	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.69	0.50 to 0.90
Fr UL coefficient	(W/m²)/°C	3.97	1.50 to 8.00
Temperature coefficient for Fr UL	(W/(m·°C)²)	0.00	0.000 to 0.010
Suggested number of collectors		3	
Number of collectors		5	
Total gross collector area	m²	22.0	
Storage			
Ratio of storage capacity to coll. area	L/m²	45.9	37.5 to 100.0
Storage capacity	L	652	
Balance of System			
Heat exchanger/antifreeze protection	yes/no	No	
Suggested pipe diameter	mm	13	8 to 25 or PVC 35 to 50
Pipe diameter	mm	20	8 to 25 or PVC 35 to 50
Pumping power per collector area	W/m²	0	3 to 22, or 0
Piping and solar tank losses	%	1%	1% to 10%
Losses due to snow and/or dirt	%	3%	2% to 10%
Horz. dist. from mech. room to collector	m	5	5 to 20
# of floors from mech. room to collector	-	2	0 to 20

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
SWH system capacity	kW_{th}	10	
	MWth	0.010	
Pumping energy (electricity)	MWh	**0.00**	
Specific yield	kWh/m²	365	
System efficiency	%	27%	
Solar fraction	%	74%	
Renewable energy delivered	MWh	**8.03**	
	GJ	28.92	
			Complete Cost Analysis sheet

Site Latitude and Collector Orientation		Estimate	Notes/Range
Nearest location for weather data		Ganzhou	See Weather Database
Latitude of project location	°N	25.9	-90.0 to 90.0
Slope of solar collector	°	30.0	0.0 to 90.0
Azimuth of solar collector	°	0.0	0.0 to 180.0

Monthly Inputs

(Note: 1. Cells in grey are not used for energy calculations; 2. Revisit this table to check that all required inputs are filled if you change system type or solar collector type or pool type, or method for calculating cold water temperature).

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface ($kWh/m^2/d$)	Monthly average temperature (°C)	Monthly average relative humidity (%)	Monthly average wind speed (m/s)	Monthly average daily radiation in plane of solar collector ($kWh/m^2/d$)
January	1.00	2.39	8.4	74.8	1.5	2.94
February	1.00	2.32	10.1	77.8	1.5	2.54
March	1.00	2.45	13.6	80.0	1.4	2.80
April	1.00	3.34	20.0	78.2	1.4	3.20
May	1.00	3.94	24.1	77.4	1.4	3.57
June	1.00	4.39	27.2	76.2	1.6	3.86
July	1.00	5.34	29.5	70.0	1.8	4.69
August	1.00	4.70	28.8	73.1	1.5	4.39
September	1.00	3.94	25.8	73.9	1.5	3.99
October	1.00	3.51	21.4	70.9	1.4	3.94
November	1.00	3.27	15.9	71.5	1.3	4.19
December	1.00	3.02	10.3	70.2	1.3	4.10

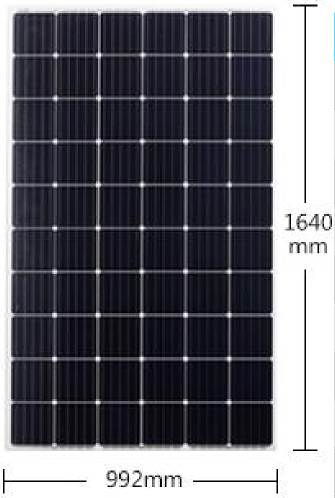
		Annual	Season of Use
Solar radiation (horizontal)	MWh/m^2	1.30	1.30
Solar radiation (tilted surface)	MWh/m^2	1.35	1.35
Average temperature	°C	19.6	19.6
Average wind speed	m/s	1.5	1.5

Water Heating Load Calculation		Estimate	Notes/Range
Application type	-	Service hot water	
System configuration	-	With storage	
Building or load type	-	Other	
Number of units	-	-	
Rate of occupancy	%	-	50% to 100%
Estimated hot water use (at ~60 °C)	L/d	N/A	
Hot water use	L/d	1,000	
Desired water temperature	°C	45	
Days per week system is used	d	7	1 to 7
Cold water temperature	-	Auto	
Minimum	°C	15.7	1.0 to 10.0
Maximum	°C	23.1	5.0 to 15.0
Months SWH system in use	month	12.00	
Energy demand for months analysed	MWh	10.81	
	GJ	38.91	
			Return to Energy Model sheet

Figure 66 Solar water heatingenergy consumption calculations (Elaboration by author)

