ENERGY-EFFICIENT BUILDING DESIGN BASED ON THE URBAN MICROCLIMATE IN THE HOT SUMMER AND COLD WINTER REGION OF WUHAN

By

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A MASTERS RESEARCH PROJECT PRESENTED
TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN ARCHITECTURAL STUDIES
WITH A CONCENTRATION IN SUSTAINABLE DESIGN

UNIVERSITY OF FLORIDA

2016

To my parents, friends and colleagues

ACKNOWLEDGMENTS

Firstly, I would like to thank my parents. Even though far away in China, they have offered me guidance and encouragement. Secondly, I would like to extend much gratitude to my committee members, Professor Charlie Hailey and Professor Donna L. Cohen, for their tireless efforts and invaluable advice throughout this master research project, English is not my first language but they still had patience to help me over and over again. I would also like to thank Dr. Michael Kung for his help since I come to American. Lastly, I would like to thank all my friends and classmates who helped me in my studies and made me feel less lonely.

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LIST OF ABBREVIATIONS

BPS— Building Performance Simulation

EPI— Environment performance Indicators

GHG—Greenhouse Gas

HVAC—Heating, Ventilation and Air conditioning

IDP— Integrated Design Process

LID— Low impact development

LCA— Life cycle assessment

LCC—Life Cycle Cost

PSED— Passive- Solar Energy Design

SEER—Seasonal Energy Efficiency Ratio

TIC— Titanium Carbide

UHI— Urban Heat Island

Abstract of Master's Research Project to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science in Architectural Studies

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AUGUST 2016

Chair: Charlie Hailey
Major: Master of Science in Architectural Studies with a Concentration in Sustainable Design

Most of existing research on climate-adaptable building usually makes use of an experimental subject in the suburb or open field in order to highlight climate characteristics. But due to the high density of people's activities and the subsequent releasing of greenhouse gasses that have caused weather conditions of the urban city become more and more complex. Hot summer and cold winter regions are often associated with high humidity and frequent precipitation throughout the year. In addition, the people who live in these areas have to rely on HVAC and other high energy consumption mechanical equipment systems to maintain comfortable living. All these situations not only cause the uninhabitable but also increased environment stress. As a main reason lead to environmental degradation, architecture can no longer be seen as a discrete, it is necessary to

meet the needs of people and use the environment in an innovative and sustainable way.

Research on meteorological data and identification of the characteristics of hot summer and cold winter regions is the basis of the design, it is necessary to start design with specific climate data information then to make an appropriate decision for the climate responsive of building life-cycle. For this research I investigate Wuhan city in the Middle and lower areas of Yangtze River as a sample climatic feature that can provide background information on the variety of climate factors such as sun-angle, humidity, precipitation, the wind, and so on. Meanwhile, the culture and demands of the environment for local people will be investigated to coordinate with a design approach that takes into account indoor temperature, noise, the sunshine, ventilation and prevent radioactive contamination. In other words, it is necessary to study the relative climate parameters to integrate a more environment friendly and habitat comfortability design philosophy. Through case studies that offer a series of sustainable constructions which succeeded in hot or cold regions, this research analyzed the energy-efficiency technologies and investigates how these systems might improve it the design process.

Design a climate adaptability building in a hot summer and cold winter region can let local people get more comfortable living environment without weather damage. As we know ‘ocean is made by million droplets’, if we implement a large-scale climate responsive industrial in the future, at the same time keep following-up research and development on systematized methods of the design standard,

the urban micro-climate condition will be improved which will result in a productive environment.

CHAPTER 1
INTRODUCTION

Global climate condition and sustainability

In the past decades, the extreme weather across the global has become more and more apparent, especially to the people who live in hot summer and cold winter area, they suffered from the greater effects of climate. NASA has repeatedly stated that, in the future, the phenomena of El Niño and La Niña will not diminish, but their influence will be increasingly strengthen. No matter how the outcome of international controversy on 'global warming hiatus', it is hard to deny the facts that glacier melting is accelerating, sea level is rising, climate is becoming warm and hence some part of people are living in the exacerbation of extreme climates. Under such an environment, how to give the responsible constructions for the society is a challenge problem. Hence, in the future, the architecture field should deeply realize that a house is not only a living machine in general sense but also a adjustor of the comfortable environment. For the sustainable development of human society, architects and planners should have a clear and deep knowledge to the interaction between building and microclimate, and, with their knowledge, design out some suitable climate-adaptable buildings to improve the living environment in the extreme climate and environment. It is quite significant to study the designs of energy-efficient buildings under the urban microclimate in hot summer and cold winter regions. The people living in the bad climate regions will be very benefited from this type of research.

Obviously, when the human society is on the way to the future, it will suffer from inevitably with the increasing of energy consumption and deterioration of the living environment. A lot of industrial buildings are destroying the land and the balance of ecology, asphalt and concrete is replacing forest and grasslands, sunlight is unable to cover soil, no rain waters the crops and some species is gradually accelerated their extinction. These bad factors are severely affecting human's living environment. In view of this, a good architect should not be a destroyer for the environment, whereas, he/she should be an excellent desingner of the comfortable environment and the greener society. Generally, in hot summer and cold winter regions, the buildings have more special requirements for the maintenance properties of structural materials, and their heating and ventilation also have different standards. So it is reasonable that we should not use the common standardization for energy conservation and emission reduction. Depending on the situation is the premise for designing a particular pattern. In the face of the huge urban population, any factor's change will affect the people's quality of living. Among them, undoubtedly, urban microclimate is one of the most important factors. With the rapid developments of energy-efficient technology， sustainability theory and multi-subject cooperation, up to now, the green building field has made a series of great advances in solving the challenge problems on the extreme climate.

Building effect on urban microclimate

Based on the thermal design index for civil buildings (MOC, 1993) and the data of national climatic statistics, China is divided into five climatic zones, they are severe cold regions, cold regions, hot summer and cold winter regions, hot summer and warm winter regions, and temperate regions. Architecture design in hot summer and cold winter regions need to consider the summer heat prevention and winter protection, but the existing buildings usually blind to this point. Because of government did not provide the unified heating system for all the construction, so most of Chinese urban residents have to install the additional air-conditioning equipment, this condition brings Chinese urban environment with a great pressure of energy consumption. However, through a statistical analysis of the meteorological data, the result shows that hot summer and cold winter regions have a unique climate patterns, some parts of regions have the abundant rainfall in spring and summer, and the other places, such as Wuhan city, can obtain the plenty of sunshine throughout all the year. The concept of the green building gives architects inspiration to design with climate. Use the energy efficient technology and the existing design concept can remarkably adjust climatic of seasonal differences. For the architecture design in hot summer and cold winter regions, it is necessary to take an integrate consideration for the uncertainty and resilience project design.

Understanding the urban microclimate is essential so that we may manipulate the relationship between the environment and the human comfortability. (Erell, E.,

et al. 2012). Urban population accounted for about 54% of the world's population in 2014, and by 2050 it will reach 66%. In 2014, America has urban population around 82%, and China has 49.6% (United Nations, 2014). These numbers show that, with the growing urban population, the city is the main place for human survival and social activity. However, the living environment of the city which people rely on is getting worse and worse, and the urban climate condition becomes the extreme one. For example, the urban heat island (UHI) is one of the most common urban-climate problems. It has heavily affected the life of urban people and this effect becomes very intensive in many countries like Singapore, China, Japan, America and UK. UHI causes mainly by thermal storage of building structure and road pavement, artificial heat releasing and green space decreasing. It greatly increased the building energy consumption for cooling requirements. As an example, British urban energy consumption for cooling is 16% higher than its rural area (Liao, Feng-Chi, et al. 2015). In order to resolve the energy-efficient problems, ones have to face to these negative urban climate phenomena. It is the first step to record and analyze the dynamic data continuously so that we can predict how climate conditions affect the performance of building thermal energy. Temperature is one of the main factors that influencing the indoor comfort. Under the improper temperature, human temperature regulation can be a disorder that may let people have long-lasting effects on mental and physical health. Moreover, it is remarkable that the different climate bodies have different adaptation abilities. Hence, a good

design for the building needs to give a full consideration to the design pattern and pay a peculiar attention to the exceptional climate condition.

Building energy conservation

The statistical data from the U.S Energy information Administration (EIA) shows that building consumes about half of energy produced in American in 2012 and building operations account of largest part of electricity consumption (Architecture 2030, 2013). The situation in China is also not optimistic, the total primary energy consumption accounts for more than 25% (Chmutina, K. 2010). These data explains why the energy-efficient buildings can play a significant role in the environment-protecting problems.

From the meanings of the words, we know that the energy-efficient building aims to use the various energy conservation methods to reduce energy consumption. The new energy-efficient building apply the integrated design process (IDP) and passive deign to each stage of the construction and take all the climatic factors into the early design stage. These ideas provide an objective analysis system for building climatic adoption research. Obviously, an energy-efficient building has a large space to improve itself and to corresponding environmental conditions. For example, by the simulation and analysis of the project and a comparison with ordinary energy-efficient buildings proved that the earth-sheltered construction have an energy-saving over 60%. (K. Liu. 2012)

Rapid urbanization of most cities on the world is leading to the soil degradation and the deterioration of natural landscape and vegetation. Changes in

urban surfaces have altered the radiative, thermal, moisture and aerodynamic properties of the environment (Givoni, B. 1998). City texture determines the surface albedo, different construction methods, and various materials use in the construction process, it is severly impacted on the environment and increasing the full life cycle GHG emission. So identify the correct design methods become an important step in the process, it is necessary for the modern architecture design to consider the space configuration and the comfortability of biological feeling (Olgyay, V., & Olgyay, A. 1963). In the past several decades, with the planning, design, prefabricate construction development, human take the energy efficiency construction industry towards to the top. Many developed countries obtain the successful low impact development (LID) system, producing the urban agriculture and the vertical gardens. We seem to have found a way to solve the problems, but, when we walk into the process of implementation, we still encounter many setbacks. Namely, the specific situations bring the different new problems.

How to identify the valid data and the right methods under certain climate conditions? How does an architecture with large and complex construction affect the urban microclimate? How to maintain the human body comfort? In order to resolve these problems, we will analyze the utilizability of natural resource, attempted selection of energy-saving materials and renewable materials that high performance, high durable and low energy consumption, and compare the obtained results with simulation energy consumption results. In the construction field it is possible to use a variety of different measures and techniques to calculation the

value of virtual water during the each construction stage. For example, as the presentation of life cycle assessment (LCA), we can have the opportunity to observe the energy consumption behind the product. There are a lot of virtual energy consumption simulation software, which can be used to confirm that the low-energy buildings result in more high efficient energy than the normal building does. All of these methods make it possible for design in a predefined comfort range. Also, according to the matching abilities of thermal insulation, homeothermy, ventilation and daylighting, we can reduce the energy usages.

The thesis is organized as follows. In chapter two, a review of existing literature focus on the study of literature. First I will taking Wuhan as an example of temperature form of hot summer and cold regions. Collect and analysis the meteorology data databases for lateral contrast. Second is for analysis of people's demands for construction in hot summer and cold region. The third point is an investigation of the specific interaction effect between the climate and construction development. After that, I study on serials existing building cases, review the advantages and defects of sustainable methods used by them for summary and conclude the feasibility of my design, which includes a few modern earth-sheltered architecture cases. Fifth, analysis the selection and take a concept design to apply the climate responsive strategies. In the last, concluding remarks idea and information for the follow-up study. After a literature review, in chapter three is research methodology that provides a description of the method to collect and process the data, at same time analytical framework has been sketched by climatic

and building information. Chapter four is case studies of climate responsive buildings each from different country, the project focus on the strategies of organize the different design system work together and the strategies of apply the corresponding methods for the different requirement. In the chapter five, it analysis the Wuhan Meteorological data by Ecotect analysis tool, then provide a concept design of climate responsive design, which based on Wuhan climate feature. In the conclusion, I take out the dynamic climate responsive strategies and the static climate responsive strategies of building design in the hot summer and cold winter region, and also provide the future opportunities for the research.

CHAPTER 2
LITERATURE REVIEW

Modern Energy-efficient Building

The United States Environmental Protection Agency (USEPA) points out that the buildings contribute to 30 percent of Greenhouse gas emission in America. Around the world, construction field consume 60% of raw materials. (Bribián, I. Z., et al 2011) As a branch of the green building system, the goals of modern energy-efficient building is according to energy-saving standard and using sustainable materials to reduce energy consumption in phases of planning, design, building and operating (X. Wu. 2007). With the prosperous development of sustainable study and popularization of energy conservation idea, more and more people realize there is a connection between environment and green lifestyle. The existing research about energy efficient building are concentrate on improvement building envelope, HVAC, water supply and drainage, refrigeration and building channel system (X. Wu. 2007). Since the concept of sustainable development been taken into architecture field, the theories and technologies of energy-efficient building have been constantly practicing in the recent decade. The sustainable development concept effectively control the whole life cycle energy consumption of the building, at the same time it also has good performance on adaptability of environment change. That is why the energy-efficient building has be widely accepted. Through the data collection by tracking of 60 cases, the results indicate that building which powered by solar energy will be more efficient than built with

greener ingredients, and the solar powered building decreased more life cycle energy demand by compared with an equivalent conventional version. (Sartori, I., & Hestnes, A. G. 2007).

The integrated design process (IDP) is one of the mainstream strategies of designing an energy-efficient building, it is characterized by use energy-conserving techniques and passive design methodologies into the first stage of design. In addition, building's ecological and economic benefit were also greatly increasing by IDP method implementation (Kanters, J., & Horvat, M. 2012). The International Energy Agency (IEA) report shows when the project included energy efficiency consideration at early designing stage will significant reduce the operate cost and the energy consumption during the building's lifespan (Laustsen, J. 2008). As we know save energy as save money, the energy efficiency building may have more cost than conventional building at early stage, but in the long term it will obtain lower cost of space heating, water heating, lighting, and air-conditioning. In the other hand, energy efficiency building does not only benefit the individual user, but also has significant value from owner to the whole society. Meanwhile, the improvement of local environment also will effect on individual energy usage. Different with IDP, the Building life cycle assessment (LCA) observed the building material production, processing, trading, logistics, new type energy use, building demolition and recycling. LCA present resource consumption of each unit of the entire construction, this help the designer can easily obtain the most objective angle to planning the building process.

In the article ‘energy use in the life cycle of a conventional and low-energy building (Sartori, et al, 2007), authors defined building energy sources into the different category which as follows. First is embodied energy that use for manufacture and construction, and generally it express in term of primary energy. Next is End-use energy which presents the building final energy usage. The feedstock energy usually shows a gross calorific value of raw materials energy consumption during production and processing stages. The Initial embodied energy present total energy consumption used in all the materials. Operating energy present the energy use in operational stages. As mentioned in previous, operating energy account for main part of whole life-cycle building energy consumption, meanwhile because of all the electric use and water consumption, in some situation it also can be seen as primary energy. Primary energy present a gross energy consumption of all the construction, it is include extraction, transformation and distribution energy usage. The recurring embodied energy present the potential energy use of recycling and regenerate material. (Sartori, Igor, and Anne Grete Hestnes 2007). All these concepts are fully illustrated energy consumption are not only a phenomenon but come from different levels, the designer need to understand this way of thinking to control the energy-saving effect.

Through the tracing observation of existing cases by Cathy Turner and Mark Frankel, the statistic shows that compared with the normal building, energy efficient building can reduce 25% to 50% of total energy use, 33% to 39% of carbon dioxide, 40% of water use and 70% of solid waste. However, currently in China, the non-

energy efficient building account over 95% of all, and energy consumption of unit area is two to three times than developed country (XiangXiang. Wu. 2007). Energy problems in China are still growing rapidly that may create an energy crisis in anytime. In order to reduce the waste of resource and ensure the national sustainable development, there is great demand of energy-efficient building in China. In recent years, Chinese building energy-saving field have made a certain achievement, the value of industry has reached fifteen billion dollars, and also create eight million jobs (XiangXiang. Wu. 2007). The aim of energy efficient building not just to save the natural resources but to maintain a balance between climate, resources and energy use.

The Evaluation and Assessment of Energy Efficient Building

There are two aspects of evaluation of energy efficient projects, first is the influences of building to the external environment, another is the quality of interior building environment that include the building's physical characteristic and it social cultural value. As a highly complex construction system, energy efficient building has more evaluation standards and assessment strategies than conventional building. After the energy crisis in 1973, the governments and organizations around the world began to build national energy efficient building evaluation and assessment systems that in order to quantitative evaluate the energy efficient technologies, observe whole life cycle energy consumption of building and potential ecology value. Now day, as more and more computer digital simulation methods

becoming mature that be used to calculation and improvement for energy-efficient buildings. There is serials assessment system have greatly contribute to modern green projects field, such as Life Cycle Assessment (LCA) system, Life Cycle Cost (LCC), BEES, GBtools and Athena (Sartori, Igor, and Anne Grete Hestnes 2007).; Many organizations also provides a very efficient project evaluation system like BREEAMS, LEED, NABERS, DGNB, GBC2000 and so on, all these make the great contribute to the great decision-making, also from Canada, Sweden, Norway and several other countries collaborated green building assessment system.

Building Life Cycle Assessment (LCA)

Building life-cycle be defined as from “a cradle to grave” in other words that means from the design stage to demolition stage. Building Life Cycle Assessment system that contribution through use cross-subject study, include Industrial ecology, chemistry, chemical engineering and construction engineering. LCA is being promoted as a tool for quantitative analysis the potential environmental impacts by product, and energy consumption throughout the building life cycle (Bayer, 2010). According to describes by the ‘AIA guide to building life cycle assessment in practice’, LCA method applied in building construction field has been presented in four levels as follows. First is material characteristic analysis, it through the calculation by process chemist and chemical engineers then obtains the data of materials contained elements and potential energy consumption. Second is production phase that is mainly for the monitor and the observation energy emission during the materials production process. Third is for the building level,

which obtains data by observation energy usage of materials installation stage, operation stage and maintenance stage. Fourth is an industry-scale analysis that mainly focus on examining the industry production and economic output or inputs and potential environment impacts of relatively small scale construction. The specific design process of LCA generally be divide into seven steps include (Bayer, 2010):

- Select an energy efficient targets for building's whole life cycle.
- Determine a research scope and goal of LCA
- Choosing an appropriate computer simulation tools. Because of each LCA analysis tool has a specific purpose and research direction, so choose different LCA tools have the different evaluation process. (as is shown in Table 2-1)
- Life Cycle Inventory(LCI)
- Life Cycle Impact Assessment(LCIA)
- Results and Interpretations improvement

Table 2-1. Features comparison of two LCA tools (Data from Bayer, 2010)

	Features	ATHENA® IE	LCAid™
1	**LCA Tool Type**	Whole Building LCA Tool	Whole Building LCA Tool
2	**Acceptable Building Type**	Industrial, Institutional, Commercial, Residential	All Types
3	**Acceptable Building Phase**	New Construction and Major Renovation	New Construction and Existi Buildings
4	**Target Users**	Architects, engineers, designers, environmental consultants	Architects, engineers, stude LCA practitioners and evalua
5	**Required User Skills**	None	None

7	**Available Building Material/Assembly Combinations**	1200 Assemblies	400+ Building Materials
8	**Units**	SI and Imperial	-
9	**Life Cycle Stages**	1. Material Extraction and Manufacturing 2. Related Transport 3. On-site Construction 4. Operation (energy only) and Maintenance 5. Demolition and Disposal	1. Material Extraction and Manufacturing 2. Related Transport 3. On-site Construction 4. Operation (energy and and Maintenance 5. Demolition and Disposa
10	**Impact Categories**	1. Embodied primary energy use 2. Acidification Potential 3. Global Warming Potential 4. Human Health Respiratory Effects Potential 5. Ozone Depletion Potential 6. Smog Potential 7. Aquatic Eutrophication Potential 8. Weighted Resource Use	1. Life Cycle embodied ene 2. Acidification Potential 3. Life Cycle Green House Emissions 4. Carcinogenesis 5. Ozone depletion 6. Summer/Winter smog 7. Nutriphication 8. Heavy metals 9. Solid Wastes 10. Water consumption 11. Primary fuels
11	**Input Method**	Manual Entry	Material Quantities can be imported from 3D Models: CAD(.dwf), ECOTECT (.eco/.a All other, manual entry

Benefit of Improving Building Efficiency

The core point of building energy efficiency development is to reduce energy consumption, save and reuse the natural resources. The statistic shows compare with the ordinary building, the energy efficiency building reduced the energy and fossil fuels use that contribute to more than 50% energy saving (XiangXiang. Wu, 2007). In the background of world energy crisis, human still not slowing down the pace, and most of developing country still need large area construction of building

and infrastructure. China as one of the most energy consumption country, it has 95% of buildings belong to high energy consumption, inefficiency, and inadequate thermal insulation performance. Most of these building rely on high consumption air conditioning to keep indoor comfortable, and air conditioning equipment is developing fast with ten million annual average increasing. (XiangXiang. Wu. 2007). Improving building energy efficiency can greatly alleviate energy shortages and reduce greenhouse gas emissions, though statistic shows that unit cost of energy efficient building is slightly higher than general building, for long term revenue is greater than it cost.

Improving building energy efficiency not only can reduce energy consumption and improve the local environment, but also is one kind of important way to bring huge economic benefits. Operating energy consumption is the largest section that share of energy consumption of building life span and also energy efficient revenue in that time can make up for the initial investment of energy efficiency cost. Those new type energy-saving equipment such as energy efficiency protective structure, multi-purpose heat pump conditioner, rainwater harvesting mechanism, have longer service life than conventional building equipment, that is mean the building maintenance cost will be cover by equipment repair cost. From the social perspective, at 2015, green construction field has created 796,000 jobs in American and contribute to direct U.S national GDP of ＄60.7 billion (U.S Green Building Council, n.d.).

Through a statistic of attendance rate and comprehension productivity, the results show that staffs become more effective in the office building after building installed energy-efficient equipment (Loftness et al. 2003). Thus it can be seen that improving the building energy efficiency can also cause the favorable changes of human psychological and physiological health. Energy efficiency doesn't mean to sacrifice living comfortable but use energy efficient strategies to reduce energy consumption and toxins emission, it create a healthy and comfortable environment for people living and working, in addition, energy efficient building also can reduce the medical care costs.

To Design and Constructive With Climate

The regional climate feature in the urban area is different with the climate feature in the nature area. This climate performance closely linked with human activity. In a global context Urban heat island (UHI) phenomenon is aggravating prove the results of human activities and large-scale urban construction. In absolute terms, in IPCC 2004 reported that building has emissions around 8.6 million metric tons carbon dioxide in 2004, and that situation will become more than two times in next 20 years. However energy efficient building has ability to reduce 35% to 80% of whole life cycle energy use (Sbci, U. N. E. P. 2009). Building should provide a favorable environment for human living instead of deteriorate the local environment. From the description of Alcofarado, M.J the goal of construction and design today should decrease the negative effect on different climate situation such

as urban radiation and energy balance, wind conditions, air pollution and thermal comfort (Alcofarado, M. J., & Matzarakis, A. 2014). The Urban Heat Island (UHI) is mainly caused by not use the correct climate adoption building pattern, lack of urban air duct and building height is desultory. High thermal admittance of building materials also is the important factor lead to UHI. On the other hand, use the unsuitable materials, lack of appropriate street layouts and orientation, may directly give rise to temperature (Priyadarsini, R. et al. 2008). From these results we can get a conclusion that Building as a unit of the urban texture, played a great role to the impact on the urban climate environment, it has relatively long life span and also has the largest potential for delivering long-term, significant on GHG emissions. I t is necessary to select appropriate Materials and energy-saving equipment and designing strategies that adopt local climate.

