GR17_BED2-HW02_Vernacular and Climate sensitive Architecture

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Abstract

The purest definition of vernacular architecture is simple, it is the architecture without architects. . . it is the pure response to a particular person's or society's building needs. If fulfils the needs because it is crafted by the individual and society it is in. In addition the building methods are tested through trial-and-error by the society of which they are built until their building methods near perfection (over time) and are tailored to the climatic, aesthetic, functional, and sociological needs of their given society. Becouse the person constructing the structure will be perfectly tailored to that individual's particular wants and needs

*[*definition of Khyati Vasani for Vernacular Architecture publication 2012]

Starting from the above definition of the so called "Vernacular Architectiure" which can be easily associated with what is traditional and popular and in the pure sense "natural" , the following work represent a way to investigate the application of the ideas below this kind of architecture that affect the thermal response of buildings, starting fromt he past in order to understand how to apply the "ancient" strategies to the present and the future.

Introduction

Shanghai and La Paz climate conditions

Before studying the vernacular architecture of the two cities it can be useful to make some considerations about the climates that characterize both of them.

Source online : https://pixabay.com/it/mondo-mappa-terra-globo-711020/

The first analysis is about the temperature all year long in order to understand the type of climate and its oscillation during the whole year.

LA PAZ (BOLIVIA)

Online source: https://www.bizbilla.com/country-maps/bolivia.html

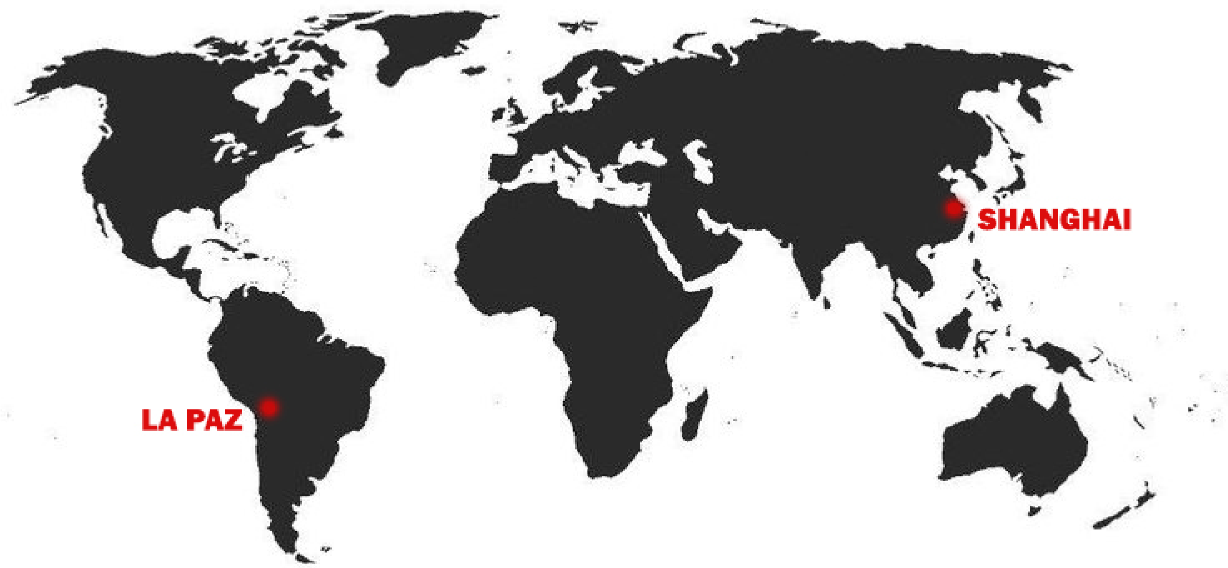

Figure 1: Analyzed cities

Figure 2: Geographic location of La Paz

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SHANGHAI(CHINA)