(2) Renewable energy generated by Solar PV

Total electricity demand of the building=397MWh



SFM-250~300		
250W	275W	300W
60pcs 6*10mm		
±3%		
30V		
8.33A	9.17A	10A
36V		
9.17A	10.08A	11A
19KG		
1640*992*35mm		

Figure 67 Solar PV Panel Parameters(Source:https://www.singfosolar.com/product_tyndcb.html)

We have chosen a 250 W solar PV panel from the *Singfosolar* brand for our calculations. It has an energy conversion efficiency of approximately 15%, is made of polycrystalline silicon, has a single panel size of 1640mm x 992mm x 35mm and weighs approximately 19 Kg. The solar panels are installed on the roof at a slope of approximately 30°.

The parts of the roof of the library and the surrounding corridor could be used to place solar panels. The RETScreen software calculates that the system is capable of generating approximately 268 MWh of electricity annually, requiring approximately 1666 ㎡ of roof area. The current roof area can meet the demand. The electricity generated will cover 67.5% of the library's electricity demand.

RETScreen® Energy Model - Photovoltaic Project — Training & Support

Site Conditions		Estimate	Notes/Range
Project name		Renovate building	See Online Manual
Project location		Ganzhou, China	
Nearest location for weather data	-	Ganzhou	Complete SR&SL sheet
Latitude of project location	°N	25.9	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.32	
Annual average temperature	°C	19.6	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	**On-grid**	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	User-defined	
PV module manufacturer / model #		Singfosolar	See Product Database
Nominal PV module efficiency	%	15.0%	4.0% to 15.0%
NOCT	°C	48	40 to 55
PV temperature coefficient	% / °C	0.35%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	**250.00**	
PV array area	m²	1,666.7	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	225.0	
Inverter capacity	kW (AC)	250.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	160.8	
Overall PV system efficiency	%	12.2%	
PV system capacity factor	%	12.2%	
Renewable energy collected	MWh	297.777	
Renewable energy delivered	MWh	**268.000**	
	kWh	268,000	
Excess RE available	MWh	**0.000**	
			Complete Cost Analysis sheet

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		Ganzhou	See Weather Database
Latitude of project location	°N	25.9	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	30.0	0.0 to 90.0
Azimuth of PV array	°	30.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1.00	2.39	8.4	2.78	-
February	1.00	2.32	10.1	2.45	-
March	1.00	2.45	13.6	2.48	-
April	1.00	3.34	20.0	3.21	-
May	1.00	3.94	24.1	3.64	-
June	1.00	4.39	27.2	3.96	-
July	1.00	5.34	29.5	4.82	-
August	1.00	4.70	28.8	4.44	-
September	1.00	3.94	25.8	3.96	-
October	1.00	3.51	21.4	3.83	-
November	1.00	3.27	15.9	3.94	-
December	1.00	3.02	10.3	3.82	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.30	1.30
Solar radiation (tilted surface)	MWh/m²	1.32	1.32
Average temperature	°C	19.6	19.6

Figure 68 Solar PV energy consumption calculations (Elaboration by author)

(3)Total Greenhouse Gases emission reduction

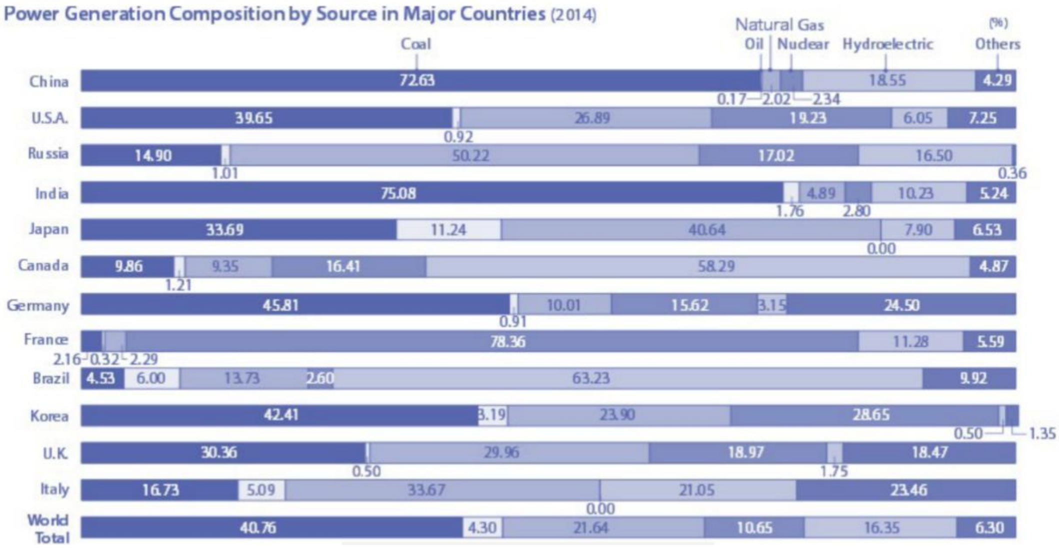


Figure 69 Power generation composition by source in major countries (2014)
(Source: Sustainable Building Design For Tropical Climates,Principles and Applications for Eastern Africa)