The level of GHG emissions is closely related to the demand of human living and energy supply. Under part of the region that has the extreme weather conditions, building energy demand and people healthy conditions face the serious challenges. According to the research by Alcofarado, M. J., & Matzarakis, A.(2014), Defined the different climatic conditions like arid and hot climates, hot humid climates, cold climates and contrast climate seasons. The author offers a serials strategies to design with these special climatic conditions, meanwhile, provide reasons to show the necessity of the Integrated Design, Use large-scale factorial simulation methods made the model predictive control.

For maintaining winter and summer seasons thermal exchange of indoor and outdoor environment, it is necessary to consider about efficiency of protecting structure like wall, insulating layer, window, shade and earth sheltered. The main elements that include of climate adoption building design can be divided into three items, first is outdoor actual weather conditions, second is indoor thermal comfort code, the third is climate control strategies. Meanwhile, climate control strategies include passive design system and active design system.

Data Hot summer and Cold Winter Region

Based on the data statistics of the global average temperature in same latitude and the Thermal Design Code for Civil Building(GB50176-93), Show as figure 2-1.China has been divided into four climate zone as follows, cold, severe cold, mild, hot summer and cold winter, hot summer and warm winter (MOC, 1993).

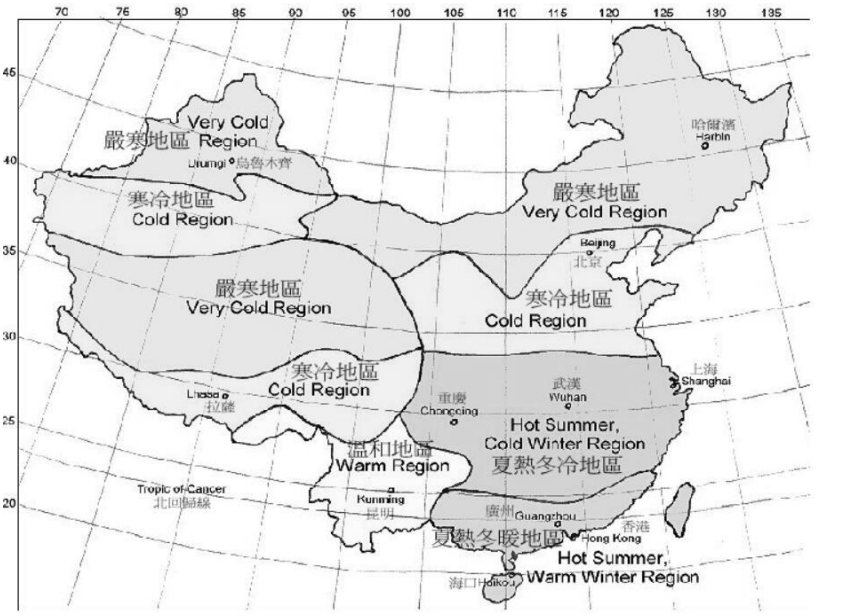

Figure2-1. China's climate zones division (Data from MOC, 1993)

This research will take Wuhan as an example of hot summer and cold winter temperature form. Meanwhile, cause this research area in the north subtropical monsoon region, and it also belongs to the continental climate so taking the January as the coldest month, July as the most thermal month for a node of the investigation. According to the datum from the China Meteorological Administration (CMA), and compare with other regions in the same latitude of the world, the temperature of research area shows 46.4 °F to 50 °F lower than average standard in January; 34.34 °F to 36.5 °F higher than average standard in July (Miao, X. 2006）. Cities in this area belong to the typical cold winter and hot summer climate. Table 2-2 shows various factors for the climate adaption elements of five cities that have typical hot summer and cold winter climate features. Data management through The 'Meteorological data set for building thermal, China'.

Table 2-2 Meteorological data set for building thermal environment analysis of part of Hot summer and cold winter region in China (dara from Song, Fangting, et al.2005)

Province	HUBEI	HUNAN	JIANGSU	ZHEJIANG	JIANGXI
Station	WuHan	ChangSha	NanKin	HangZhou	NanChang
Calculated temperature of the exterior heating(℉)	32.18	33.62	29.12	32.18	33.44
Heating period for design calculation (days)	49	31	79	43	38
The exterior calculated temperature of ventilation in winter (℉)	32.18	38.3	30.02	32	33.62
Outdoor design relative humidity for winter air conditioning(%)	72	90	79	82	80
Outdoor average wind speed in Winter(m/s)	2.6	2.4	2.7	2.6	3.4
Outdoor average wind speed of most direction in winter(m/s)	3.9	3.4	3.2	3.8	4.8
Most wind direction in winter	NNE	NNW	ENE	NNW	N
Rate of most wind direction in winter of all(%)	20	25	13	23	30
Atmospheric pressure of exterior in winter (Pa)	102447	101830	102790	102180	101977
Sunshine rate in Winter (%)	31	9	35	23	25
The exterior calculated temperature of ventilation in Summer (℉)	89.6	89.96	95	90.32	91.04
relative humidity in summer for ventilation (%)	63	63	65	62	61
Outdoor dry-bulb temperature for summer air conditioning (℉)	95.54	97.7	94.64	96.26	96.08
Outdoor wet-bulb temperature for summer air conditioning (℉)	83.12	84.2	82.58	92.22	92.94
Outdoor average wind speed in Summer(m/s)	2	2.4	2.4	2.7	2.3
Most wind direction in Summer	SE	S	SSE	SSW	S
Rate of most wind direction in summer of all(%)	9	22	11	19	18
Atmospheric pressure of exterior in summer (Pa)	99967	99563	100250	99980	99867
Annual dominant wind direction	NE	NW	NE	NNW	NNE
Rate of annual dominant wind direction	10	16	9	10	19
Extreme annual maximum temperature (℉)	103.28	105.08	104	104.54	104.18
Extreme annual minimum temperature (℉)	-0.58	13.46	8.6	16.52	14.54

Architecture in Hot Summer and Cold Winter Region

Usually the core aim of climate adaptation is trying to control the fast changing environment factors. More and more climate adaptability buildings have been built around the world, such as Hut Ken Yeang bioclimatic skyscrapers, Swiss Alpine

Club, Tjibaou Cultural Center by Renzo Piano, Swiss Re by Norman Foster. Because of these successful cases let local people can enjoy in the health and comfortable environment, and it also contributed to regional natural resource protection. According to the research by Jianqiang Li introduces the characteristic of the cold dry winter and damp hot summer region. On the annual average, these regions have over 70 days that temperature higher than 30 ℃ with relatively humidity more than 80%, around 60% of rain days in summer that reached 1200mm, these regions also have plenty sunshine around 1100~2500 hrs (Jianqiang Li. 2012). Meanwhile, in this paper author describes a serials of building climate-adaptable strategies to improve innovative cooling, protect air quality, and also introduces the glass and isolation materials selection, passive natural ventilation system design, heat transfer system, green public space and greening roof system. In the conclussion of paper shows the peripheral structure can be able to adopt different climate standard to face the outdoor temperature increasing and humid decrease in the hot summer and cold winter region. (Jianqiang Li. 2012). Through investigation on existing cases, different construction mode have different performance on sunlight and wind load energy efficiency ability. The adaptive capacity of various systems has greatly impact between architecture and environment each other. In order to control energy consumption and create more resilient building, it is necessary to take an intergrate consideration of waste energy use, passive design and intelligent design. (Jianqiang Li. 2012).

Eco-efficiency materials selection

In the background of modernization, building materials market become hugeness and disorder. This situation generally along with the amount of energy waste, environmental pollution, and resource damage. If architects choose the inappropriate materials may effect on whole building life-cycle and even cause the long-term energy consumption. In the article 'Life cycle assessment of building materials' (Bribián, I. Z., Capilla, A. V., & Usón, A. A. 2011). Author discussed relationship between the energy behavior in materials and environment also introduce the development of eco-efficiency materials. Through the comparative analysis, author mainly uses the LCA method to calculate each production parameter of materials then figure out the assessment data of life-cycle energy consumption and GHG emissions. Research results show that different material usage can lead significant changes in energy performance. And If chooses the new-type green materials and improving innovation of manufacturing process can greatly reduce the negative impact of building usage stage on the local environment. Results also provide a direction for manufacturing companies to adjust the principle and producing way. The properties of the materials will decide the energy consumption of building in the future, cause it calculation process need consider various factors even from different times and usage method. A lot existing energy efficiency cases are using locally raw materials and recycling wasted product for the project, and through the LCA experiment they have excellent sustainability performance. (Bribián, I. Z., Capilla, A. V., & Usón, A. A. 2011). The

code of eco- materials generally include items such as density, thermal conductivity, primary energy demand, global warming potential and water demand. Through multiple comparisons with these data, it is a possible to find a correct way to use eco-efficiency materials appropriately and change part of contrary conventional ideas of energy efficient building design.

Summary

Unlike traditional building design, energy-efficient building in a hot summer and cold winter region have greater responsive to the environment and humans comfortable. That is significant to take clarify the streamline of IDP design before the designing stage, A lot of existing green building cases have already proved that choose appropriate design method and improving building energy efficiency technical are greatly reduced GHG emissions and negative effect of building on micro-climate. Though the policy, green construction system and citizens sustainable education are wildly adopted energy-efficiency theory. But in the specific climate condition, the defects of common standards are also appearing, the vague of technologies selection of climate adaptability need careful consideration. There is no energy-efficient infrastructure can be used as universal, especially for the materials selection. For example, the prefabricated agglutination bamboo is a new type of sustainable material with strong bearing capacity, can defend fire and insects, but if architects use it into cold winter region, will add stress on HAVC system, meanwhile it consumes more water resource in the material

production stage. So the energy efficient building depends on the site and the special circumstance (Yang Ruizhen.October.2013). The LCA and another assessment system provide the amount of reference data for improving energy building efficiency. It is possible to create a more flexible designing process for those people who live in the extreme weather condition such as the hot summer and cold winter region.

CHAPTER 3
METHODOLOGY

The purpose of this research is to use the effective methods to design an energy efficient building in a region with hot summers and cold winters. This project focuses on the application of passive design and the energy-saving technologies that related with energy consumption of the building whole life-cycle, building structure and materials. The study methods show as follows: first is the study of existing cases and experiments that inorder to understand the mutual influence on the passive design and local climates. Second, is the collection of climate data of Wuhan by analysis the information from local official meteorological monitoring center, after that is the comparison of these data and relate information to improve the methods of building climate adaptability.Third is a concept design located in Wuhan, it is in order to understand the possibe methods that relate with multiple functions of each energy-saving section to improve the building's climate adaptability and energy efficiency.

Research Approach

Over all, the research is on the basis of quantitative and qualitative analysis. The topic of building climate adaptability and energy-conservation design belong to the interdisciplinary research, which means it is necessary to make manual correlation to find out the datum from different environment and background. In the other hand, there are two cooperative methods support each to prove the research hypothesis, First, is the retrospective-prospective method which use to collect the

data about application of existing energy-efficiency technologies. Second is a short survey for the opinions of local living condition from local students who have been studied related area and the green building design specialists. After that there are two kinds of established energy modeling software help to processing all these data, then make the data visualization in the concept design section. This research associated with multifactorial fields, so it is significant that identify and remedy knowledge gap by comparison related results of cases study before the analysis and conclusion.

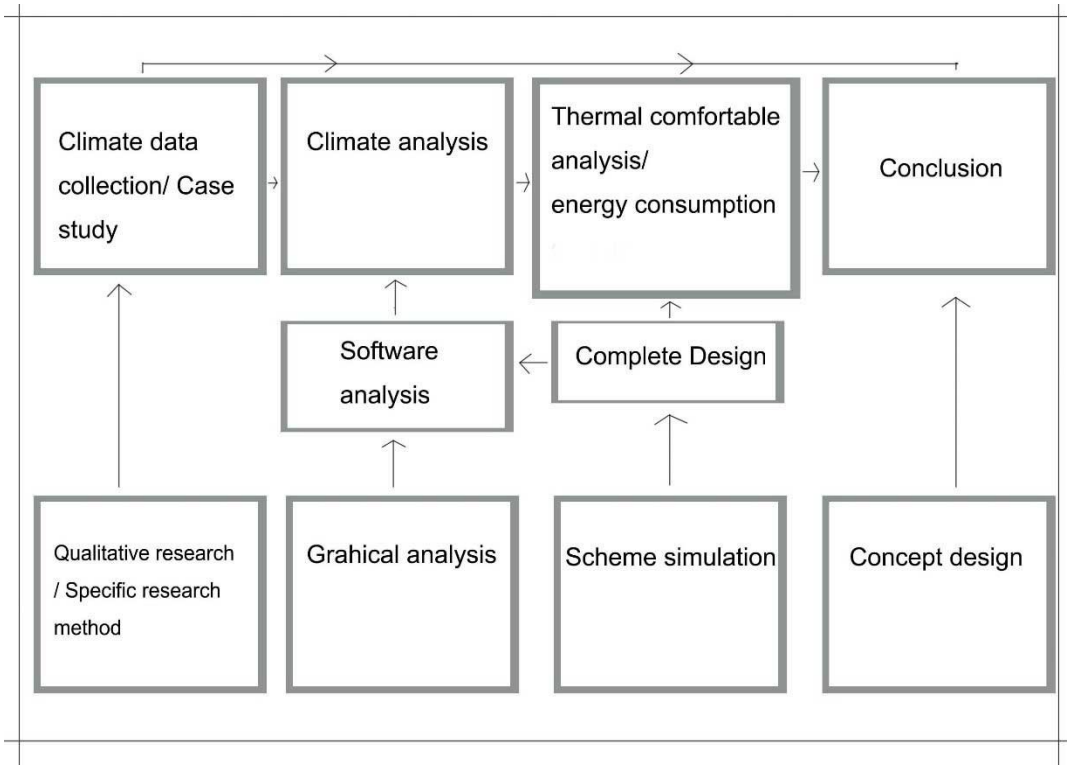

Figure 3-1. The flowing chart of research

The survey in Two Kinds of Climate Conditions

The primary data of local climate is collected from related literature and local meteorological dataset. The main parameter is divided by different seasons; data set includes air temperature, wet-bulb temperature, relative humidity, surface temperature, wind direction, wind speed and radiation. Then import the related data into software like Autodesk Ecotect Analysis and Givoni to obtain the specific design standard for each item, and it will show the climate change effect on people energy usages like electricity and water. These data also used for debugging the trivial difference of final building model. However, digital simulation always following the human perception, for the demand of the indoor comfort level, I made a simple survey for the local people who are living in Wuhan. The main information I got includes indoor temperature requirements in summer and winter seasons, which passive design method it is acceptable for them, the dependence rate of HAVC and how climate change effect on them daily life.

Building Life Cycle

Design a building with climate is a dynamic process, it is necessary to identify the building life cycle period before we do the climate analysis, select an appropriate design method and thermal comfort assessment. Show as Figure 3-2, It summarized a building energy consumption period for the concept design and data analysis, this period mainly based on building life-cycle assessment of LEED

building and construction. It is help to make a better decision in the early stage by preview a whole life-cycle energy consumption in different stage.

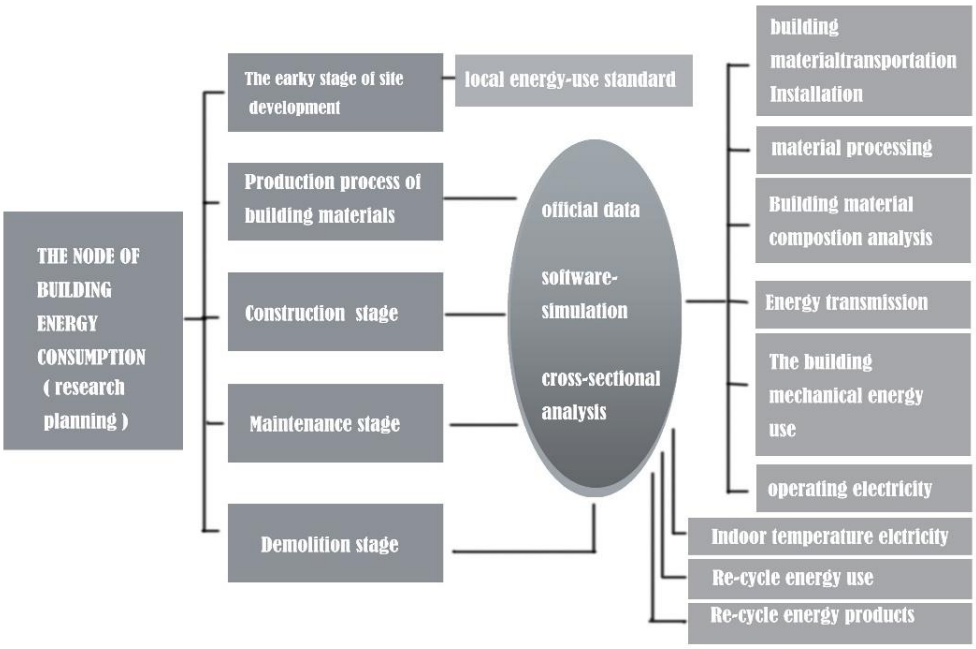

Figure3-2. Energy consumption footprint for the study

Investigation and Research on Climatic Adaptability Building

A primary reason to build a house is to adjust climate of small area for people living comfortable. In the part of case studies; first is basic information about space usage, it is for discusses of building scale and relationship with the local environment. Second is the application of the specific energy-saving methods, such as passive- solar energy design (PSED), the composite retaining structure of building and green roof. which also divided by the seasonal condition. Third is summarize the space for improvement, and consider which method can be application in the hot summer and cold winter region. Through the cases study can obtain the characteristic of building energy consumption, it can help to avoid

inappropriate design method. And also through the case study find out the method which can both used in winter and summer, and also classify the methods can flexibly use in others specific climate.

Summary

Data statistic stage including three major part: First, is from the viewpoints of micro-climate adaptability, collect useful meteorological data and observation the trend of climate change to decide design scheme. Second, make data visualization by related software then compare with the datum from literature. Third is from the viewpoints of architecture and urban city, through the cases study consider about the energy saving strategies and urban green land development, from macroscopic to the microscopic, then obtain the results for determine building methods. These steps not only rely on dataset and software simulation but also used network survey from local people. After data statistic, I will provide a concept design in the hot summer and cold winter region and summarized design experiment. Then through cross-sectional study and semi-experimental analysis obtain the dynamic solution and static solution of building design which matching each of parameter weight, In the last take out the collusion of appropriate method to design the regional climate building.

CHAPTER 4
CASE STUDY

The Ewha University Building by Dominique Perrault Architect – Seoul, Korea

The case in Seoul, Korea. It is designed for the Seoul Ewha University which is one of the best female student college in the world. The goals of design include connecting the relationship between the campus, the city of Shinchon and local environment. In the other hand, it also reduce the building energy consumption during the operate stages and efficient use of the limited construction spaces.

Background information

This is a typical earth-sheltered building fully covered by Green roof and surrounded by the city. Overall of the building looks like a valley, a sinking aisle as Figure 3-1 in the middle is the main outdoor public space for the students and the teachers. Near the both sides of sinking aisle is the six-floor-high glass wall that brings the natural wind and sunshine into the interior space. The project released by Dominique Perrault Architecture (DPA) at 2004, completed at 2008. The total area occupies 70000 sqm, site area is 19000sqm and landscape setting up an account of 31000 sqm (Dominique Perrault architect 'DPA', 2008). Earth-sheltered structure not only provides a remarkable pastoral nature space for people simply relaxing, but also make a closly connection between project and urban landscape

integration, in addition it also improved the performance of the building energy-efficient strategies, such as rainwater storage, heat insulation and so on.

Table 4-1. Basic information the space usage of The Ewha University (Data from Dominique Perrault Architecture, 2008)

Program/ Userspace	Data	Program/ Userspace	Data
Classrooms(sqm)	3600	Administrative program (sqm)	5700
2 amphitheaters, audience capacity (seat)	90	Commercial program(sqm)	5700
2 amphitheaters, audience capacity, (seat)	200	2 Screen cinema(seat)	162
Library(sqm)	2000	Bank (sqm)	100
Computer rooms, workshop space and study hall(sqm)	6000	Post(sqm)	300
4 amphitheaters, audience capacity (seat)	80	Fitness club(sqm)	1000
Hall and Common use space(sqm)	15000	Theatre(sqm)	750
Underground car park (vehicles)	750	Chapel(sqm)	200
Student plaza(sqm)	1000	Student theater and exhibition hall(sqm)	1000

Figure 4-1. Site plan (Data from Dominique Perrault architect DPA)

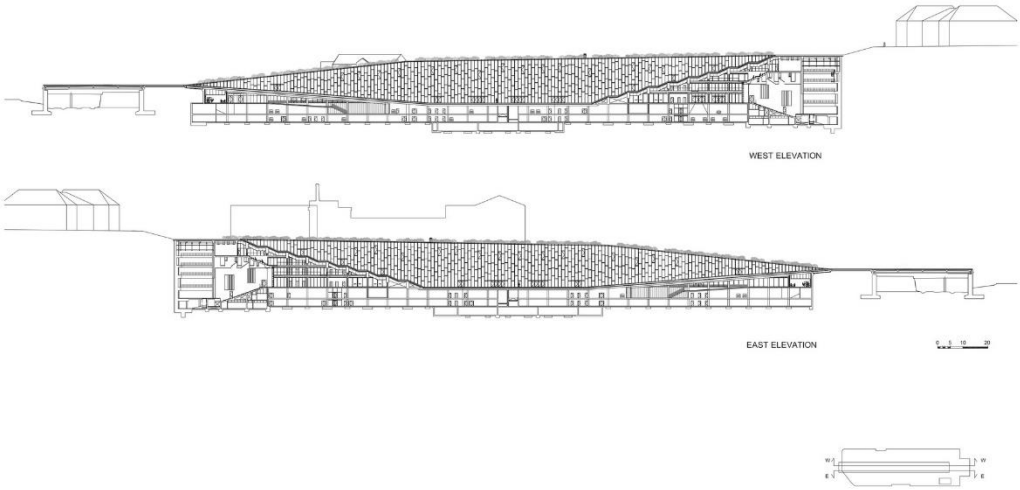

Figure 4-2 West& East Section, (Data from Dominique Perrault architect DPA)

Passive-solar Energy Design (PSED)

As Table 4-3 and 4-4, Ewha University project has great energy-efficient performance of heating and cooling system. The glass walls of building toward to north and south direction each respectively covered the entire elevation, these let the sunlight be able to directly into the interior, this method ensured enough demands for inside lighting and winter heat absorption; indoor facilities can store

and release thermal energy when indoor temperature have changed. Generally, for the earth sheltered building can only use the open roof or patio to solve the problems of lack of the passive- solar energy design. The core aim of the PSED is not to rely on the artificial devices like heat storage, heat accumulator, water pump, but through the building itself to reduce the conventional energy consumption. At the same time, PSED also reduces the cost and difficulty of construction.