Online

source: https://www.thinglink.com/scene/789929442850897923

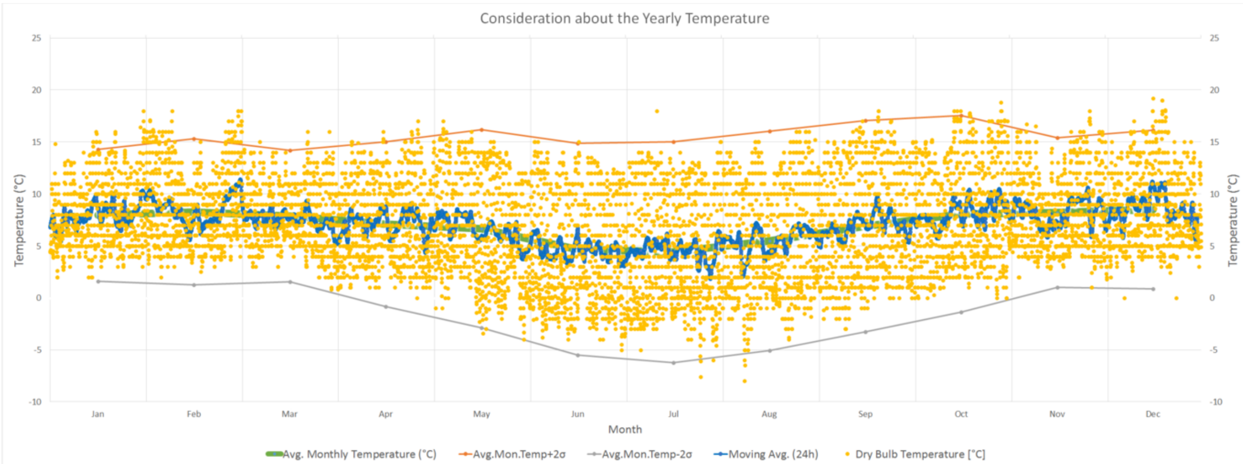

Figure 3: La Paz temperature during the year

Figure 4: Geographic location of Shanghai

Figure 5: Shangai temperature during the year

Source:

Personal Excel file

The first thing that can be commented is the fact that for La Paz type of climate, the average monthly temperature Tdb is a good representation of the entire spectrum of temperatures all over the year, because La Paz has the particularity that its temperature is varying between a compact interval of temperatures all over the seasons, so if we consider a deviation of +/- 2σ and compare it with the scatter Tdb values all over the year, the results show extreme interval values that content almost all the temperature values all over the year. Regarding the mobile average, La Paz has a slightly smooth curve all over the year, this can be interpreted by the fact that the seasons doesn't differ significantly between them in terms of temperature and the hourly values of Tdb for everyday are slightly the same.

Regarding Shanghai, the scattering of the Tdb values is higher comparing the first analyzed city, even though, the deviation interval accepted (+/- 2σ) includes almost all the scatter values all over the year. The moving average curve isn't as smooth as the one of La Paz and this might be traduced as a possibility to take advantage of the different hourly temperatures to create passive heating/cooling in intermediate seasons.

The second analysis has been made considering the average monthly amount of solar energy radiation received by the horizontal surface, without any kind of obstruction It,h (kWh/m2), and the values of the two cities have been used to plot two different graphs (one for each city) making it possible to evaluate the differences and compare them.

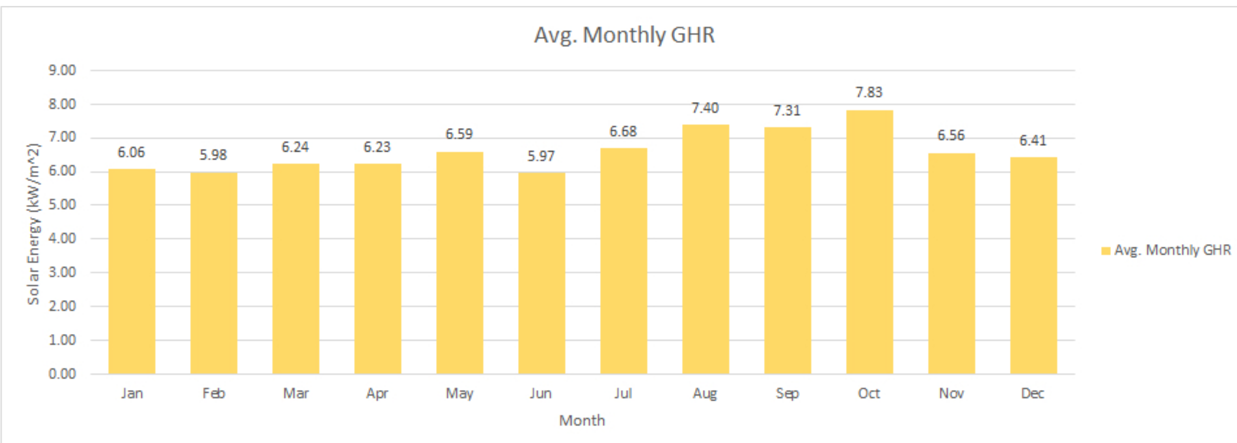

Figure 6: **La Pa**z solar radiation on horizontal surface

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Comparing the two analyzed cities, in La Paz the monthly average values are almost the same all over the year due to its altitude and the positioning with respect of the equator line that it has. On the other hand, for Shanghai the values changes more or less like the season changes all over the year.