Greenhouse gas (GHG) emissions are an important factor affecting the global climate. Many countries have begun to develop or are implementing plans to reduce greenhouse gas emissions and move towards the "Carbon Neutrality" goal. The table above shows statistics from 2014 about fuel mix for electricity generation in the world's major countries. It can be seen from it that developing countries such as at that time China and India still have a larger share of non-renewable fuel mix for electricity generation. According to statistics, in 2018, the share of coal energy use in China drops to 58%, and in 2020 it is reduced to 56.8%[31]. It can be seen that China is gradually reducing the proportion of non-renewable energy use, but this is a process that will require long-term efforts, and in the short-term coal still dominates the proportion of energy use.

Therefore, in the design of this project, we have used renewable energy sources instead of conventional energy sources wherever possible. Software calculations have also been used to derive the amount of carbon dioxide that can be reduced by each system.

Solar Heating Water:1.81 tCO_2/year

Ground Source Heat Pump:36.36 tCO_2/year

Solar PV: 202.61 tCO_2/year

Total:1.81 (SH) + 36.36(Heat pump) + 202.61(Solar PV) = 240.78 tCO_2/year

[31] *China Energy Data Report (2021) - Energy Comprehensive*
https://news.bjx.com.cn/html/20210608/1157035-4.shtml

Background Information

Project Information

Project name	Renovate building
Project location	Ganzhou, China

Global Warming Potential of GHG

1 tonne CH_4 =	21 tonnes CO_2	(IPCC 1996)
1 tonne N_2O =	310 tonnes CO_2	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Natural gas	2.0%	56.1	0.0030	0.0010	45.0%	8.0%	0.491
Coal	72.6%	94.6	0.0020	0.0030	35.0%	8.0%	1.069
Large hydro	18.6%	0.0	0.0000	0.0000	100.0%	8.0%	0.000
Diesel (#2 oil)	0.2%	74.1	0.0020	0.0020	30.0%	8.0%	0.975
Nuclear	2.3%	0.0	0.0000	0.0000	30.0%	8.0%	0.000
Electricity mix	96%	216.6	0.0047	0.0068		7.7%	0.788

Fuel mix should total 100%

Base Case Heating and Cooling System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	100.0%	216.6	0.0047	0.0068	100.0%	0.788
Cooling system						
Electricity	100.0%	216.6	0.0047	0.0068	500.0%	0.158

Proposed Case Heating and Cooling System (Ground-Source Heat Pump Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	100.0%	216.6	0.0047	0.0068	446.5%	0.176
Cooling system						
Electricity	100.0%	216.6	0.0047	0.0068	395.1%	0.199

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Heating system	0.788	0.176	69.8		42.66
Cooling system	0.158	0.199	150.8		-6.30
			Net GHG emission reduction	t_{CO2}/yr	**36.36**

Complete Financial Summary sheet

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Heating system	0.226	0.000	8.03		1.81
			Net GHG emission reduction	t_{CO2}/yr	**1.81**

Complete Financial Summary sheet

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Electricity system	0.788	0.000	257.280		202.61
			Net GHG emission reduction	t_{CO2}/yr	**202.61**

Complete Financial Summary sheet

Figure 70 Greenhouse Gases emission reduction calculation table (Elaboration by author)

According to the calculations carried out through RETScreen software, the ground source heat pumps, solar PV and hot water systems can help reduce greenhouse gas emissions by 240.78 (tCO_2/year).