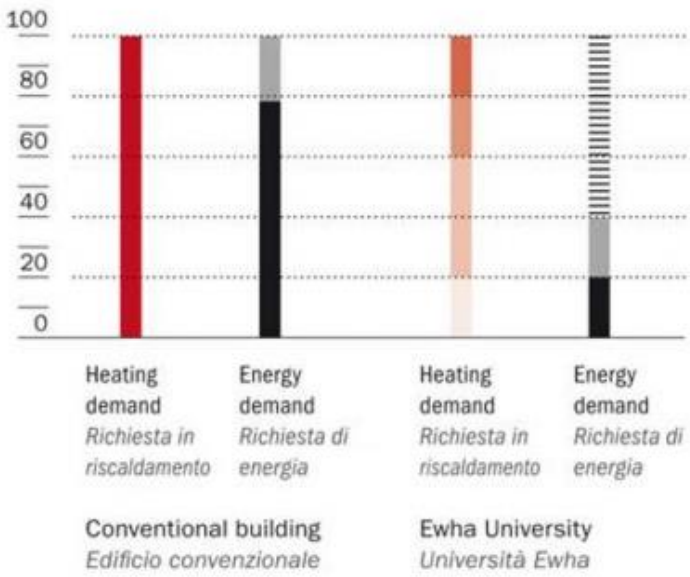

Figure4-3 Heating energy comparison, data sources: (Dominique Perrault architect 'DPA', 2008)

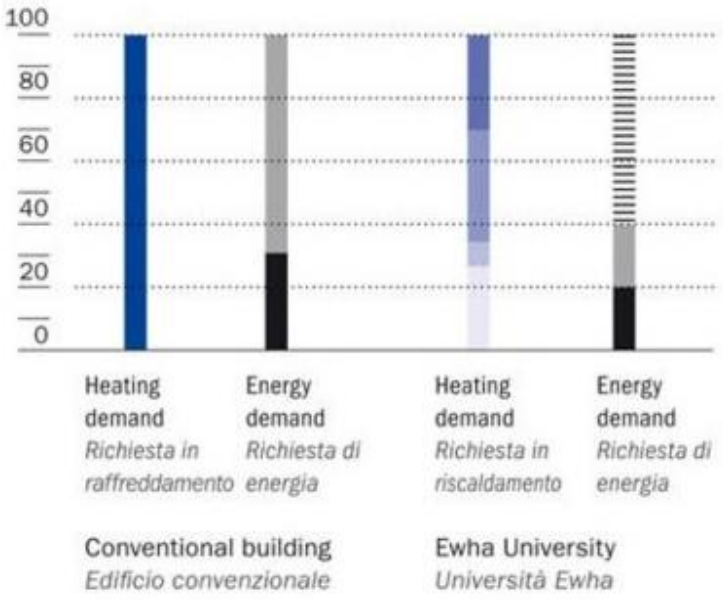

Figure4-4 cooling energy comparison, data sources: (Dominique Perrault architect 'DPA', 2008)

For cooling in summer, the Ewha University improved heat dissipation by using air convection system to organized natural ventilation. This strategy is composed by three major parts; first is natural wind pressure ventilation system, show as figure 4-5, use the local eddy that created by the pressure of leeward side and windward side of building to drive the air flow. Second is thermal natural ventilation, this method has more adaptability to work with changes of the outside temperature conditions. Because of different air density between the indoor and outdoor, high-temperature air will rise and go out through the roof vent, meanwhile, low- density fresh air be inhaled into building through the bottom vent. Third, show as figure 4-6, 4-7 is mechanical aids combine with the wind pressure ventilation and thermal ventilation. In summer, the foundation slab drainage under-layer is equipped with pipes connected to water tanks; the air is pre-cooled to lower the temperature by

approximately 7℃. In winter, building use CHP plants to produce electricity and heat, the air temperature is pre-heated to raise by approximately about 11℃. (Dominique Perrault architect 'DPA', 2008)

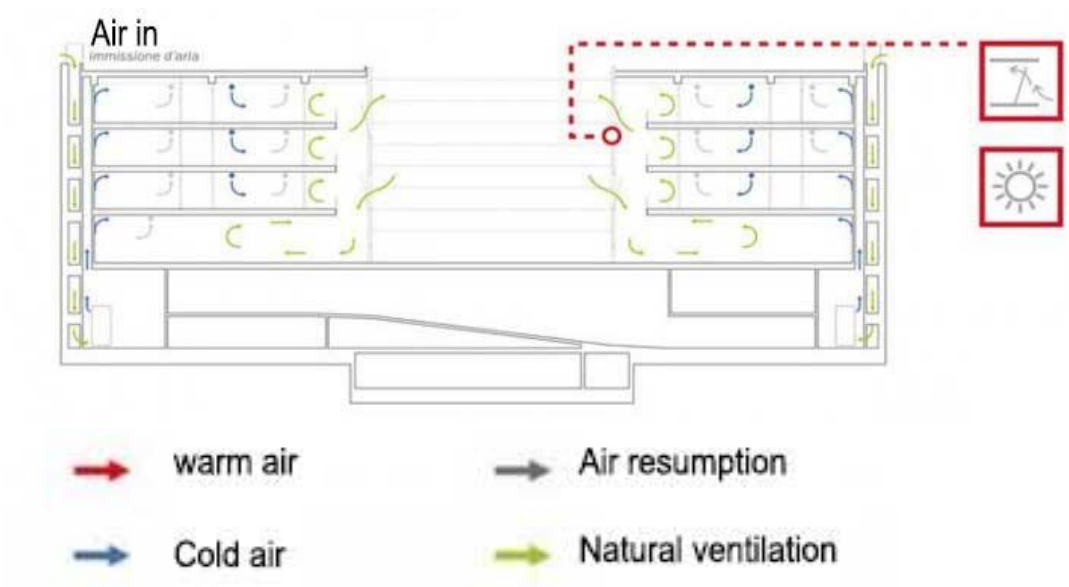

Figure 4-5 MID season: Natural ventilation and natural lighting in the Ewha University (Dominique perrault architect 'DPA', 2008)

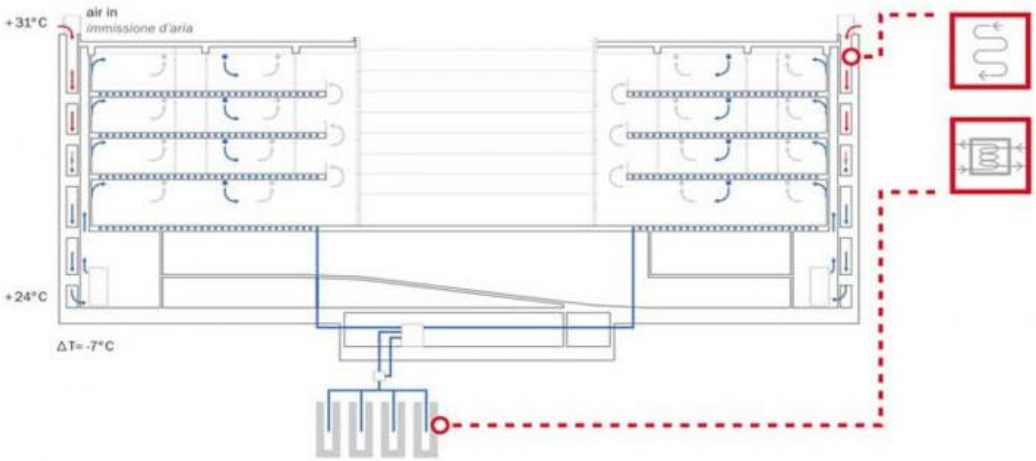

Figure4-6 Summer: thermal labyrinth and ground water energy in the Ewha University(Dominique perrault architect 'DPA', 2008)

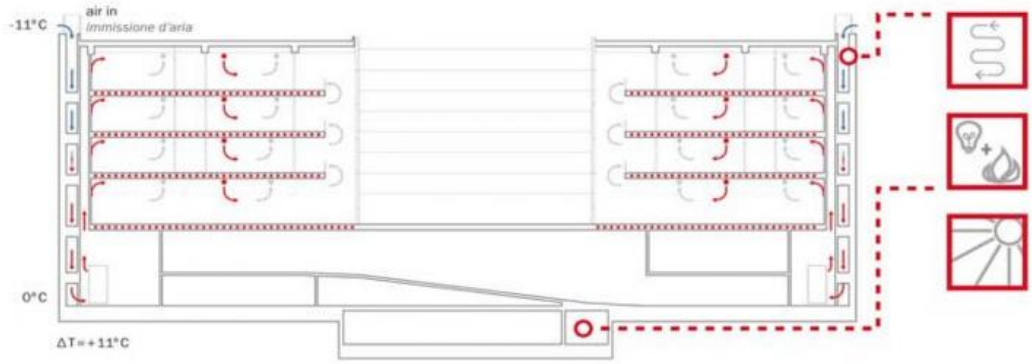

Figure 4-7 Winter: thermal labyrinth and ground water energy in the Ewha University (Dominique perrault architect 'DPA', 2008)

The composite retaining structure of building

The structure of roof, wall, doors and windows are fully consideration with the ventilation and sunshine, at the same time, it also used for shading and insulation. Except earth sheltered part of the composite retaining structure of the building, steel and glass curtain wall responsible for the direct sunshine adoption and stable sunshade. The double-layer tempered glass like Figure 4-8 has the great insulation performance than traditional one, two pieces of glass with one suspended heat mirror film construct the unique dual-space structure. Also in winter, the insulation gap provide a buffer zone to retaining the heat loss in the building. For the sunshade, building installed the steel vertical sun shield, it is mainly to shade the sunshine that from north-east, north and northwest. The connecting structure of double curtain wall is aluminum alloy material with high thermal resistance and volume stability. Aluminum alloy is a commonly energy-saving material which has low impact and high recovery value. However, the glass curtain wall is one part of all the system, it cannot work independently for high energy-efficiency improving ,

it is necessary to work with other retaining structures. Wall through the heat storage structure layer like polystyrene improve the thermal insulation ability, for the different wall orientation use the different thermal resistance value to arrange the indoor thermal buffering. Building use ventilation, evaporation and long wave radiation methods to increase the heat dissipation from the wall. At same time project sets ventilation gaps in the wall, window, beam and pillar that also help to avoid the moisture condensation on a structure, all these strategies are effectivly to control the indoor humidity.

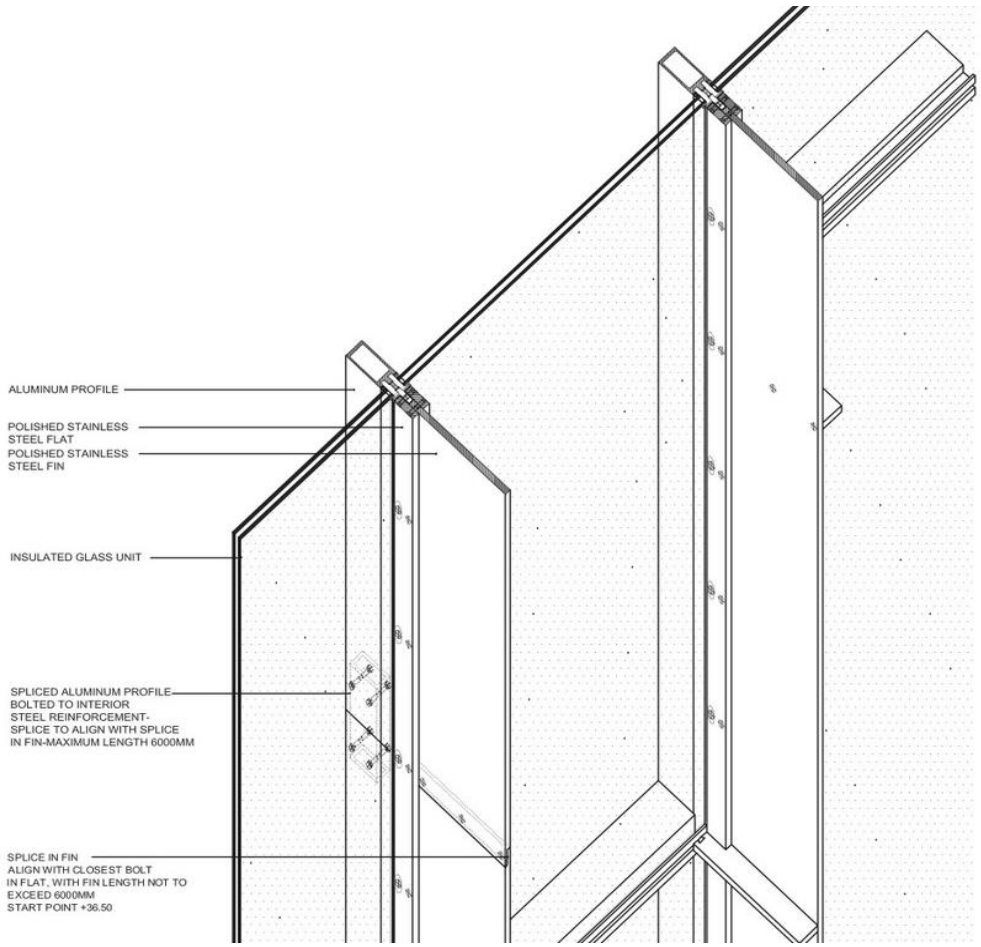

Figure 4-8. Detail of glass wall of Ewha University (Dominique Perrault architect 'DPA', 2008)

Earth sheltered structure

Roof is the one of most important maintenance structure. The half-earth sheltered structure of Ewha University maximize use its advantage for the energy-efficiency. Earth sheltered means building be covered by natural entities, it as few as a possible to change of original landform, meanwhile use the natural heat insulation ability of soil to make building energy-saving and local climate adoption. There is the different temperature of soil between the upper layer and down layer, the general condition in summer, down layer temperature of the soil is lower than local outdoor temperature; there is the contrary performance in winter. After the rain, water evaporation will take away with big part of heat energy. This process ensured stable temperature and humidity of the indoor environment. Soil for roof garden mainly used humus soil to promote plant growth, heat insulation, and also it decrease the load of the roof structure. For the local climate, outer soil layer transition and absorbed building GHG emission, provide more space for the green vegetation, it is significant reduced operation energy loss, low building high improve the urban air duct. The earth-sheltered structure also brings the earthquake resistance and noise insulation resistance for users. In the other hand, according to statistics, Maintenance cost of the building is 18% lower than conventional building in the same scale and saving the more doors and windows construction cost.

Green roof

Building surface reflection and operating GHG emission are the major reasons cause of urban heat island. Vegetation cover can effectively resolve these problems. Use plants to covered roof as a reparation damage to the urban environment, students and faculties can easily contact nature environment in any time, the building not only devotes itself to the people but all the local biological. From a spatial perspective, green roof improved thermal environment of indoor and outdoor, ensure the living comfort and health, avoided the ecological disruption. From the climate view, green roof absorbs the heat energy, reduce the sunlight reflection. From the architecture view, plants improved the insulation and water storage function of soil, and also reduced the energy consumption of building external envelope structure. Now day, green roof becomes a necessary method to practice the urban low impact development and passive designing system. Green roof structure includes the following layers (from top to bottom):

- Planting soil layer – Use artificial soil that benefits for plant growth, such as perlite, peat moss, vermiculite and another type of light soil
- Filter layer – In order to catch impurities that fall down from the planting soil layer, ensure the drainage pipe working.
- Drainage layer – When the water absorption of plant and soil layers approaching the saturated value, drainage layer help to release the excess water.

- Root barrier – Can be able to withstand penetration power and corrosive from roots to protect understructures. Materials include aluminum coil and high- density polyethylene (HDPE).
- Isolation layer – Avoid preventing rejection between the Root barrier layer and waterproof layer.
- Waterproof layer – The Ewha University used flexible waterproof that composite by waterproof coils like ethylene diene monomer (EPDM), hollow foam and waterproof coating.
- Thermal Insulating layer – Light polyethylene foam plane.
- Building structural layer – Thick roof panel, mainly use of precast reinforced concrete.

Rainwater treatment

The earth-sheltered structure provided the advantage of using passive design, the more gradient the pitch, the more effective of the roof for drainage and water collection. At the same time, rainwater collection system not only can provide re-use water in the season that lack of rain, but also can mitigation the stormwater and recharge the groundwater. The Ewha University has the high-efficiency rainwater treatment system for reducing the portable water consumption. Rainwater is collected from the roof, stored, and then used as needs arise. Through the rapid run-off green roof surface, rainwater can fall into the bottom pipeline. There are three types of equipment under the building for the rainwater

management, first is rainwater collection pipeline, it is for divide rainwater from green-roof. Second is a rainwater sewer which can clean the collected rainwater before it is stored in the main rainwater tank. Third one is a rainwater tank, which provides re-use water for the flushing toilets, irrigation and vegetation watering. Water collection system works with the geothermal system and thermal bridge of building can supply the adjustable temperature of re-use water that reduced electricity energy consumption. (Dominique Perrault architect 'DPA', 2008).

California Academy of Sciences (CAS) by Renzo Piano Building Workshop -San Francisco, CA, USA

Background information

The natural history museum covered 197,000 square feet area, and there are 1,700,000 plants covered on the living roof. Show as 4-9. Two domes help to bring in sunlight, when open the window glazing on the dome can also support ventilation. Soil covered structure effectively reduced the demand of air- conditioning. The double photovoltaic cells panels provided more than 5% of the total electricity energy use. 90% of materials of the project is renewable, there are 15% fly ash, 35% slag in concrete and 68% of insulation comes from recycled blue jeans. 90% of office space covered by the skylight and natural ventilation. The project has 30% less energy consumption than the federal standard. The reclaimed water from the city be used to irrigation, flush the toilet. All these sustainable achievements helped

this building obtain credits for LEED platinum certification. (Renzo Piano Building Workshop, n.d).

Figure4-9. Plan view of CAS. (Renzo Piano Building Workshop, n.d)

Green roof

The typical tar-and–asphalt building caused the urban heat island, project applied plants to replaced hard pavement. According to the statistic, the green roof of CAS absorb around 3.6 million gallons of rainwater per year, due to the soil heat absorption and photosynthesis of plants, it helps to reduce 40 degrees than a standard roof and makes indoor temperature 10 degrees than a traditional roof. The photovoltaic cells on the roof also reduced 10% of the energy needed that about 400,000 pounds of GHG emissions per year (Renzo Piano Building Workshop, n.d). At the same time, the roof with the curve modeling which draws cool air into the room reduce the regional wind resistance, it can effectively improve on microclimate.

Heating and cooling

Visitors can easily look the outside landscape from the inside of the museum, the glass wall of building used low iron content for the excellent permeability, these glass curtains provide sufficient landscape view and natural light. For the ceiling glass, it not only helped to bring in sunlight but also can support for ventilation, reduced the dependence on HAVC system and air-conditioning. The circular skylights on the top of rainforest and planetarium, it can automatically open and close for emission or storage the indoor thermal. All this project used the highly-insulating window and façade system which has high performance on thermal insulation to ensure the completely climate control and natural sunlight serve.

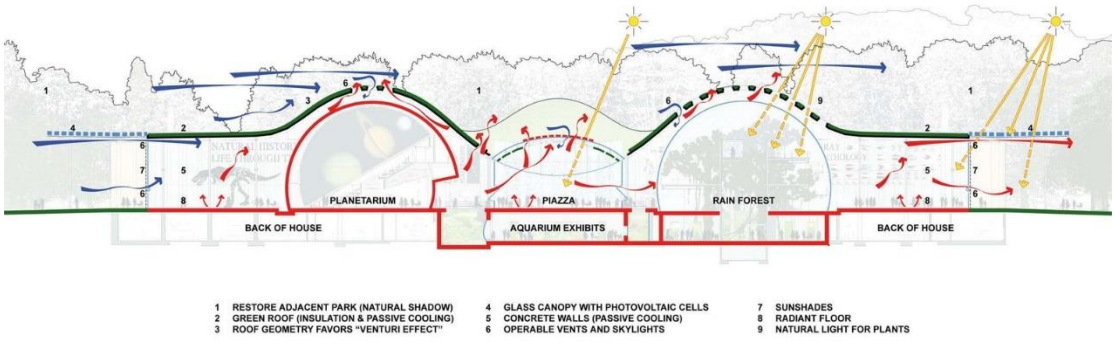

Figure 4-10. Indoor ventilation of CSA. (Renzo Piano building workshop, n.d)

They also used radiant floor heating for interior comfort that can saving energy, the hot water tubes embodied in the floor, heating the other part of structure then

effect on indoor air temperature, because of the large floor area, the impact of this method is obvious. The heat recovering systems collection the waste heat by HVAC equipment to decreasing the cooling load. The high- lying ventilation flaps generally open at night, like other cooling devices it is controlled by indoor temperature, Co2 condition and air humidity.

Nanyang Technological University (NTU) School of Art, Design and Media (ADM) by CPG Consultants – Singapore

Background information

Completed in July 2006, the building is the first professional art school in Singapore, total area is 215,000 square feet. A green roof of this five-story school has a 45-degree slope, it is responsive to the hot ambient temperature, intense sunlight and slowing runoff of Singapore. The various fountains be set in the courtyard, this interior space not only beautifying the surrounding landscape but also effectively decrease the microclimate. Due to the tropical climate, Singapore has plenty sunshine with overly hot and humidity through the year, building placing the facades which fixed with a double-glass curtain to facing north and south. The courtyard in the middle conduct the natural wind and skylight into the room. (CPG Consultants. n.d.)

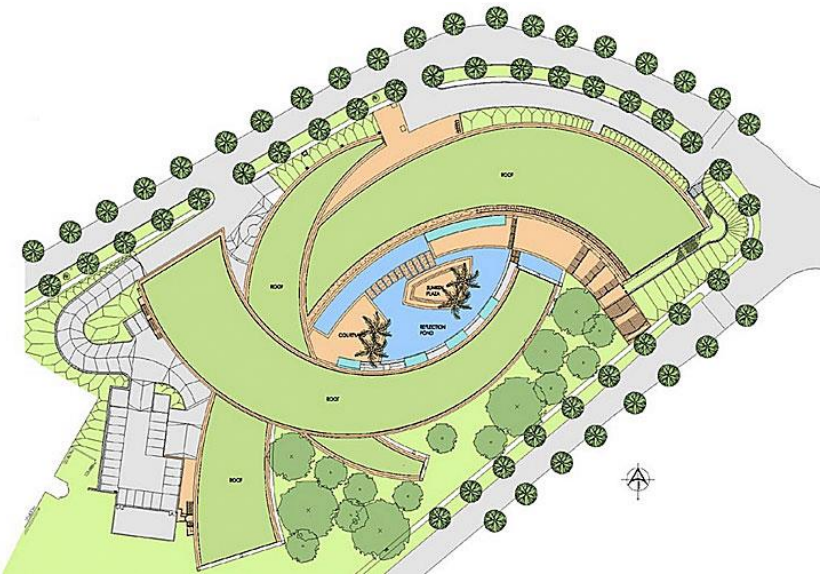

Figure 4-11 Plan drawing (CPG Consultants. n.d.)