Another analysis has been made comparing the vertical radiation on the different surface of a building during the year. This is important to understand what will be the passive strategies to use with the aim to minimize the energy consumption of our construction. The follow images have been calculated using climate consultant and show the 4 surfacese first of La Paz and than of Shangai.

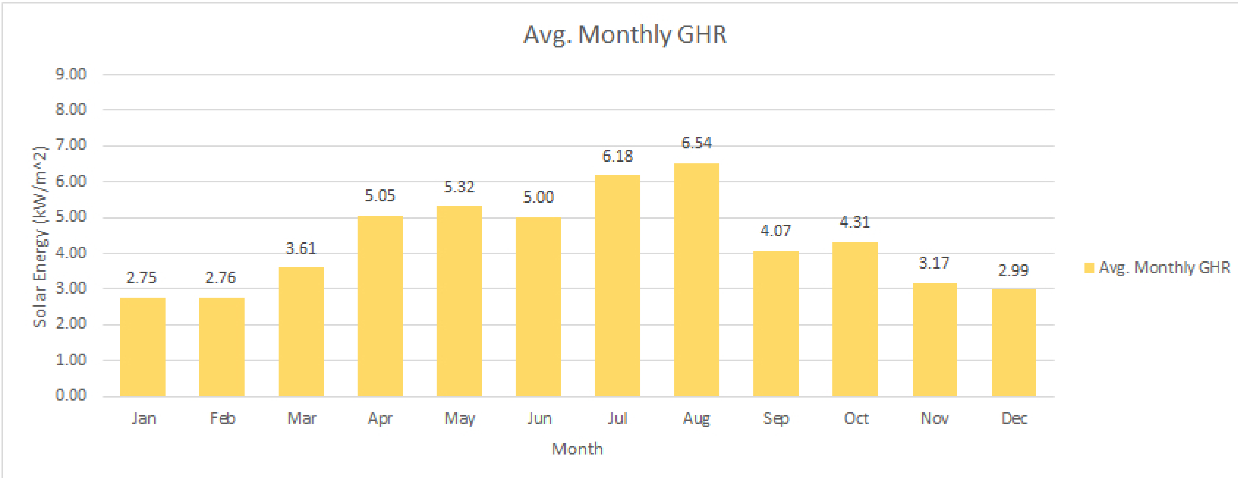

Figure 7: **Shangai** solar radiation on horizontal surface

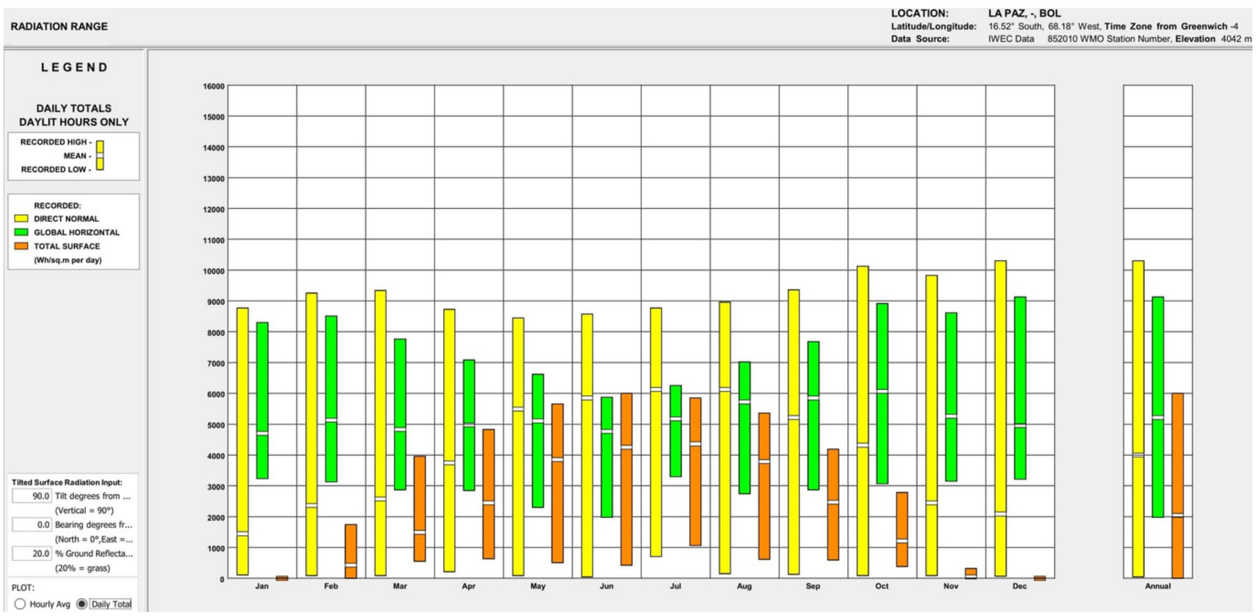

Figure 8: **La Paz** North Surface

The last analysis is about the eating and cooling period. The following 2 pictures are related to the psychrometric chart of the two cities wherei it is showed the heating period, the cooling period and the probability to find a certain temperature in that time frame.

As it is possible to see from the psychrometric charts, starting from **La Paz** there is no a cooling period but only an heating one, first of all it is thus impossible to consider a complete analysis because this aspect represent a limit. Then considering that a set temperature point has been evaluated to be at 18°C which is a value out of the generally desired internal comfort conditions (between 20°C and 26°) there is not a comfort zone that can be considered but only a value which should well fit for all periods of the year.

Concerning **Shanghai**, on the other hand, it is possible to see the temperature distribution in both heating