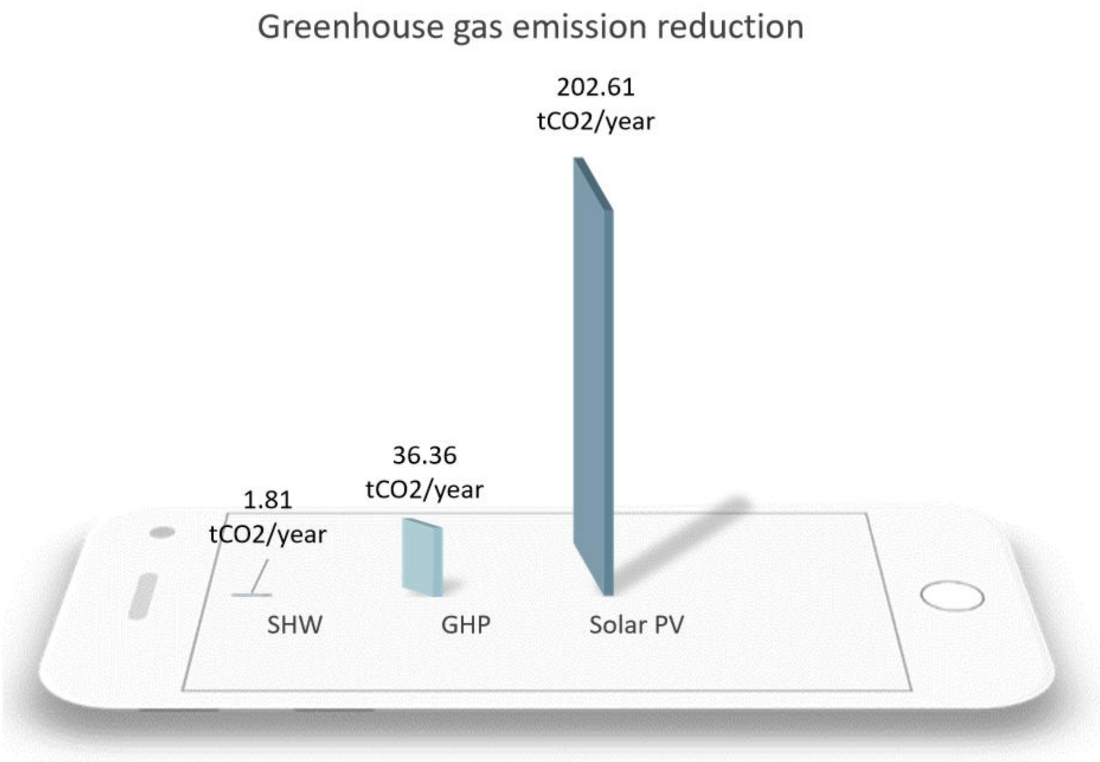


Figure 71 Total greenhouse gas emission reduction results (Source: Elaborate by author)

5.PHYSICAL MODEL

6. CONCLUSION

In the overall context of global warming and increasing resource scarcity, sustainable development and construction in the building industry will provide a great contribution to the goal of carbon neutrality, and it is also has great significance for the renovation and revitalization for the existing context. This is not only a requirement for new buildings, but also important for the renovation and revitalisation of existing buildings and environments.

China has a long history of urban construction and has left behind many old buildings that cannot meet the needs of modern life during its long construction cycle. However, for historical district, the renovation should consider the authenticity of the culture and historical feature. Therefore, urban regeneration needs to find a balance between historical features, urban fabric, human comfort and sustainable construction.

Taking the Ciyun Pagoda site renovation project in Ganzhou as an example, we attempts activating the current site status in terms of sustainable sites, water recycling, energy and atmosphere, materials and resources to improve the congestion and inefficiency of the existing site. The premise of the design is based on following the historical fabric and architectural features of the ancient city, and is guided by international green building standards and sustainability manuals.

At the site level, the road network has been reorganised to increase connectivity. After the landscape reorganization, greenery, pools and permeable pavement were added, which effectively reduced the heat island effect. At the building level, we focus on the energy consumption, lighting, ventilation and materials of the library to make it more energy efficient. The calculations are then performed using the BESTenergy software to obtain the final average annual greenhouse gas emission reductions.

In addition, by using program Ecotect we understand the shading environment of current site and the new building, determinate the best position strategy to place the solar panels and the fact that the library does not interfere the surrounding buildings. For ventilation, we used software to stimulate the outdoor and indoor wind environment in different prevailing wind and minimum wind velocity to determine openings of window and ventilation strategies to reduce the building energy consumption by using natural ventilation as much as possible.

The renovated public space will serve as a showcase to awaken the curiosity and vision of sustainable living scenarios for the citizens, and at the same time, the revitalization will bring preservation and new vitality to the ancient architecture and the history of Ganzhou, allowing this thousand-year-old city to embrace a new future.

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FIGURE LIST

TABLE LIST