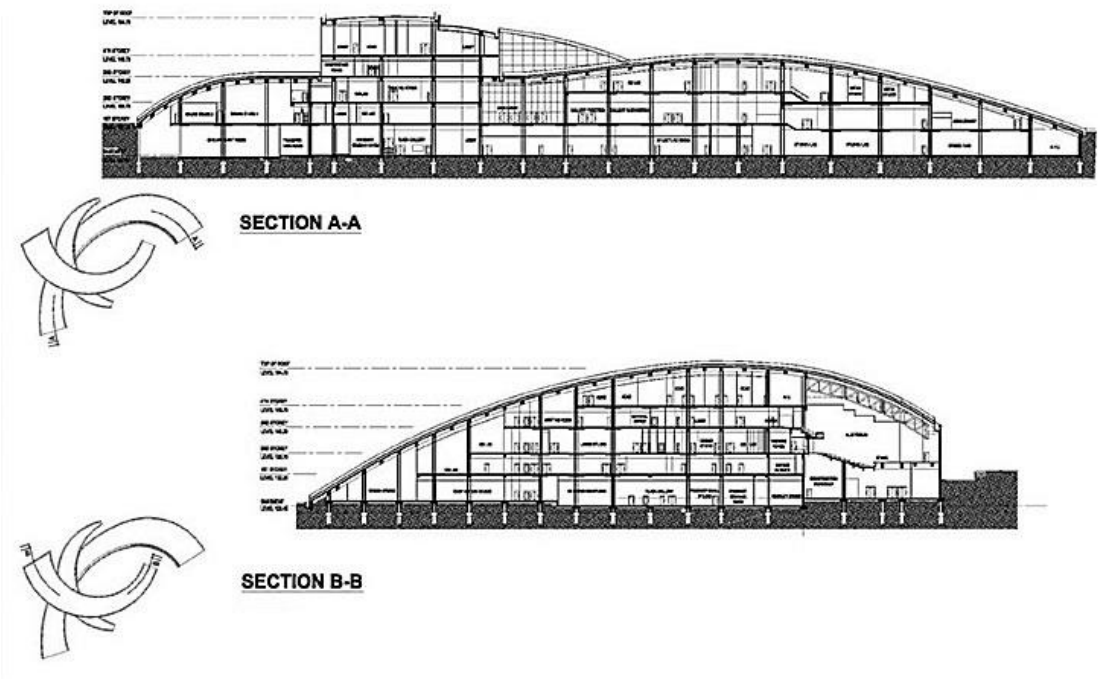

Figure 4-12 Section (CPG Consultants. n.d.)

Green roof

The green roof not only gives large 'extra' space for people socializing and relaxing but also provides a good platform for ecological and energy saving. In Singapore, the average annual precipitation reached 175 mm, and average relatively humidity reached 84%; around 70% of rainwater is effectively collected by the green roof. Rainwater harvesting system as part of water circulation, all the rainwater will be conduct to the wastewater separation and treatment system for flirting and cleaning, then send for irrigation, sanitary water use and other operation water use. At the same time, the green roof protects direct sunlight radiation resistant heat energy across the roof, reduced load of cooling air-conditioning. A large area of plants on the green roof is also improve the indoor and outdoor air quality, decrease the demands of healthcare expenditures. Except that, green roof also improve the electromagnetic radiation reduction, noise reduction and increased roofing membrane durability. (Nanyang Technological University (NTU) School of Art, Design and Media (ADM), July 2014)

Heating and Cooling

The exposed façade glass curtain bring in enough sunlight for working and studying, and it double structure has insulation barrier with dark color that prevent heat gain and loss by the different intensity of sunlight. In order to meet the cooling and heating needs, building used environment- friendly air conditioning system which is low cost and easily installation, one of this units can work for fifty rooms.

This system can automatically control each part of compressor work for different cooling and heating request. Except air machinery conditioning, building applied a series of passive design. In order to take the advantages of venture effect for indoor ventilation, building effectively use the Venturi effect for adjusting indoor thermal. Show as Figure 4-13, it along with the transfer of heat energy that drive by the air movement to create self-air movement in the building. In the low area, high air pressure drives cool wind move to the low-pressure area. In these process, air temperature from cold become warm then released by the vent on the top, after that warm wind will be cooling by cold flow through the green roof, as this way, it effectively avoids abandon air heating the atmosphere. In the conventional building, a large part of heat energy made by the light bulb, however the project used fluorescent light for release less heat than normal light bulb. (Nanyang Technological University (NTU) School of Art, Design and Media (ADM) ,July 2014)

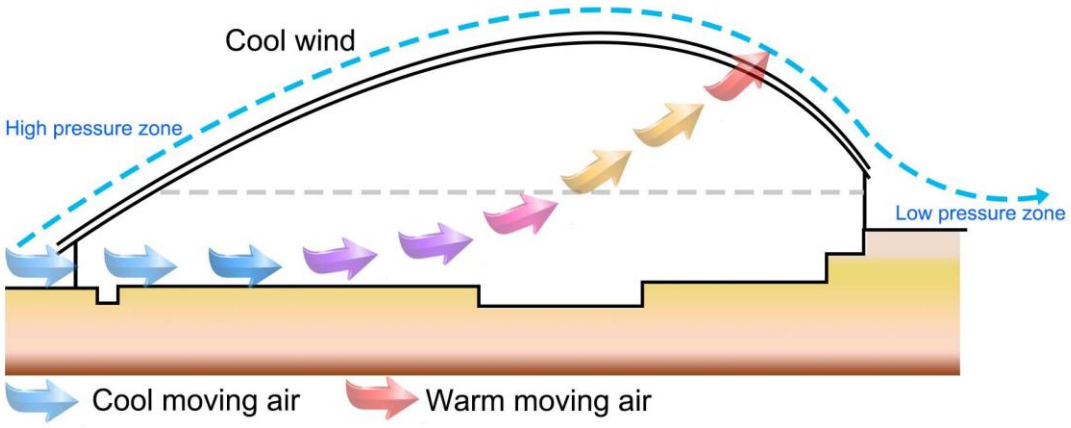

Figure 4-13 Venturi Effect on Section BB'

From case study to the design

These cases illustrate the thermal exchange between the indoor and outdoor environment, there are three methods as follow. First is the conductive of building envelope, second is air convention; third is thermal radiation of building surface. In addition, under a hot and humid climate condition, the evaporative heat loss also can significant effect on the thermal exchange. Through the heat exchange patterns control formed the basic climate design strategy. In summer, design should focus on reduce the heat gain, heat conduction, warm air permeability and sunlight radiation. Meanwhile it should also pay attention to Increase the heat loss, natural ventilation, thermal radiation release and evaporation heat loss. All these cases are large public facility buildings, there are plenty reference value for the design in Wuhan, such as green roof system, courtyard design, passive solar design and thermal envelope. Nanyang Technological University (NTU) School of Art, Design and Media (ADM) and Ewha Woman's University used sloping roof and connecting interspace to extremely improved natural sunlight and air pressure ventilation. There are four aspects generally affect the climate responsive strategies selection. First is collect the data of local sunlight radiation, wind power, temperature and humidity, and manage these data to consider about local architecture lighting, ventilation, evaporation and solar energy consumption. Third is to meet the requirement for passive design by consider about the group layout,

building shape and local structure. After that use quantitative analysis method for design strategy assessment and final decision making.

CHAPTER 5
A CONCEPT DESIGN OF SUBWAY STATION IN WUHAN

Introduction

Figure 5-1. Aerial view

An Idyllic scene is an old song written by The Tang Dynasty poet Wang Wei, it is describes the silence and leisure view in the mountain. Without noise, Birds, flowers, all the universe follow the law of nature, all the creatures living together and make each other become better. My grandmother told me that riverside was like this scene at a long time before, however with the development of Wuhan, Industry and construction broke the silence, green space and lake be removed, the sounds of birds also disappeared. Now is time to bring it back.

It is not only a traffic hub but also the hub for natural resources. This public facility includes functions of transportation, commercial and tourist landscape. The design purpose is to fit local climate, reduces the building energy consumption in

the special weather conditions. Meanwhile, it will not destroy the local ecological system but reducing the building energy consumption. Meanwhile, promote the collection of the local waterbody, pretreatment different water-class system. Also, the building used various energy-efficient technologies that can also enhance the comfort of users living.

Site Analysis

Location

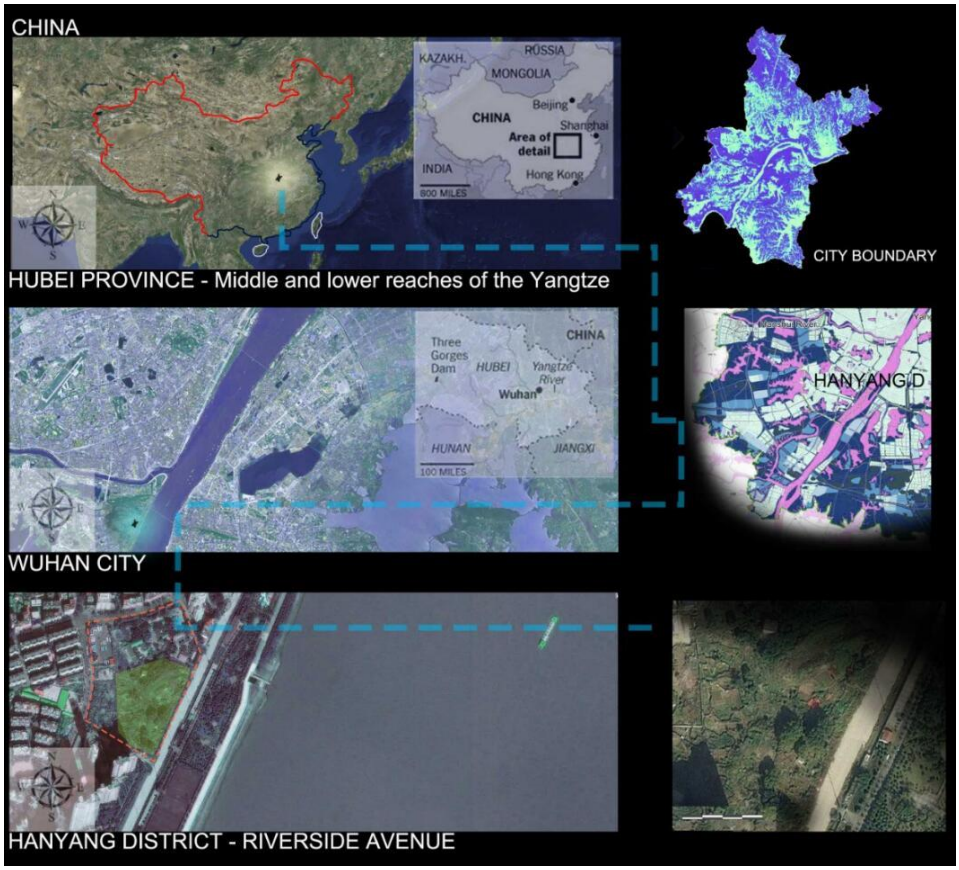

Figure 5-2. Location analysis (Software: Arcgis, Photoshop)

The project is located in Wuhan city, where a typical hot summer and cold winter region. Wuhan has a long history and plenty natural resources. The gross area of the city is 8494 square kilometer; the urban area is 8494 square kilometer, urban residential population about 10.338 million, urban population density about 1152 square kilometer. Agriculture area accounts about 66.04% of the gross city area. Wuhan city now has 147 lakes, total area lakes area reached 17535.27 hectares, a large amount of water areas and wetlands provide plenty space of the biological habitat for fishes and other animals. From Wuhan municipal bureau

statistic, the region of Wuhan in the Yangtze River have 88 species terrestrial animal and 45 types of water animal.

The building is in a reconstructing natural park which located near the Riverside avenue, one block from Yangtze River. Currently, the parcel in the reconstructing stage, the master plan is to build a quiet scenic site in the fast bustle city, the main factors of the site includes plants, trees and lawn. There are no tall building in the block, because of soil quality is relatively soft not suit for high construction. Topography form of the parcel is relatively fluctuant and general slightly inclines to the southeast direction.

Site traffic

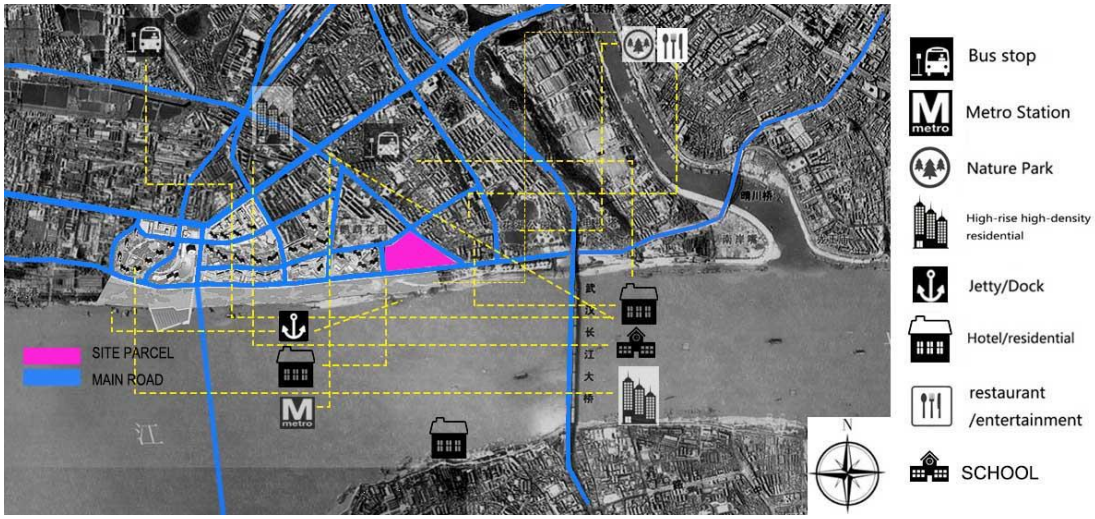

Figure 5-3. Site traffic analysis

The site near the river has the complex and diverse underground water network; it is also a major transport Center at Hanyang district. Because a large number of residential areas around the site with high school and kindergartens and at the middle of two Yangtze River Bridge, there are heavily traffic stream

throughout the year. The design considered about the significant load of pedestrian flow.

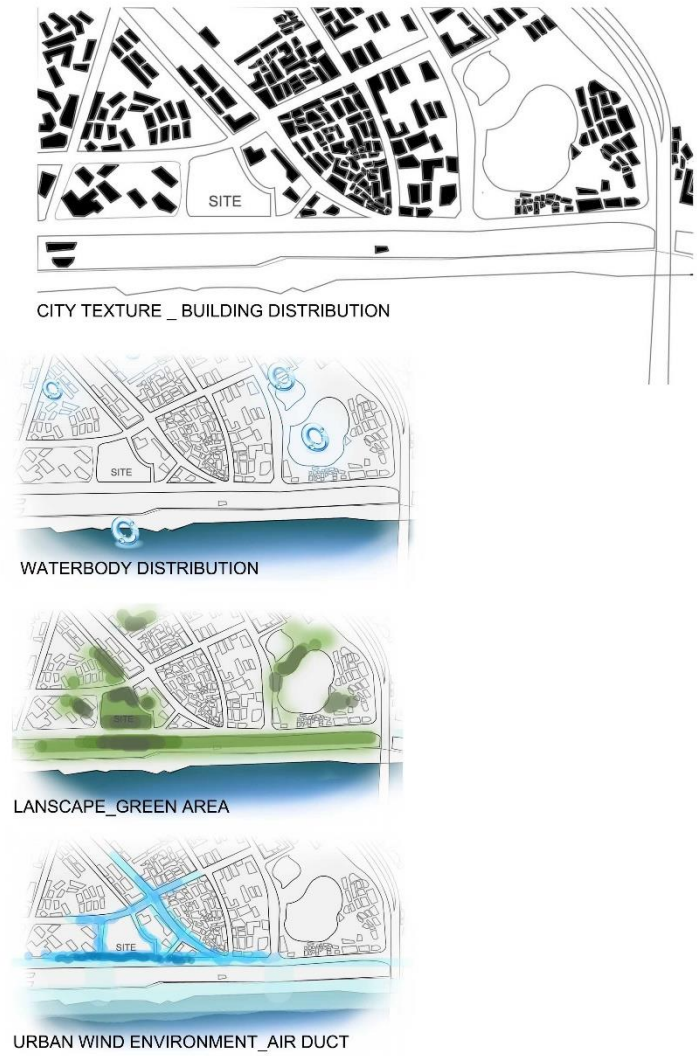

Figure 5-4. Urban relationship analysis

Most of surrounding building like sub-quadrate, so I designed a curved building hope to bring a etherealize element into a busy and tedious environment. The curved surface can also help to design the green strategies of water and wind. There is no tall building around the site, have good urban air duct, but at the same

time, no screen can obstruct cold wind from north-east side. Green infrastructure and blue infrastructure linked with each other. But now with the development of urban construction, this link has be interrupted. The building is also for connecting the city and ecological environment.

Site plan and size of project

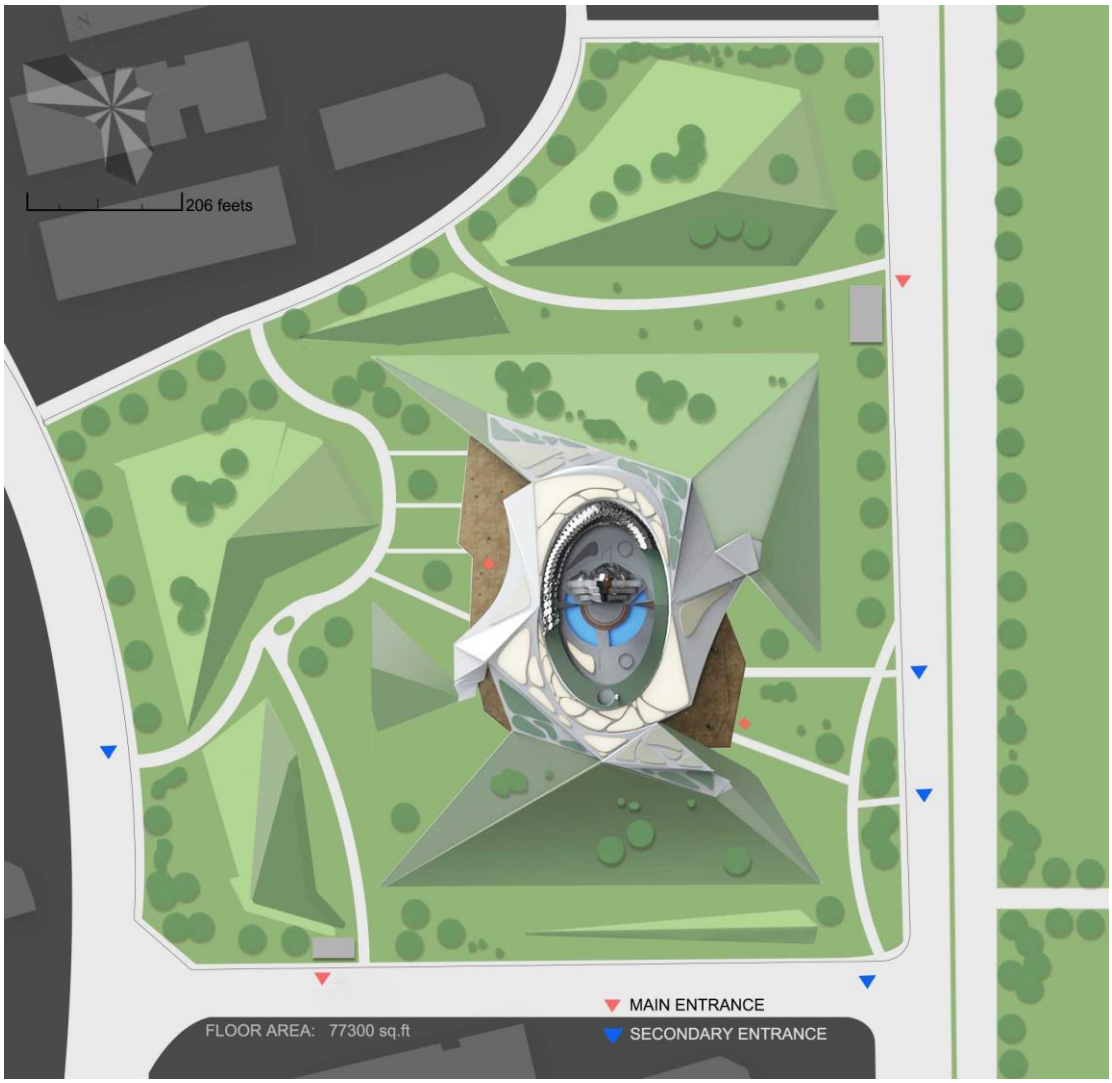

Figure 5-5. Site plan and size of project

In order to protect those original plants on the slope and save the utility of land use, it is inappropriate to remove the slope for the construction. So building is half-

earth sheltered, the roof covered by different vegetation layers and connect with slopes. Building is embedded between the three small hills. People can easily go to the roof runway from any point of slop for the relaxe and entertainment. Those people who need enter or exit the subway station can come through four main entrances and five secondary entrances. The secondary entrances are mainly served for park walk and be divide by pedestrian traffic system.

A successful size decision of building design can take the advantage of original site condition, the construction land area of this project is 16492 square meter, there are three major elements for determines this size and overall shape of building. First is the huge flow of people that need large space for activity and safety, the high population density means high energy generate and it will also cause the high internal cooling loads. Second is the multiple function organization, it is necessary to consider about the transportation, shopping and entertainment space. Third is the performance of energy efficiency. Building massing is closely related to passive design, the first floor account half of building total area that is in order to use the advantage of green and soil covered structure to reduce the cooling energy consumption, and also support rainwater harvest. In addition, there is a typically oval courtyard around 6217 square meters in the central that can appropriately conduct the natural sunlight into the room, at the same time, it also leaves enough area for the central pond for reserve water. The thin annulus building lets wind and sun can easily cross the interior to increase the heat loss in summer.

Climate in Wuhan

Wuhan city has a muggy and wet climate in summer, this type of weather will last from June to September, there no obvious daily variation of local temperature. The average temperature is 77°F to 80°F in hottest month，about 20 days higher than 95°F, the highest temperature in past 50 years is 103.28°F at 2005. In the winter, generally start from December to February with high air humidity, about 70 days temperature lower than 41°F, the average temperature in January is 32°F to 50°F. (The annual and daily value data set 1981-2010. Aug， 2012)

Winter and summer Psychrometric chart.