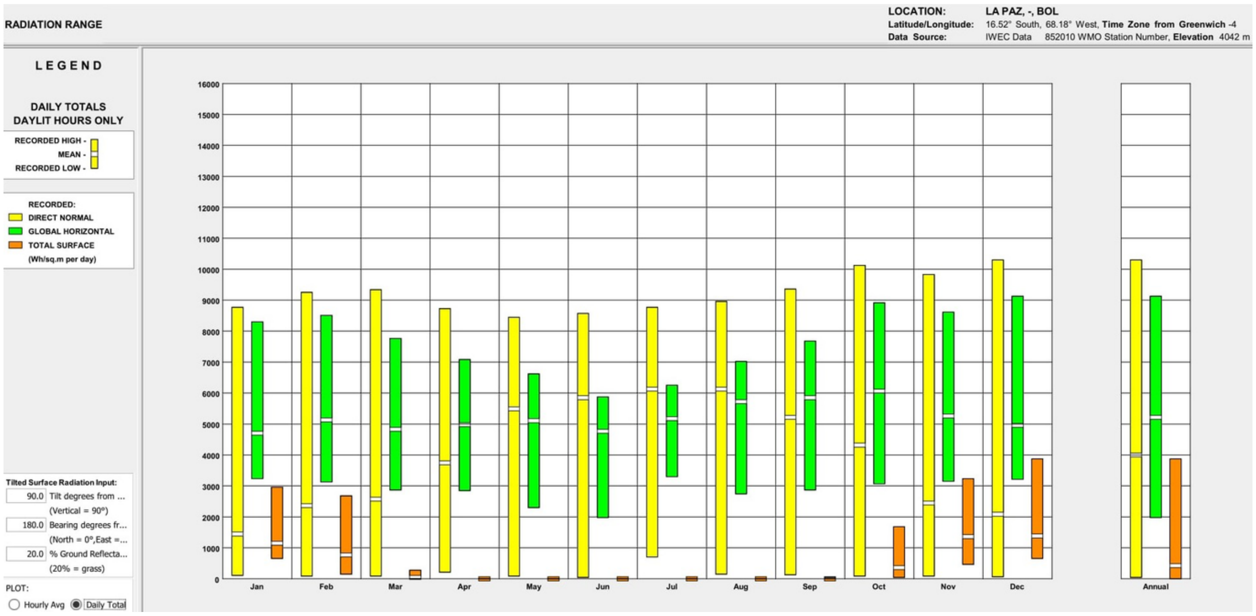

Figure 9: **La Paz** South Surface

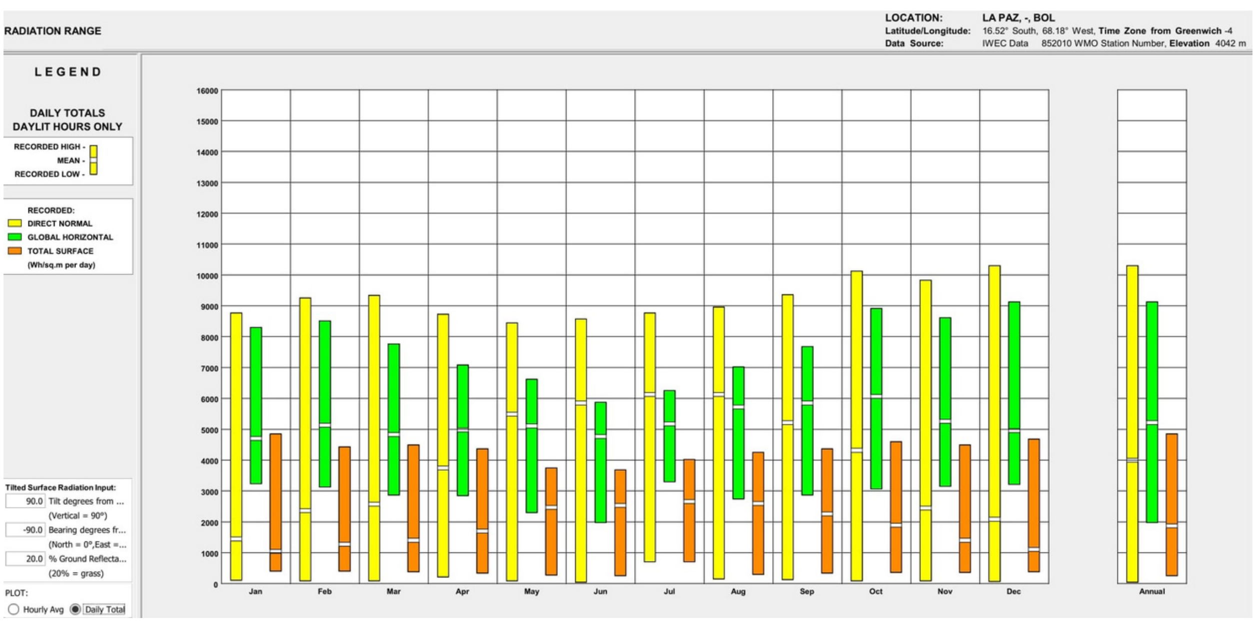