(Software: Ecotect, weather tool. Data Source: Meteorological data set for building thermal environment analysis of China)

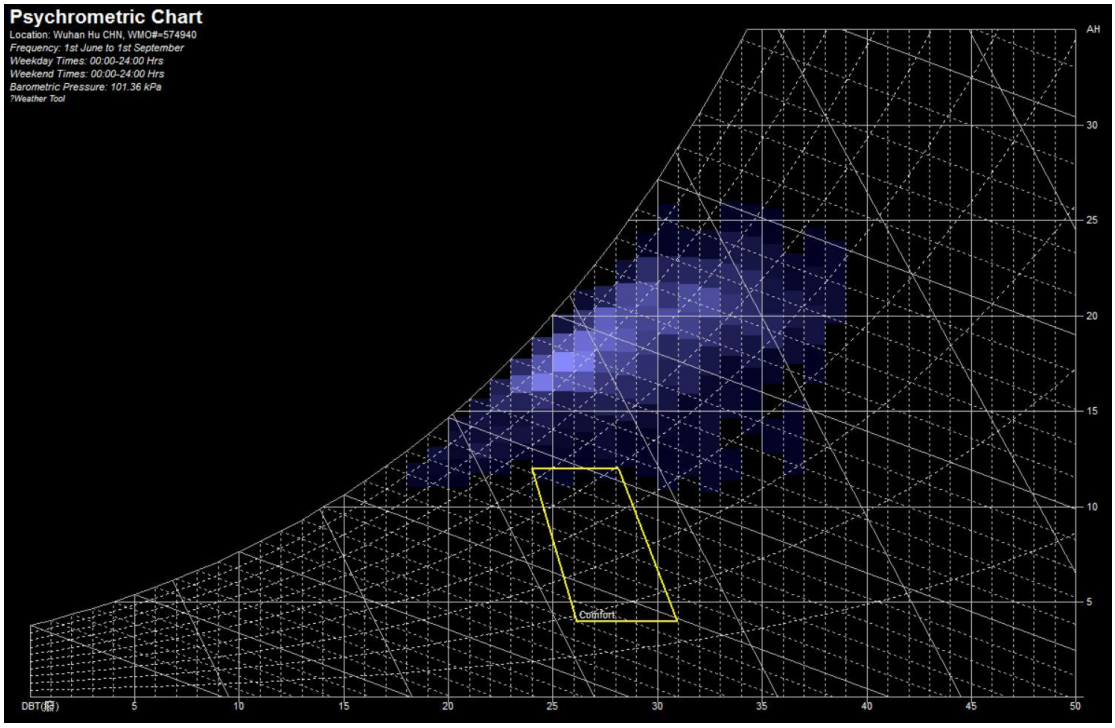

Figure 5-6. Summer psychrometric chart of Wuhan.

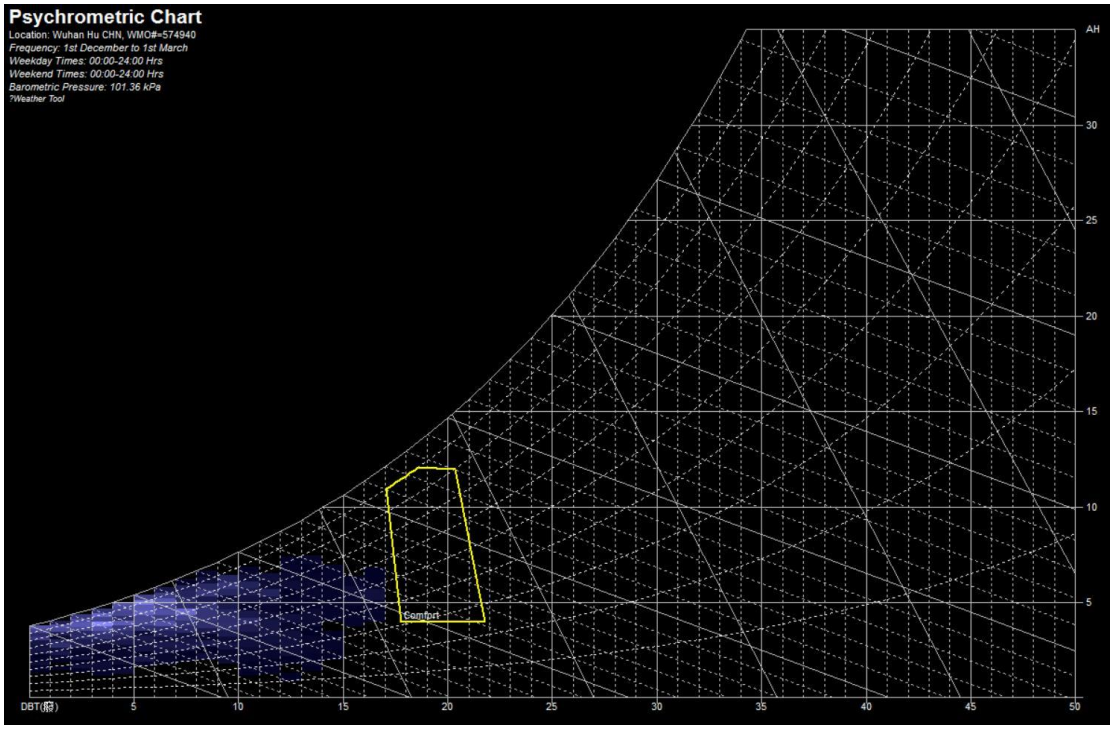

Figure 5-7. Winter psychrometric chart of Wuhan.

The Psychrometric chart is used to determine the state of the air in the thermal environment. There are four basic parameters show on the figures: temperature, humidity rate, air pressure, actual vapor pressure. The abscissa axis represents Air dry bulb temperature (DB, ℃); the vertical axis represents absolute humidity (AH, G/ kg); curve represents air relatively humidity (RH, %); The purple blocks represent specific heat capacity (VOL m^3/ kg). Yellow line represents a living comfortable area and the relationship with all the parameter. We can clearly see there is a great deviation between the comfort standard and actual temperature. In the actual design it is necessary to face the excessive hot humid summer and cold dry winter.

Trend of historical temperature variation - January, April, July, October

Figure 5-8. Historic temperature of Wuhan

From the historical average temperature, we can see that summer keep a high temperature and be on the rise, winter is cold and the temperature is not stable. Design should avoid the impact of the minimum and unstable temperature in the winter.

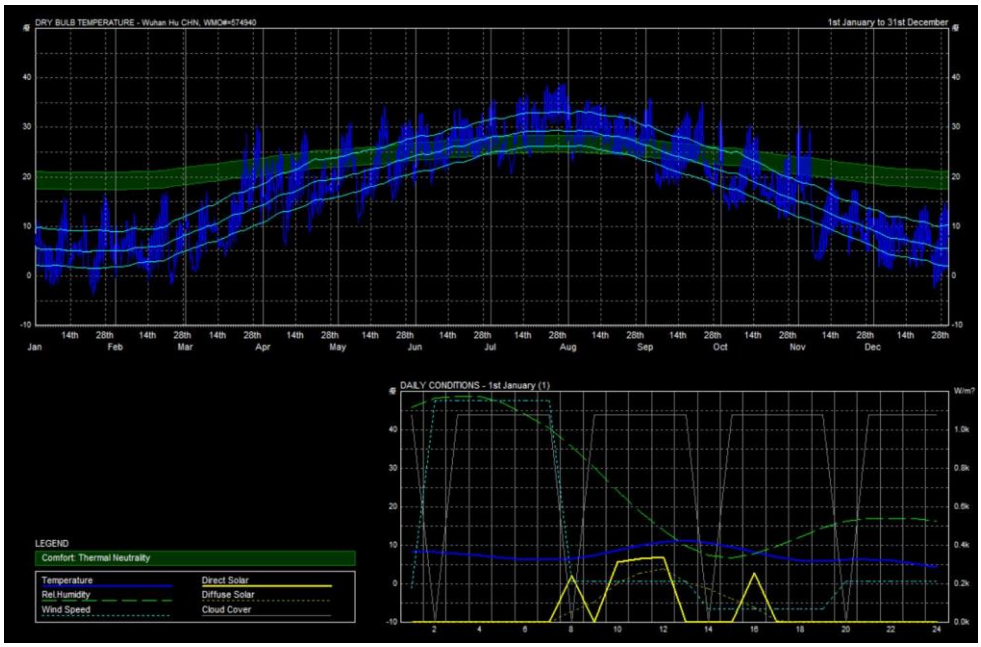

Figure 5-9. Annual dry ball temperature of Wuhan by Ecotect analysis

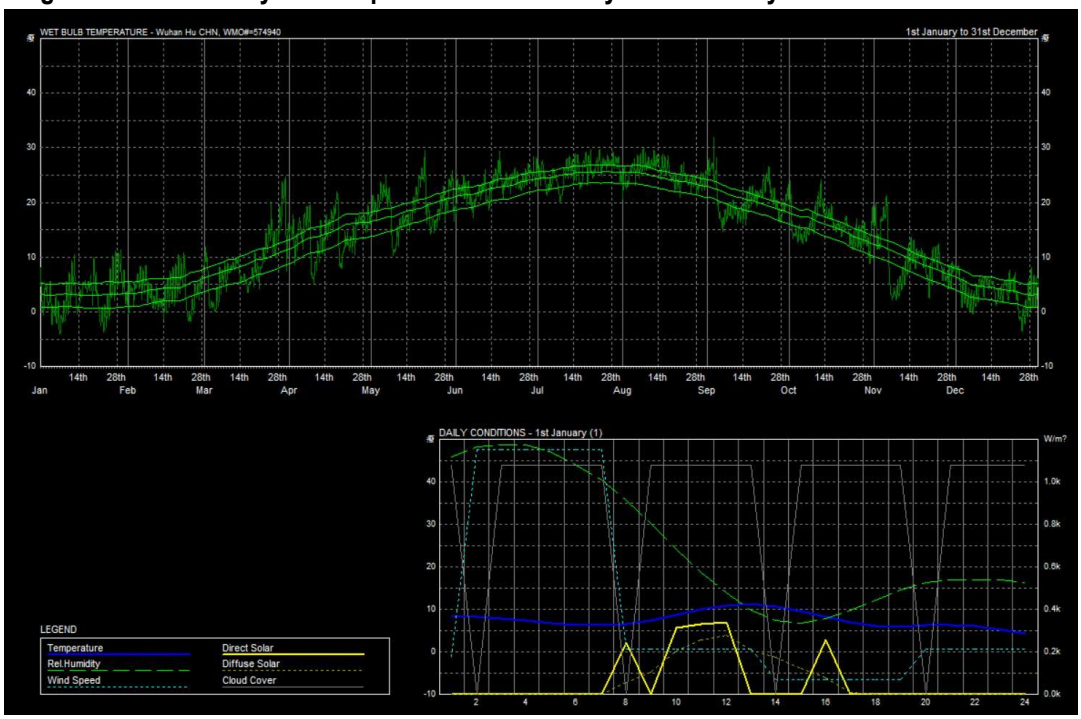

Figure 5-10. Annual wet ball temperature of Wuhan by Ecotect Analysis

The abscissa axis is data, the vertical axis is temperature and relative humidity, the green line is the best comfort of temperature. We can make a dynamic analysis of the annual building heating and cooling period. From the middle of May to September need using cooling equipment, from December to March need using heating equipment.

Summer climate factors comparison (Software Ecotect, weather tools)

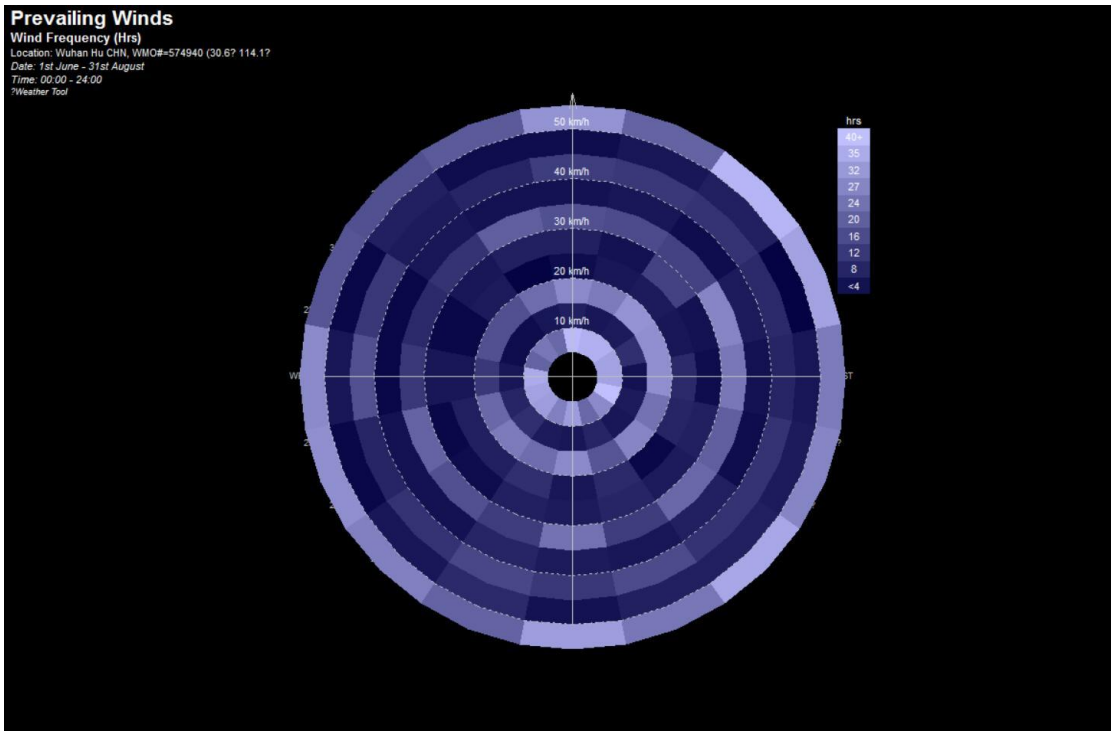

Figure 5-11. Winds rose of summer

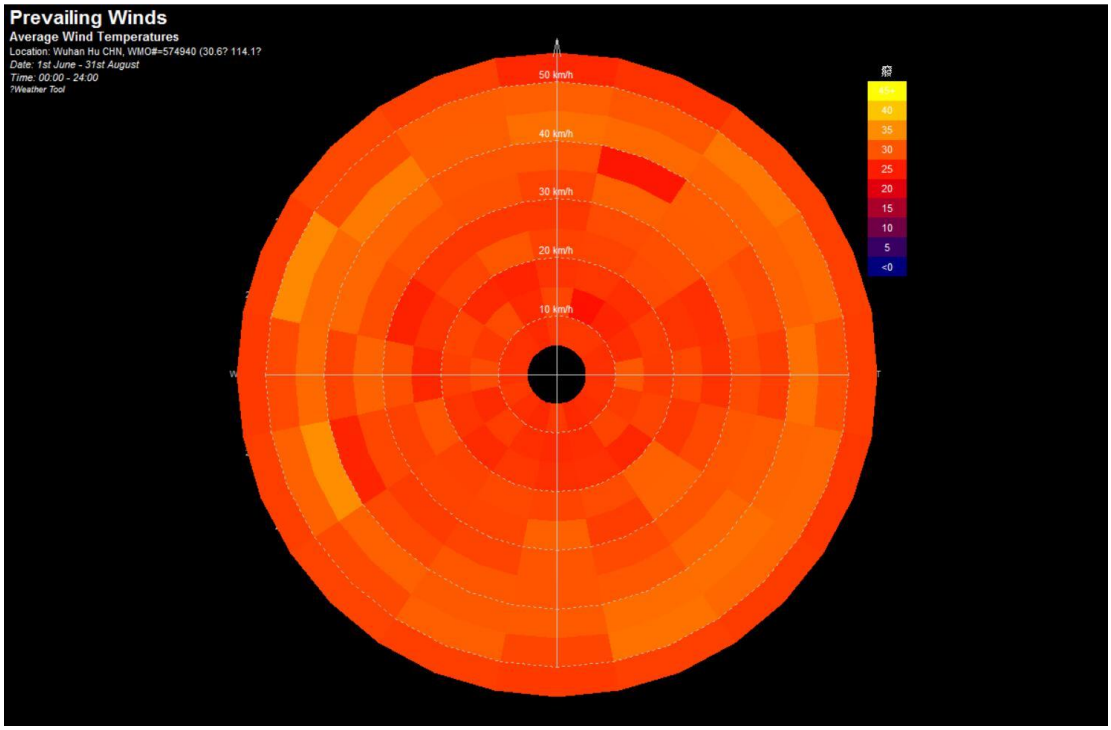

Figure 5-12. Wind warm of summer

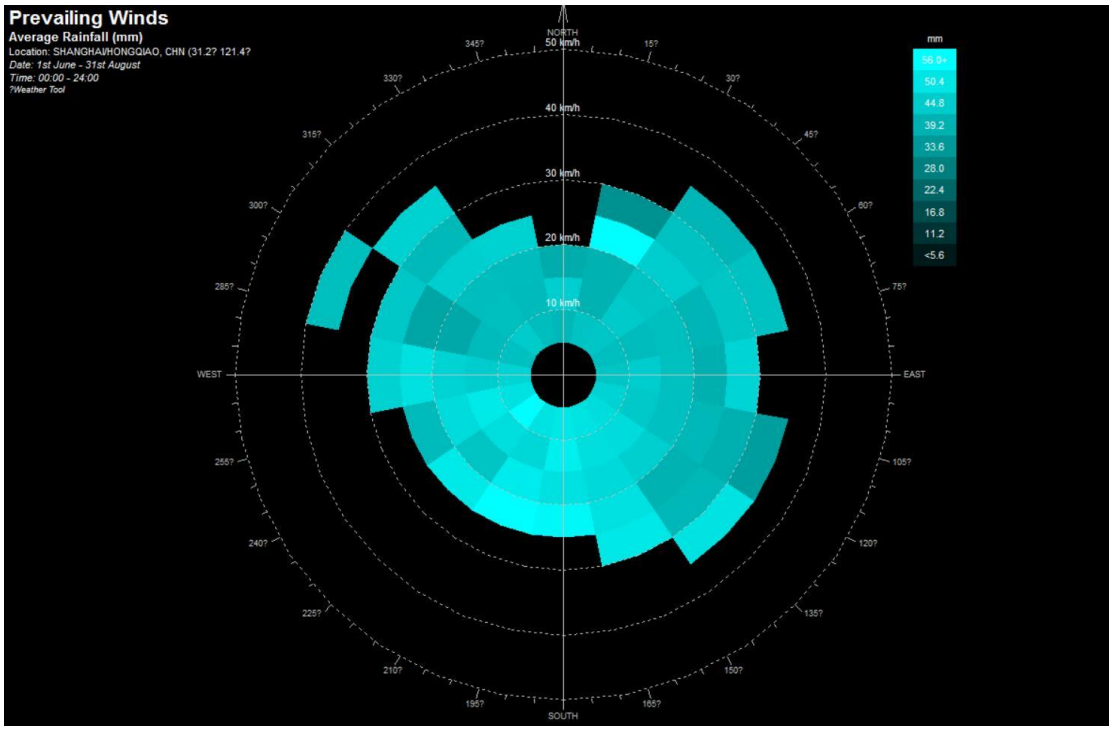

Figure 5-13. Rainfall in summer

Figure 5-14. Summer humidity

Winter climate factors comparison (Software Ecotect, weather tools)

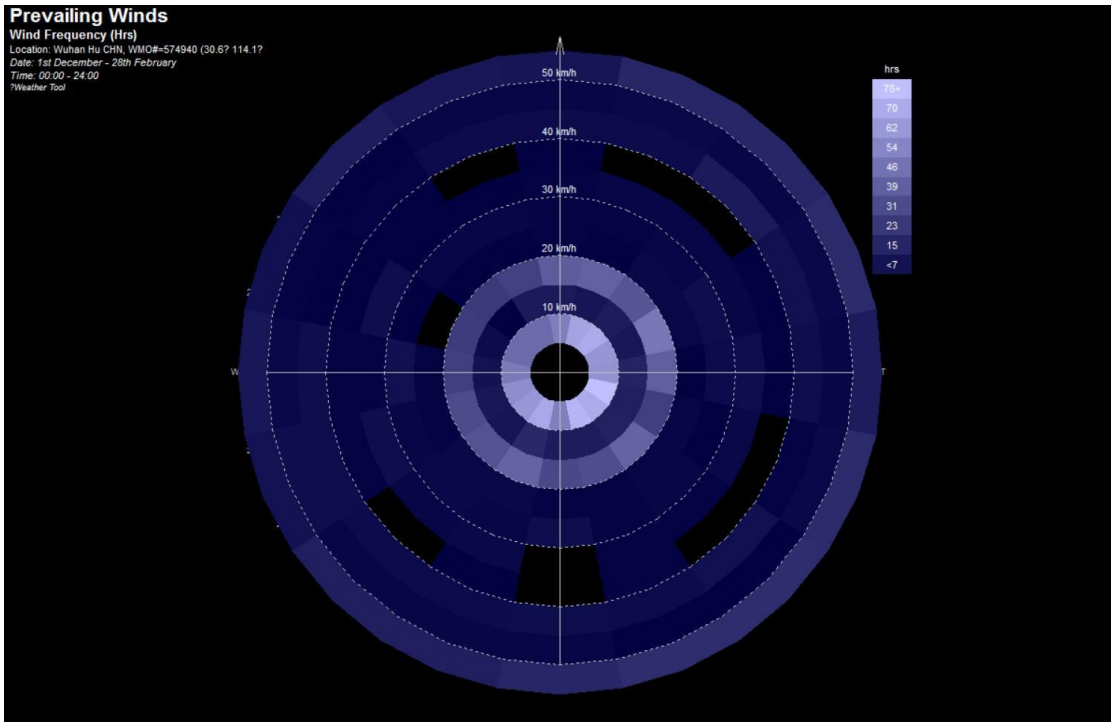

Figure 5-15. Winds rose of winter

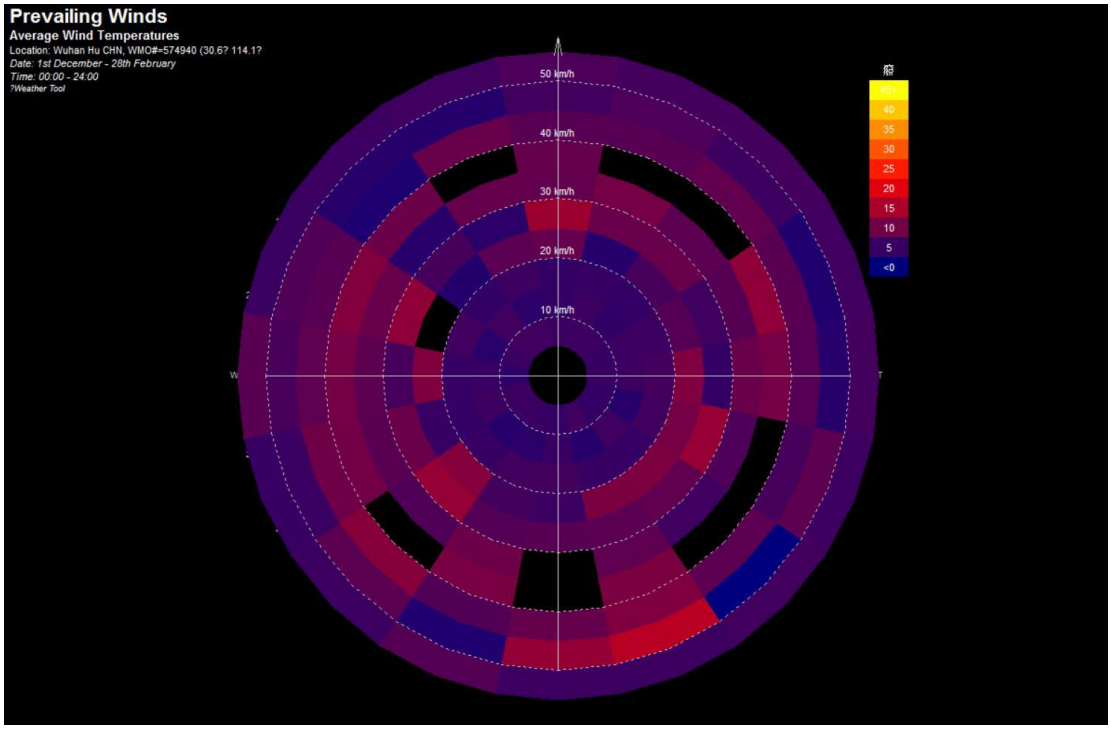

Figure 5-16. Wind warm of winter

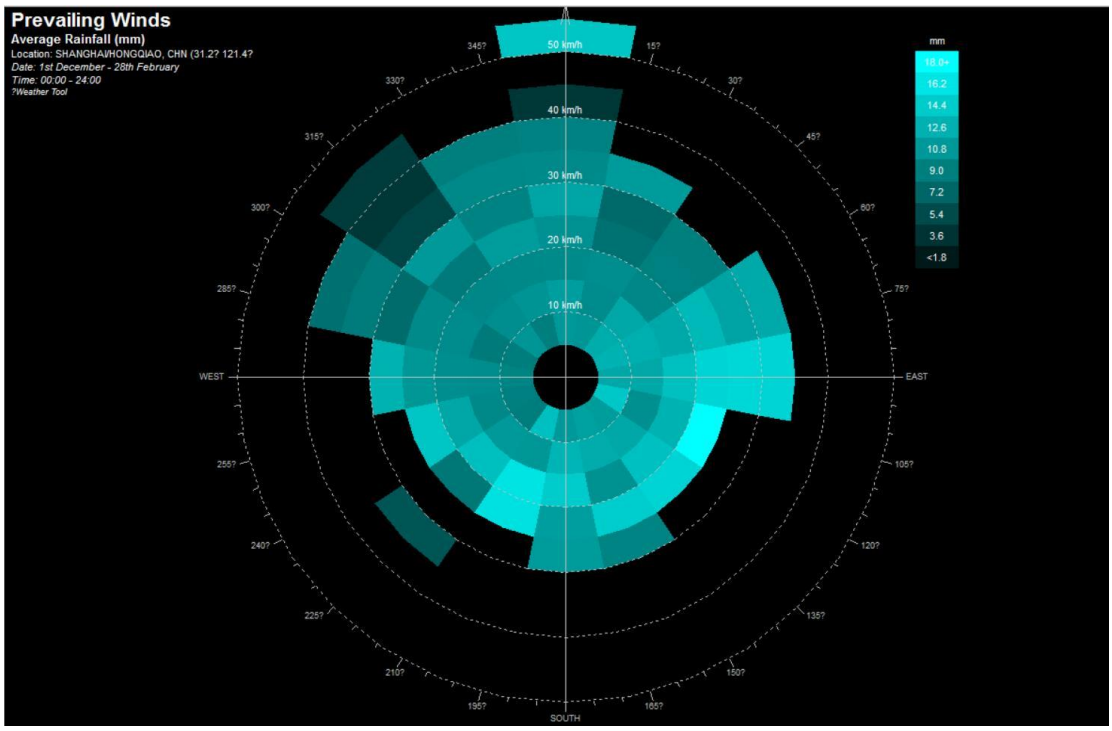

Figure 5-17. Rainfall in winter

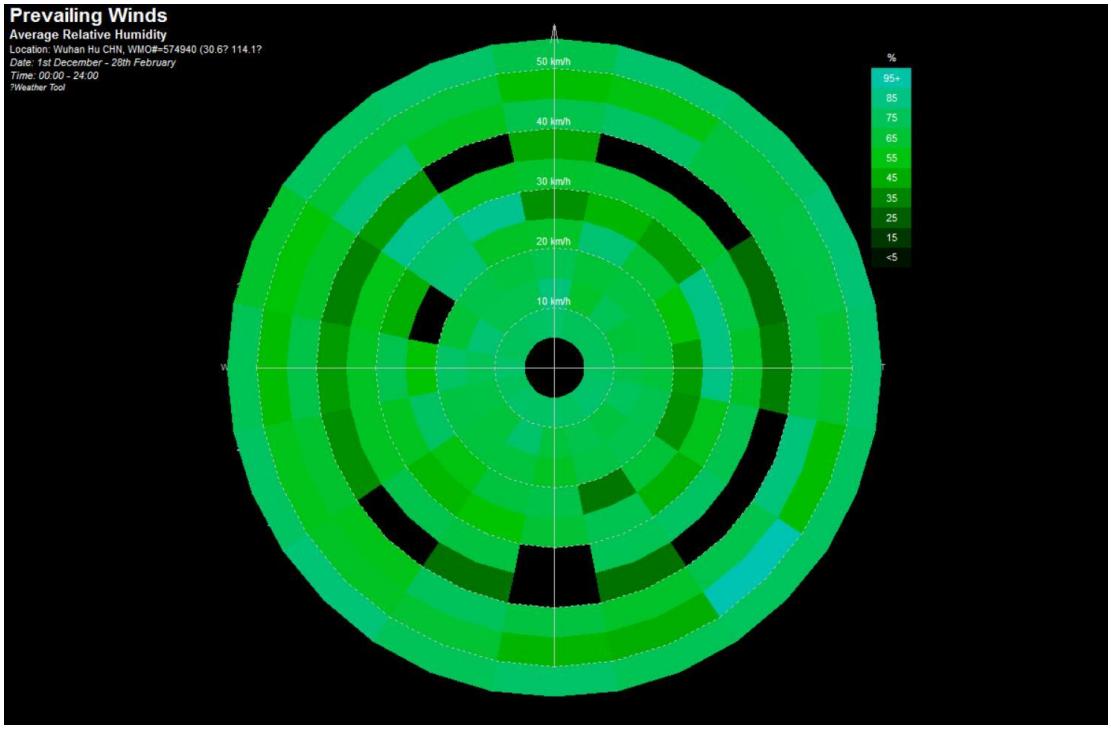

Figure 5-18. Winter humidity

The color is more darker means the relative value is more higher, the wind rose chart according to the annual frequency of occurrence can be seen as maximum wind value and minimum wind value. These charts show the main wind direction of Wuhan in summer is south- east, and north- north east in winter, The annual most wind direction is from the north- east. However, Wuhan does not have the high wind speed, that's mean is not simply to use the passive ventilation for the indoor thermal comfort and collect he wind power. Wuhan city has the high precipitation in the both of winter and summer season, especially in summer the value is overly passed the capacity of the public drainage system. In another hand, rainwater resource can be effective use for energy consumption, and as a unit of urban system, the building has responsibility for share a load of the urban sewerage system.

Sunlight

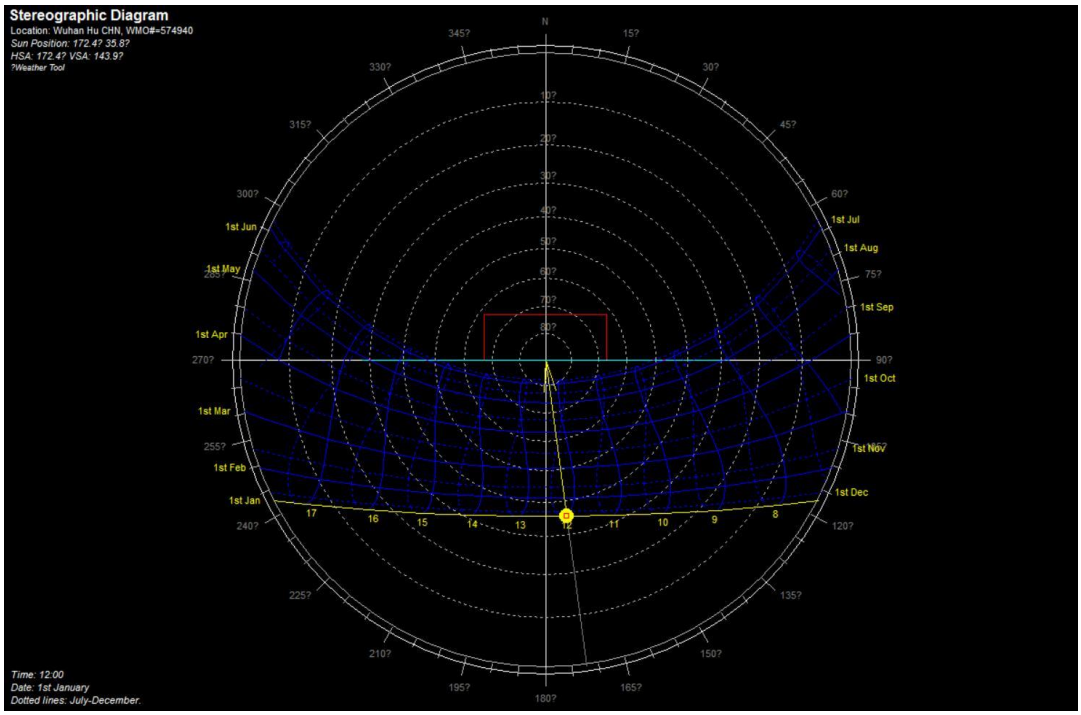

Figure 5-19. Sunlight environment in summer- 12:00 pm.

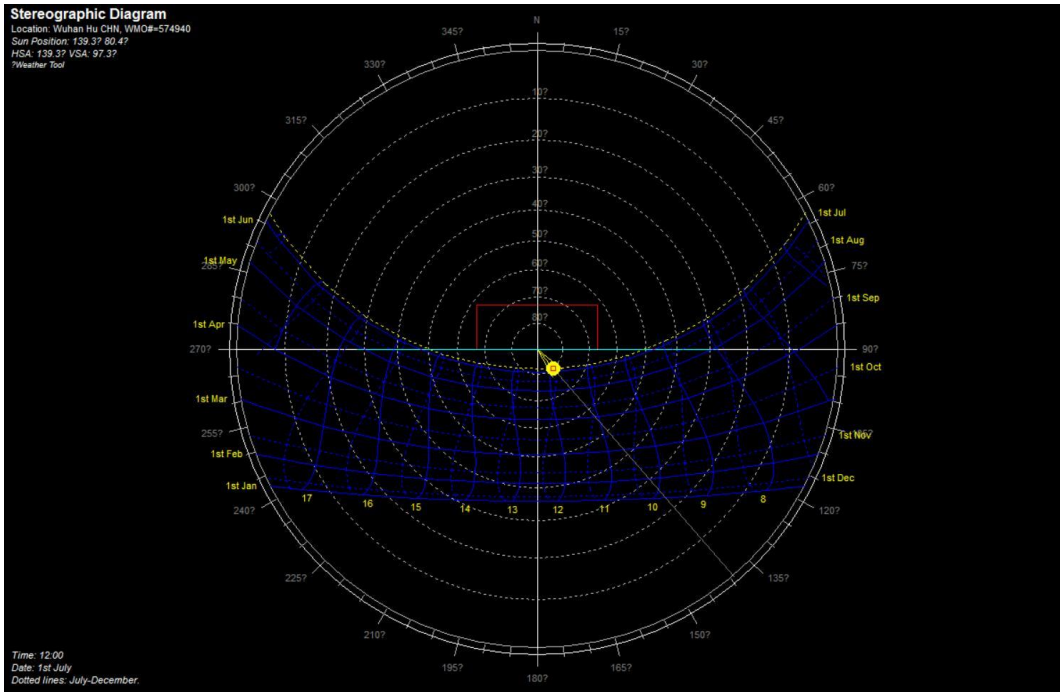

Figure 5-20. Sunlight environment in winter- 12: 00 pm

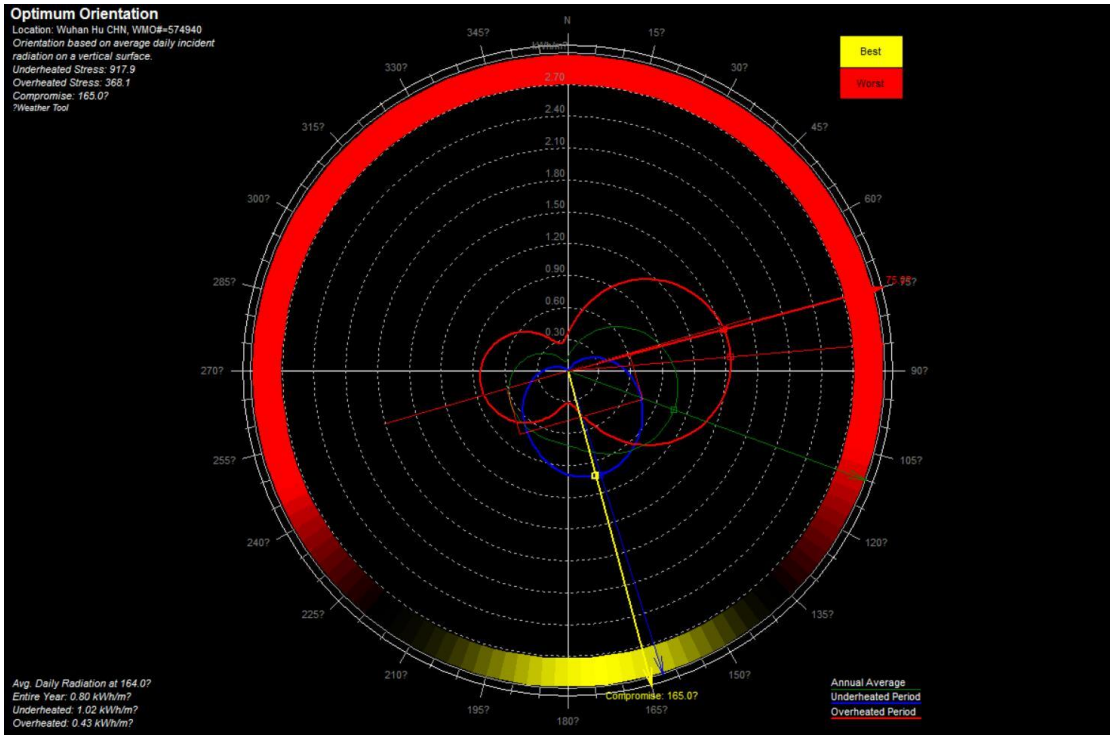

Figure 5-21. Optimum sunlight orientation

Ecotect Weather Tool according to the annual solar radiation provides the best suggestion for building direction. The horizontal axis is month and the vertical axis is radiant exposure rate.The green arrow line is the most appropriate direction of annual average radiant exposure. The blue arrow line is the best direction for radiant exposure in cold seasons. The red arrow line presents the best direction for radiant exposure in hot seasons. We can see from chart the best solar radiation direction of Wuhan is South by East 30 degrees, on the other hand, east by north 20 degrees is not recommended to sunlight design.

Orientation of building

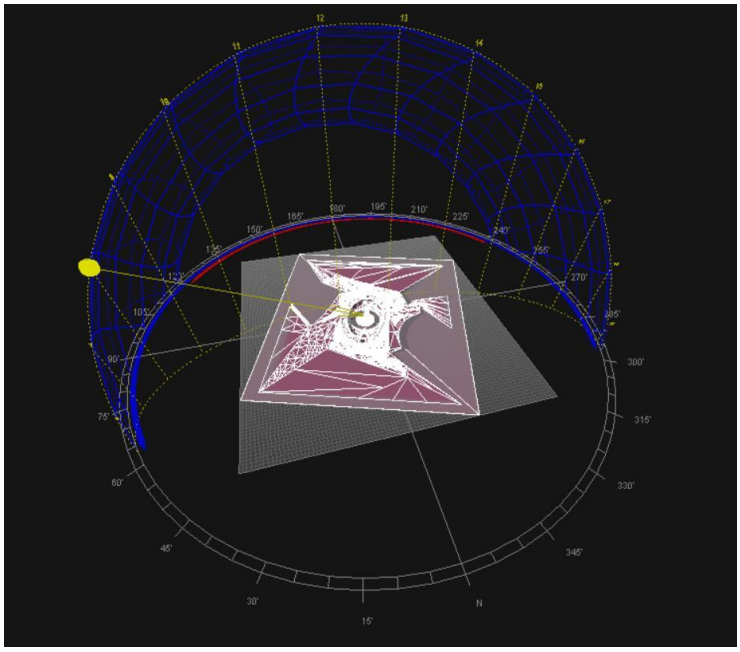

Figure 5-22 8:00 am, summer

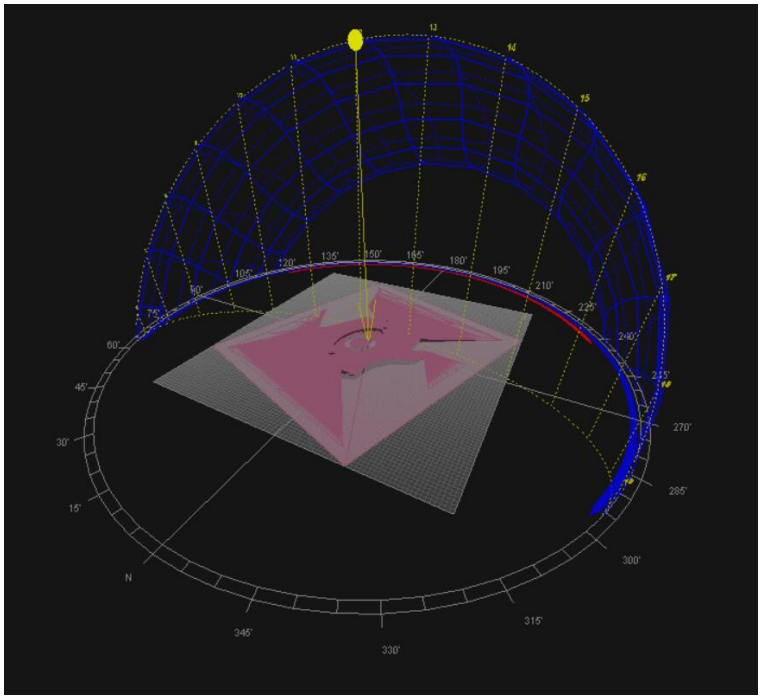

Figure 5-23. Sunlight at 12:00 pm, summer

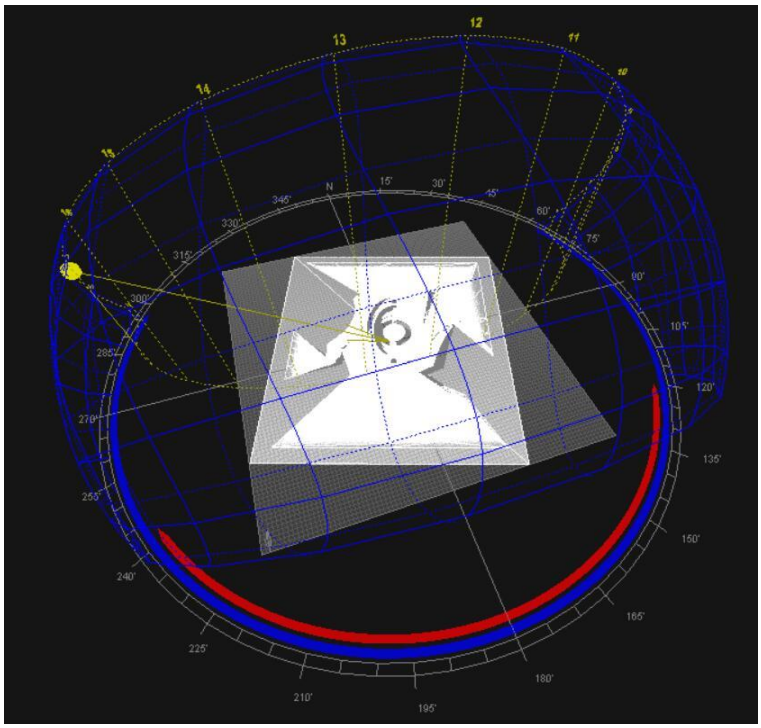

Figure 5-24. 5:00 pm, summer

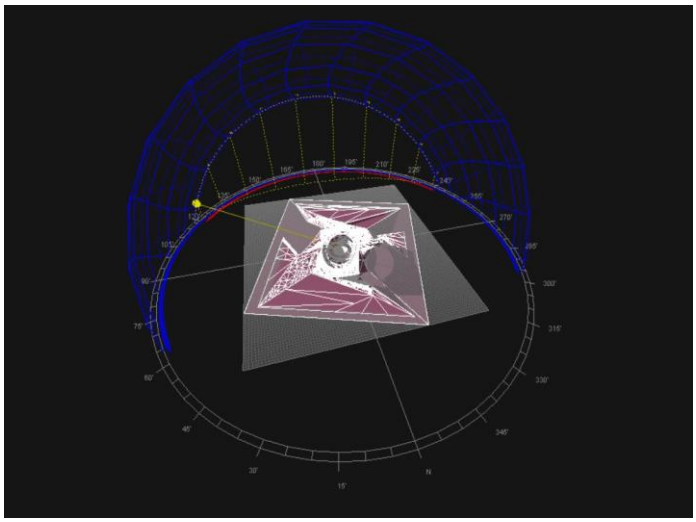

Figure 5-25. 8:00 am, winter

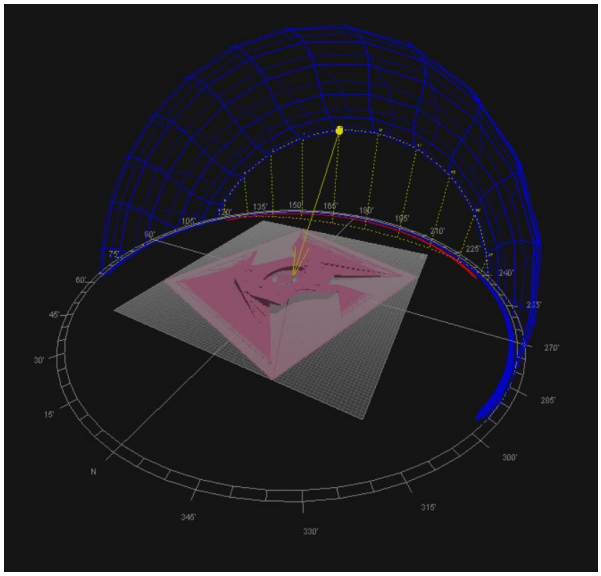

Figure 5-26. 12:00 pm, winter

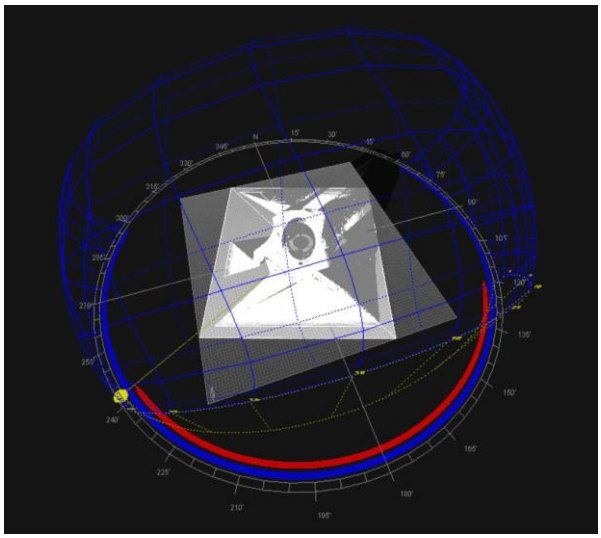

Figure 5-27. 5:00 pm, winter

According to the demands of winter heating and summer ventilation, the best building orientation decided east by south 30 degrees, about 30 degrees angle between the predominant wind directions in summer. As we can see from these graphics, building received more irradiate radiation in summer and the atrium is the most radiation area. The earth sheltered structure excludes a big part of direct sunlight and keep the relatively stable indoor temperature. In the winter, the building has abundant changes of light and shadow on both sides of east and west.

Covered area provided heat storage function to keep the indoor thermal comfort. To response climate change, the building has been installed compluvium, mirror reflection, lighting tube to satisfy the sunlight demand in winter.

Architecture morphology and surface design

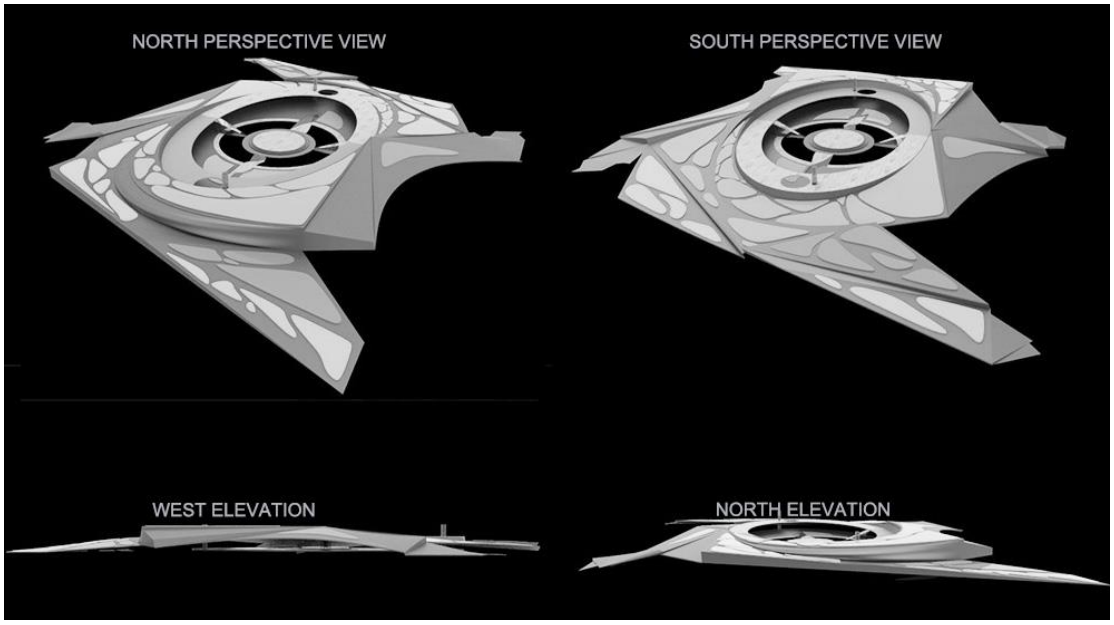

Figure 5-28 Architecture Morphology and surface design

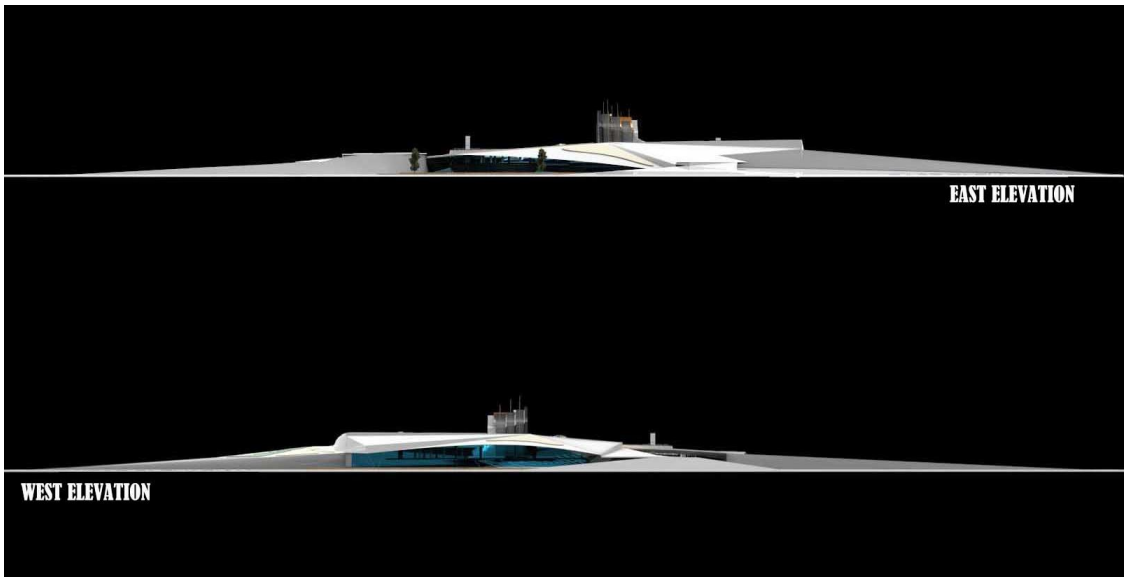

Figure 5-29. Building Elevation

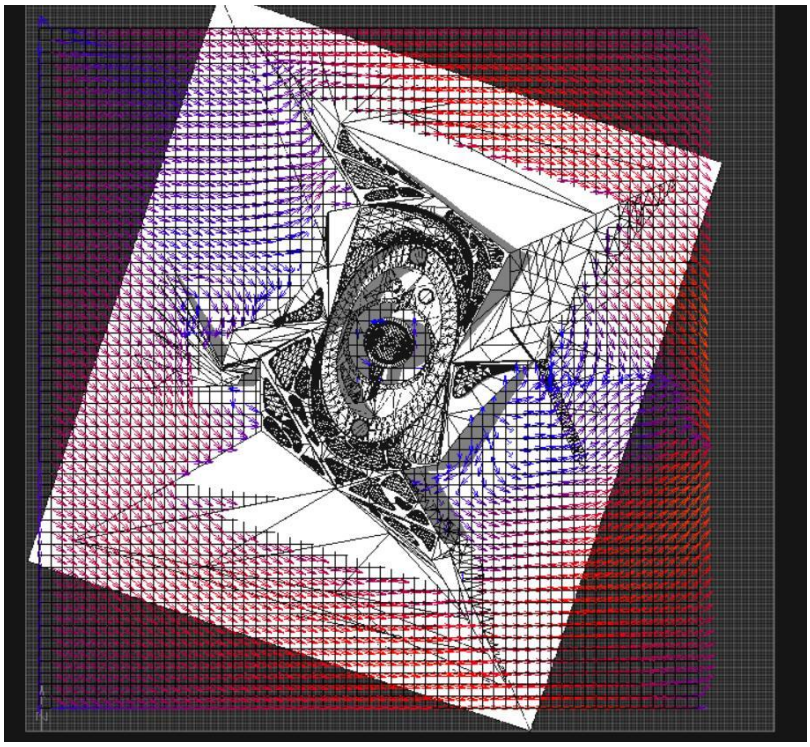

Figure 5-30. Wind flow in summer

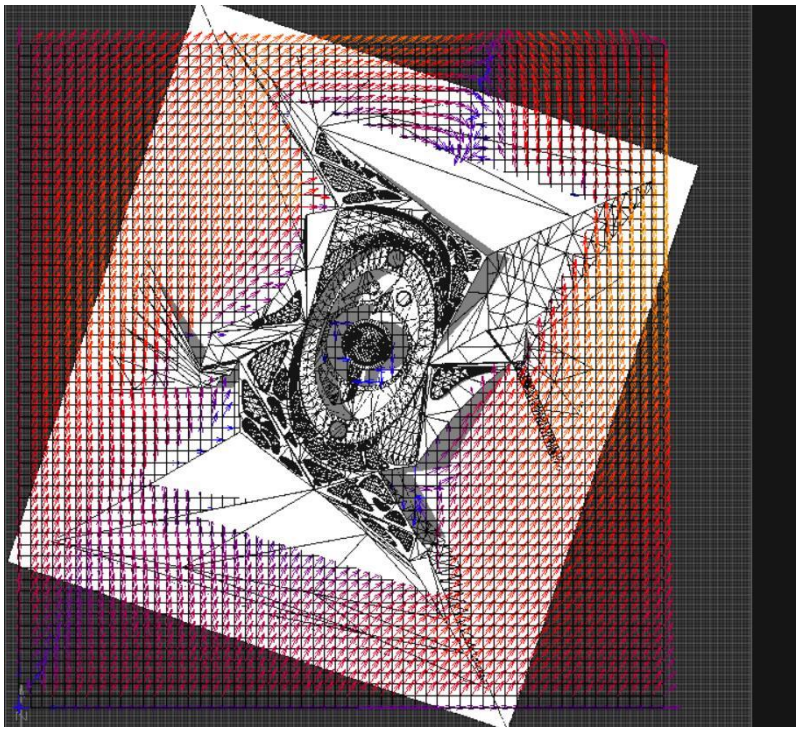

Figure 5-31.The wind flows in winter

The extended eaves can effectively block the high angle of the sunlight in summer, at the same time it also can keep enough low angle of the sunlight in the winter. In order to avoid wind resistance and reduce the pressure, building surface did not use acute angle. Each inflection point is for the surface airflow and makes it looping, then diverted the wind to each event. According to the Wuhan seasonal wind direction, the sharp corner at north-east and southeast of the building can break the wind. Like a polyvalent wall, the building surface composite by multiple layers, the out-layer used to avoid reflect heat energy from sunlight and keep slightly hollow to ensure the humidity rate of inside wall. The middle layers are central controlled to storage or evaporate energy; it is key point to control the air condition through moisture and dryness. The bottom layer is for hold up the long-span structure. The concept of surface design based on metabolism, from function angle is related to thermal condition, light condition, humidity, air quality, indoor humidity and human activity.

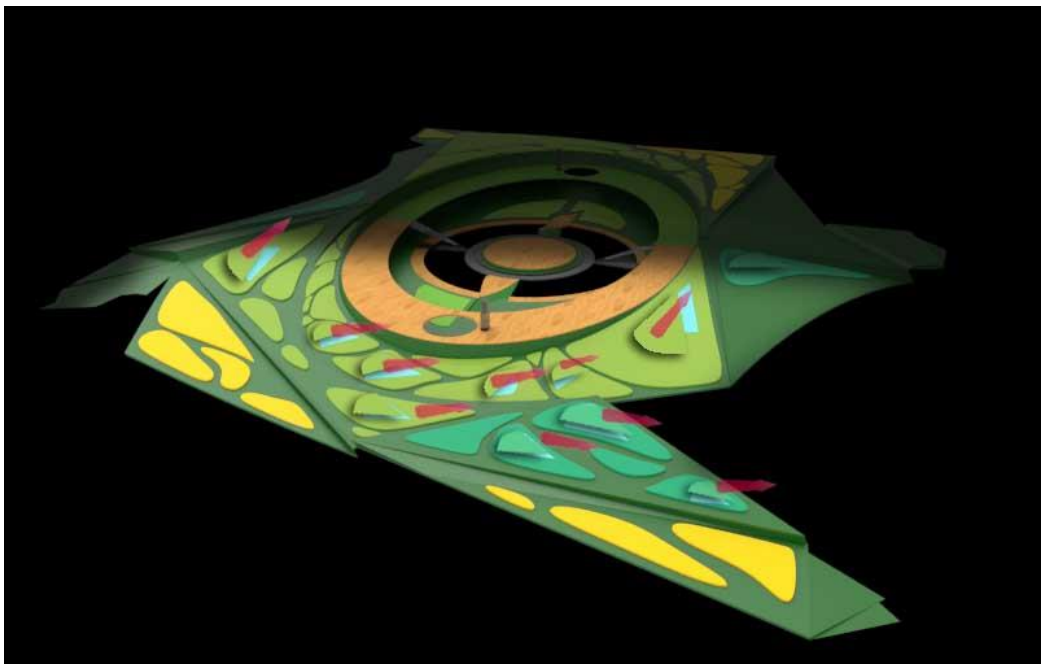

Figure 5-32. The movable green roof

This is a movable green roof, the green spot can cover the skylight in summer, and move away to expose roof window in winter. The green roof reduced the urban hard pavement area, and improving the absorption of solar radiation by photosynthesis and transpiration. In the summer it can effectively control the heat energy absorb, reduced the load of air conditioning. Not just simple replace to soil, for those walkway, surface water run-off, wind duct, vegetation area are not be fully green covered.

Interior space design and atrium ventilation

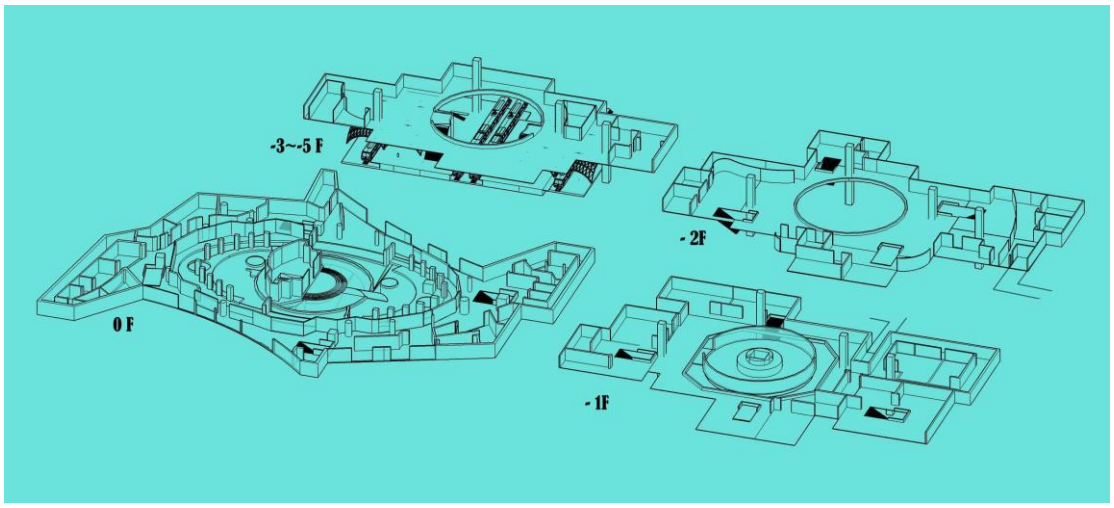

Figure 5-33. Axonometric of floor levels

There are five underground levels, interconnected each by elevator, stairs and central open space. The main function is for the metro transportaion which at the bottom floor, the rest of the floors provide dining, shopping and office function zones. Atrium space brings the sunshine into the first floor, and it works with window walls that insides of building to take cross ventilation through the interior space by wind pressure and thermal pressure. For the underground ventilation, it mainly rely on the circular central open space and ventilation towers, all the internal wind flow and air thermal energy will be brought to here together. On the other hand, you can stand at any point of central space to observe the condition of all levels. The stairs have a long cross section, enough to bear the massive flow of people. Transparent spaces not only convenient to people walk-through with various purpose but also make the all kinds of energy transfer become more easily.

Interior climate responsive methods

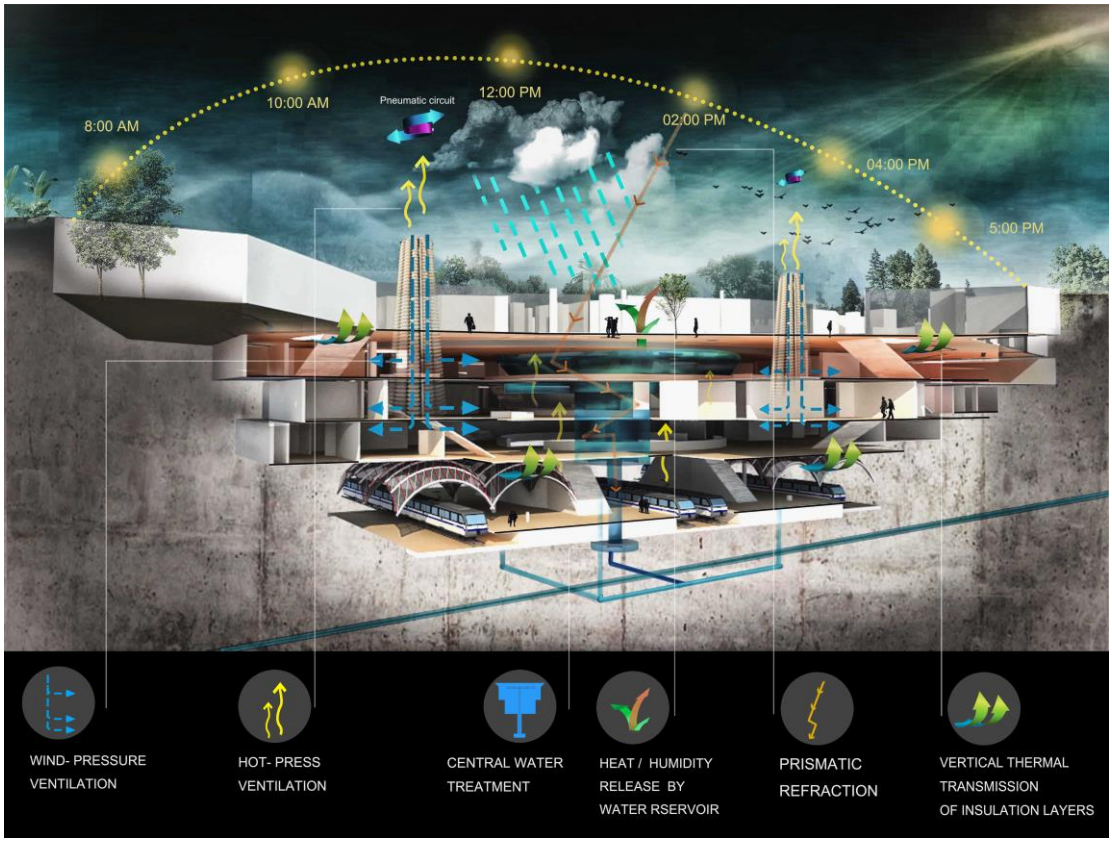

Figure 5-34. Architecture section

The central reservoir

As the core point of building energy junction, the central reservoir system cross all the levels extends to the ground aquifer. Water resource collectt from the artificial pool, rainwater collection, underground water, municipal water and reuse water. In order to reduce water energy consumption, the different class of water usage will outlet different quality water for drinking, domestic use, sanitary water, equipment operation water, cooling and thermal water and greenery irrigation. The container material is double layer prism glass, and it depends on the turbidity of water, from outside to inside. The outer circle of the container has the most clarity

water, it can be able to refraction the upper light to the down layer, the first ground floor can directly affect by sunlight. There is water layer in the each floor panel, different season contains with different temperature water for heating and cooling the air, also adjust the indoor humidity. Cooling and thermal equipment in each floor attach with humidity control device that can absorb or release the air with different temperature.

Ventilation Tower

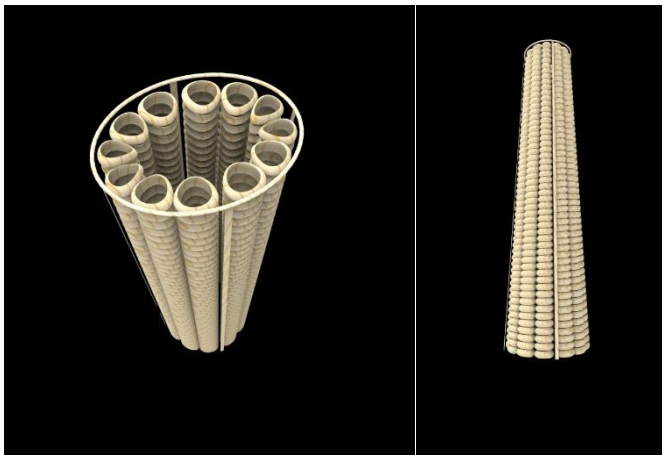

Figure 5-35. Ventilation tower

There are ventilation towers located at the both sides of north and south. It inspired by 2000 B.C the ancient Egyptians, they established original ventilation system in building that from the basement extend to the roof, through temperature different between indoor and outdoor generate air circulation. At the same time, each affected room by ventilation tower installed air value for adjusting wind power. For keeping the humidity, they set the water pot and moist wood charcoal in the tower. After thousands of years, this method was replaced by air condition but now

day, more and more negative affect of air condition being exposed, such as high energy consumption, noise and harmful substance release. With the development of technologies, there is possible to improve the ancient method for building passive design. These two cylindroid towers are composed by the countless small unit. Through wind pressure and thermal pressure take out the extra heat and water vapor, each unit of the tower with a built-in a wind catcher equipment and air filtration. Each outlet valve is central controlled to responsive the different weather. The bottom of towers connected with an interior water network, it is for regulating the temperature of the reservoir.

Energy efficiency in summer

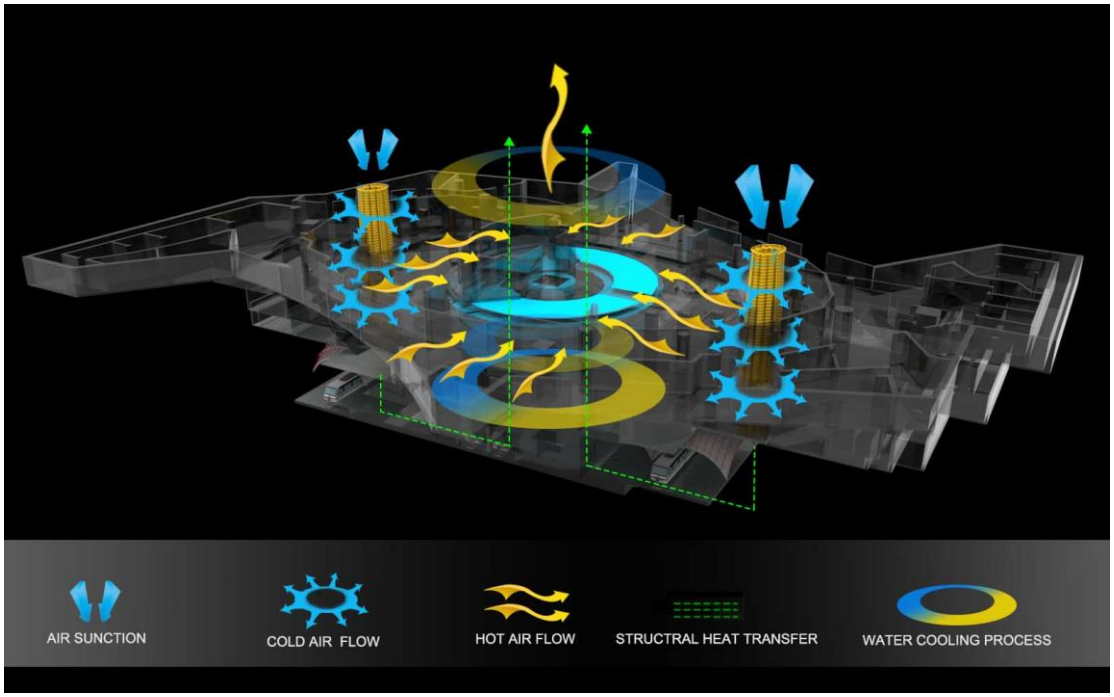

Figure 5-36. Energy efficiency in summer

In summer, project obtain the direct heat respectively from atrium, building glass curtain, building surface and shallow pond which in the ground floor. These heat energy mainly for the operation power and indoor lighting. Sunlight heat the top of ventilation tower, meanwhile warm the air in the tower, hot air rise with the indoor heated air flow, then air duct generate the siphon effect. The cold fresh air be absorbed from other side of building, generate a horizontal duct in each floor, the water layer used cold water to cooling the fresh air, then hot air be forced to push out from the tower by the high density of cold air.

Energy efficiency in winter

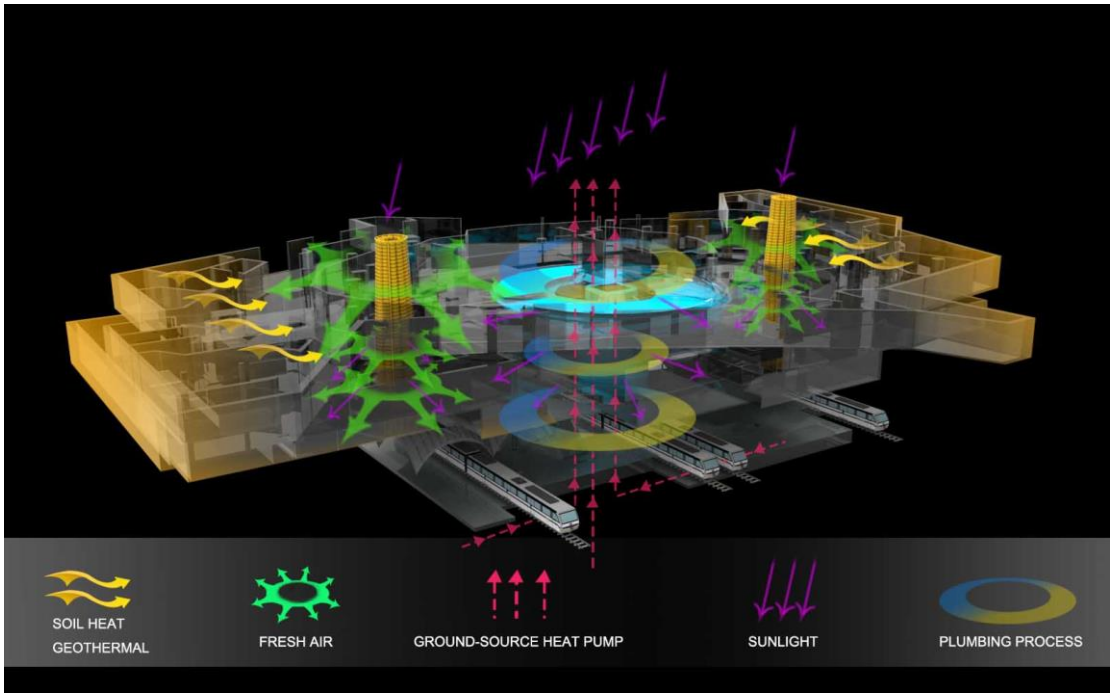

Figure 5- 37. Energy efficiency in winter

In winter, Sunlight and heat energy is mainly for the directly indoor thermal and water heating. Project obtain the heat energy through the direct heating and

indirect heating like: soil heat storage, ground source heat pump, light well, light wall of ventilation tower, light pipe with a solar tracking device, optical fiber and an optical sensor. Because of indoor air pressure, the direct vent of the tower will be turn off to eliminate the heat air. The pipeline of ventilation tower will be joint with indoor thermal equipment for heating the air, then sending to the indoor space. In the other hand, the tower will also use to collect daytime heat energy and sunlight. The operational heat energy will be collected by the central reservoir, this method has two benefits: one is provided domestic hot water, another is auxiliary wind delivery through change the heat pressure.

Central hall in the courtyard

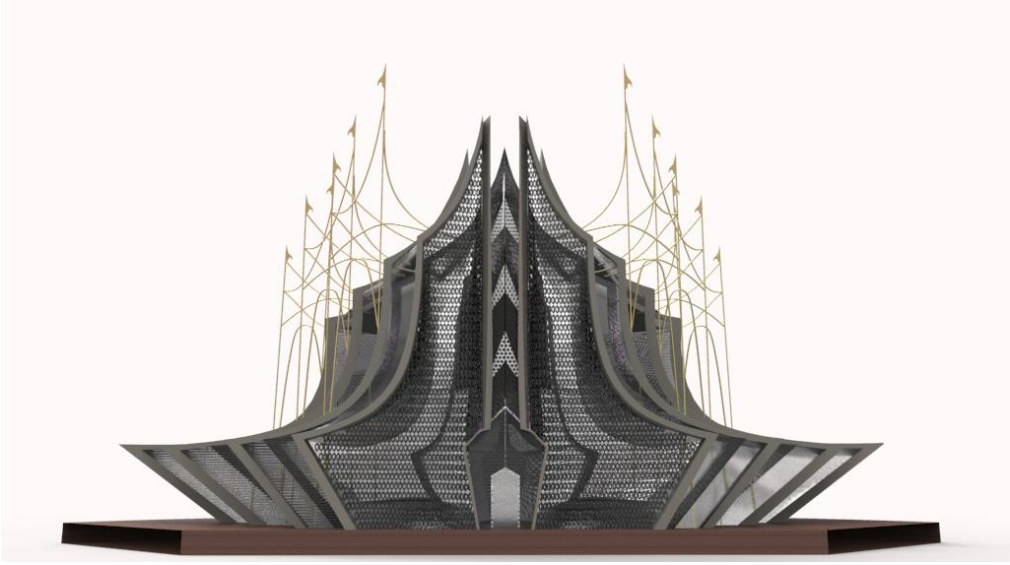

Figure 5- 38. Front view of central hall in the courtyard

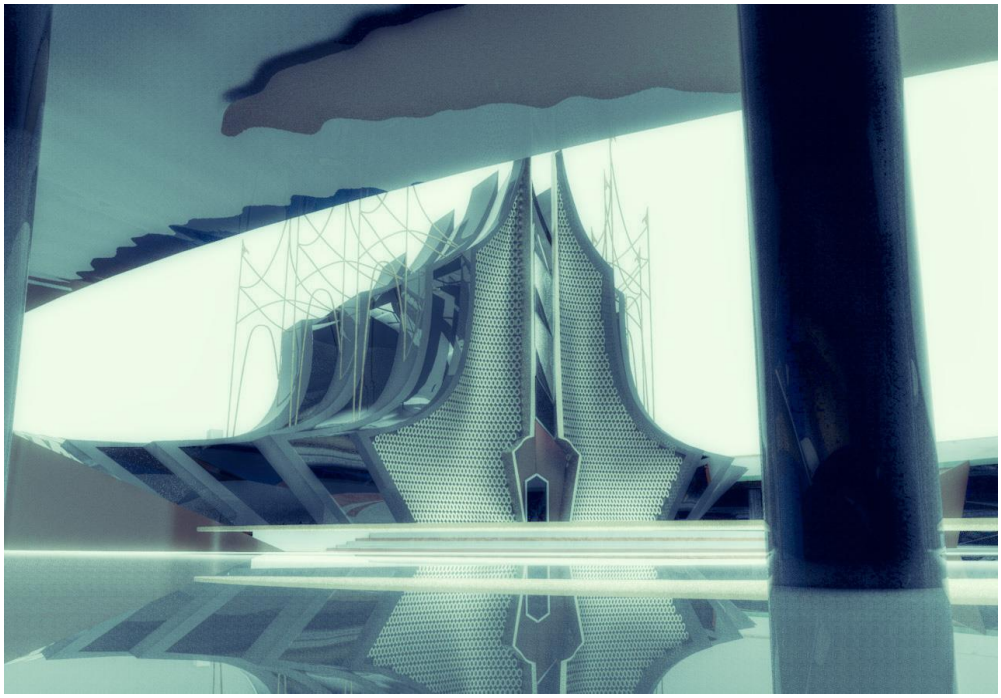

Figure 5- 39. Perspective view

Same as outside building, the central hall ace to the south by East that can accepts most natural sunlight. It is shape looks like a blooming lotus which is Wuhan's representative. The inspiration for spires of the building came from patterns of Chu Dynasty culture. This building used for foresight, relaxing, soft drinks and a small exhibition. And also this building provide one of the exits gate for the people who want to visit Park.

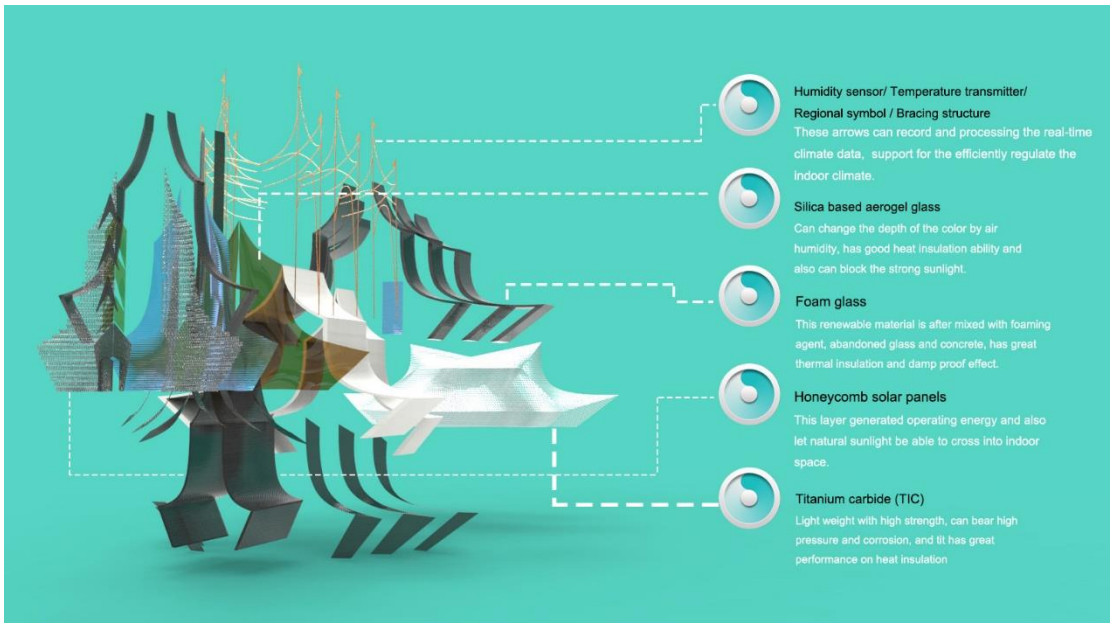

Figure 5-40. Analysis of central hall

Start from south elevation, the first curtain layer made by countless honeycomb solar panels, this layer generates operating energy and it let natural sunlight can able cross into the indoor space. The second layer is a double structural sealant glazing curtain that improving the permeability of curtain, it can effectively storage the heat energy; the joint points made by metal with a gap that great at thermal resistance. Third layer is a silica- based aerogel glass which can change the depth of the color by air humidity, it has the good heat insulation performance and also can block the strong sunlight. The material of curve shape in both sides of east and west is foam glass, this renewable material is after mixed with a foaming agent, abandoned glass and concrete, has great thermal insulation and damp proof effect. The north side section is a set of reticular and irregular curve surface it made by titanium carbide (TIC). TIC has plenty reserves in the local area of Wuhan, it has light weight with high strength, can bear high pressure and corrosion, and the most important it has great performance on heat insulation so been used to made the

surface of a spaceship. Consider about TIC has high reflectivity that not help for reducing the UHI effect, so set it to north side for accepts relatively less of sunlight. The arrows on the top not only present regional symbol but it also work as humidity sensor and temperature transmitter, these arrows can record and processing the real-time climate data that support for the efficiently regulate the indoor climate.

Summary

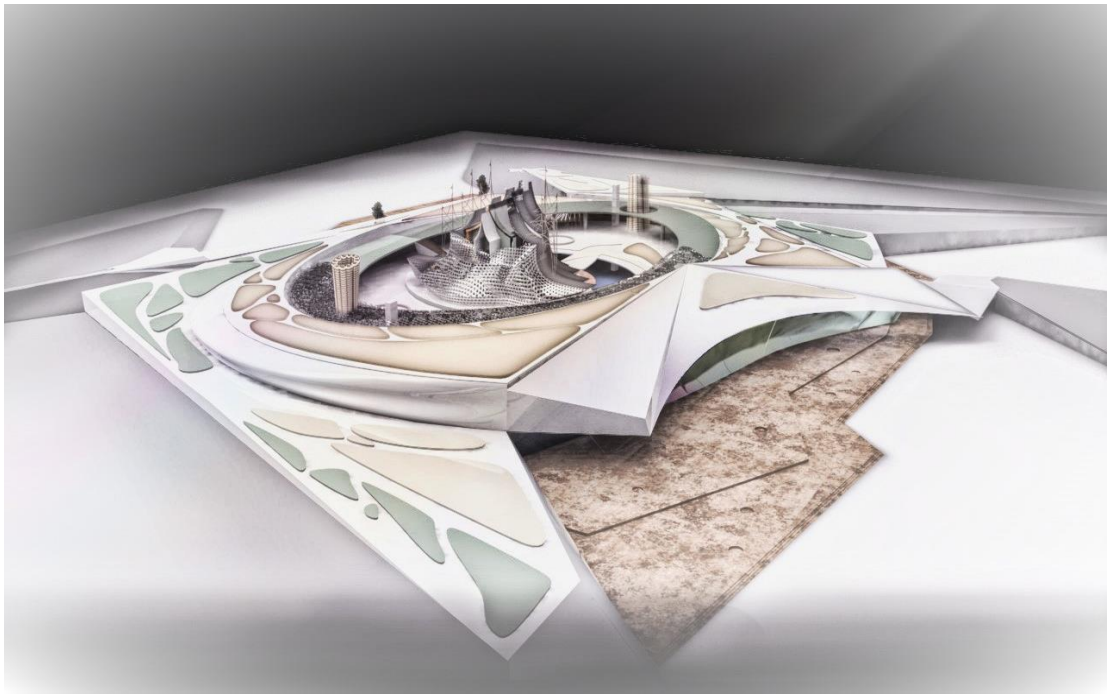

Figure 5-41. Aerial view of project

This concept design is from the perspective of climate feature, analyzed energy efficient building design methods in Wuhan city which has special weather condition in summer and winter. First is to identify the purpose of energy efficiency design through analyzed the climate data in Wuhan. Then according to the site topographic element decide to use the earth-sheltered building, and take advantage of soil covered structure which has the excellent natural thermal storage

and water collector performance. Earth sheltered building not only provide a large green area to reduce the UHI, but also increased more possible to response the humid and hot in summer, and the cold temperature in winter. Building apply the ventilation tower for air circulation and water reservoir; use green roof for water treatment, and selected high insulation materials for the building envelope. The energy efficient section of this project is not independent but support each other, passive design with machinery energy saving work together, exchange the generated energy for different functions. All these make the most energy-efficiency system.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

Dynamic climate adaptive strategy

Through analysis of the climate responsive problems of building in Wuhan, the actual project needs to focus on high temperature and cold wind in summer, in winter need pay attention to cold and moist climate. It is essential to flexible control the humidity of roof in the summer. The roof need to be able to cooling by the evaporation and conserved the rainwater by the green vegetation layer, water of the soil and vegetation layer can reflection sunlight and absorption the heat energy that can be able to reduce the thermal conductivity. In the winter, green roof can draining the water for increase the structure thermal conduction. The stationary shading structure may solve the exposure in summer, but blocking the passive solar energy in winter, so apply a dynamic shading system which can adjust angle and length for the different sunlight demand. For the plants selection of green roof in Wuhan, it is necessary to meet shallow root, drought- proof, fast water emission and cold- resistant, such as Parthenocissus henryana, ophiopogon japonicas.

For the ventilation, due to the volume of wind energy is instable in summer and winter, so the design of ventilation tower and air layer of the floor need to add wind catcher equipment or control the scale for the ventilation effect. At the same time, it is also necessary to install a valve on the each air inlet that can centrally

control the building ventilation system, turn it on in the summer and turn it off in the winter.

The less wall set up, the more flexibility to control the indoor ventilation, so as much as possible to design the slight and removable wall can reduce the needlessly enclosure space. The barrier layer can use double structure air grill that can storage thermal energy and also releases it. The air vent grill can select material like aluminum or local materials such as bamboo. In addition, the indoor vertical greening also can improve the humidity, temperature control and air quality, in summer, these branches and leaves form the vertical irrigation system can screens out much of the sunlight radiation and cooling the air temperature.

Static climate adaptive strategy

The dynamic climate adaptive strategies might work if party has enough funding and an appropriate location. The static climate adaptive strategy fit for more general construction can even be seen as design premise. It seems like using fixed climate responsive design to solve two kinds of climate conditions. First is building orientation, it should combine with the both supply and demand of winter sunlight and summer shading into the integrated design, avoid the cold wind, and keep the ventilation in Summer. Through analysis the meteorological data of Wuhan, we can see the best orientation for building in that area is 10 degrees of the south by east to 10 degrees of the south by west. After determine the best orientation, designer can uses the specific method in the later design to cover the defect of orientation.

For the passive solar energy design, an appropriate shape of the building is very important, there is a particularly close connection between the urban micro climate and building configuration. From the perspective of thermal flow, when we design a building appearance, the obtuse angle and curve is better than the right-angle for air- circulation. In addition, the aerodynamic curve can conducts air flow, help for air pressure exchange and it also can support roof cooling and evaporation. The large building exterior envelope can accelerate the heat dissipation; however, it may lead to high volume of energy consumption, so designer should consider to reducing the interior space deep, increasing the building windward area for natural ventilation and heat release. It is also necessary to think about shadow of indoor and outdoor of the building, the 'movement space' which people will not stay for long time need less shadow in summer and the 'static space' which people will sit or work need a balance between the sunlight and shading.

In Wuhan, the annual warm seasons is longer than the cold seasons, at the same time, the cost of sun shading are much higher than artificial daylight, so for the part of sunlight design should pay more attention to the winter radiation. It is also necessary to increase the south side area of the building, meanwhile decrease the deep-plan, one basic way is to add a sunspace at south side elevation and use thermal storage wall to connect sunspace and room. The sunspace have a certainty distance between the interior space and it can be seem as a buffer space for storage the heat energy. In the winter, sunlight can directly exposure into the sunspace, the thermal storage wall can absorb heat energy to make the low-

temperature irradiation for indoor cold air then air density will be decrease and air rises upward then from the gap into the room, meanwhile cold air go into the sunspace. The air at the bottom of the sunspace create negative pressure that can achieve air circulation and warm the indoor space. In addition, use piloti structure can drive air circulation and improve the indoor climate condition, in the winter, it also support the response to sunlight and effectively avoids indoor humidity.

Compare with earth-sheltered and conventional

In general, the earth-sheltered building have a lot advantage to support energy efficiency design, especially in the extreme climate condition. Due to covered by soil and vegetation, these factors make the envelope system of building become more resilience, when it facing the extreme hot and cold temperature, the building no need rely on the mechanism system for adjusting the indoor comfort. The earth-sheltered building with a maximum reducing the energy consumption and GHG emission. The 'natural surface' not only considerably cut down the envelope maintenance cost but also reduced the operation spending, absorb the heat energy and release water to cool down the temperature in summer, conduct winds flow and improve the local micro-climate. Whether from the appearance or internal function, the architecture and natural landscape become integrated, increasing the green area of the city. It is also benefit for integrated lands use planning, effectively use slope on the site. At the same time, earth-sheltered building can effectively

prevent eolian dust and noise, block the pollutant and radiation, all these are positive effect on people's physical health and mental health, it is suitable for living.

However, compare with conventional building, earth- sheltered building still have some disadvantages. First is natural sunlight and natural ventilation, especially for those underground building. For thermal comfort, it is necessary to design the active management system, though it may bring some finical matters. Second, the outdoor landscape vision is restricted, staying in building for long term will trigger out depressed psychology, architects should pay attention to humanized when design the indoor environment. Third, due to the new type of bearing structure has more cost, earthwork excavation and removal of spoil involves much higher real costs.

The misunderstanding of current designing and development

In Wuhan, or even China most developers are ignoring the climate problems and potential value of energy efficiency, even they understand the condition of global energy. They would rather than sacrifice the huge energy to meet the plot ratio or create more space for sale. Energy efficient building and green building even become the sell points, a slogans without meaning. A lot of expensive material existing in the market and be labeled as 'green'. The government just see the energy- efficient building as an individual, however, the best way to change the urban microclimate depends on grand and long- term goal, policy should focus on building group organization and block layout organization. The policies and criteria

are static but weather and technology development is dynamic; no matter from design or assessment, all need a dynamic and comprehensive view, especially to analysis the results of computer simulation. Part of Chinese architects just follow the market, short benefits and less willing to do the research on new materials. The judgment criteria of energy efficiency performance of structure or materials are depend on commercial promotion, for example, part of energy efficient material is extensive applied on construction, just because it good at one aspect but not fit the local climate or have others negative impact as following.

Future Opportunities for Research

Rainwater treatment, thermal insulation and ventilation performance of building structure are the three major problems of construction in Wuhan. But for Hot summer and cold winter region around the world, still have much subtle areas with the difference of climate situation and thermal demand situation. It is necessary to categorize the hot summer and cold winter region by specific temperature variation, periods of precipitation, detailed architecture function and the size of projects. New construction and renovation construction also have a different climate responsive system, in this area, it is necessary to refer to green building evaluation system to identify energy saving purpose. At the same time, the planning department in the hot summer and cold winter area should consider about the relationship between overall layout and building energy efficiency. The building shading rate and buildings layout are the significant factors that impact on site microclimate, an

inappropriate parcel layout will indirectly increase the pressure of energy consumption. On the other hand, human body comfort study will be the next step to study on architecture in the specific environment, because people and local biological will determine that if a project is success in the final, instead of value of the number. In the end, for those people who are living in the severe weather, energy-efficiency means the future for them, it is possible to stop building depravation climatic environment. Now day, building no longer as the symbol of power or will as before, and it will become merchandise in the future, the building will be given more responsibility for the human living environment.

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BOGRAPHICAL SKETCH

He Zhang was born in pinjiang, Hunan province, China. He got his Bachelor degree of Environment art at HUST (Huazhong University of Science and Technology) and was accepted to the graduate school of HUST in Art design of the College of Architecture and Urban Planning. He attended the interdisciplinary program between HUST and University of Florida from 2015 to 2016 in sustainable Architecture design. Now He is currently pursuing his graduate degree in Master of Science in Architectural studies, with an expected date of completion in fall 2016. He hopes to keep study in architecture field and design with the sustainable thinking.