Figure 10: **La Paz** West Surface

and cooling period.

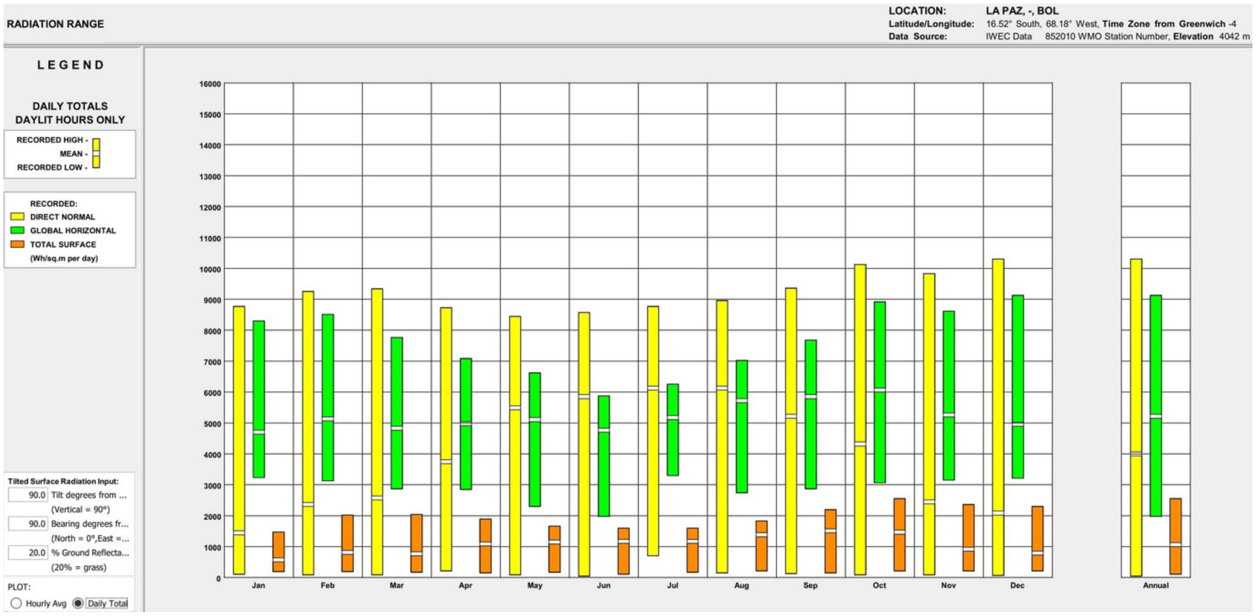

Figure 11: **La Paz** East Surface

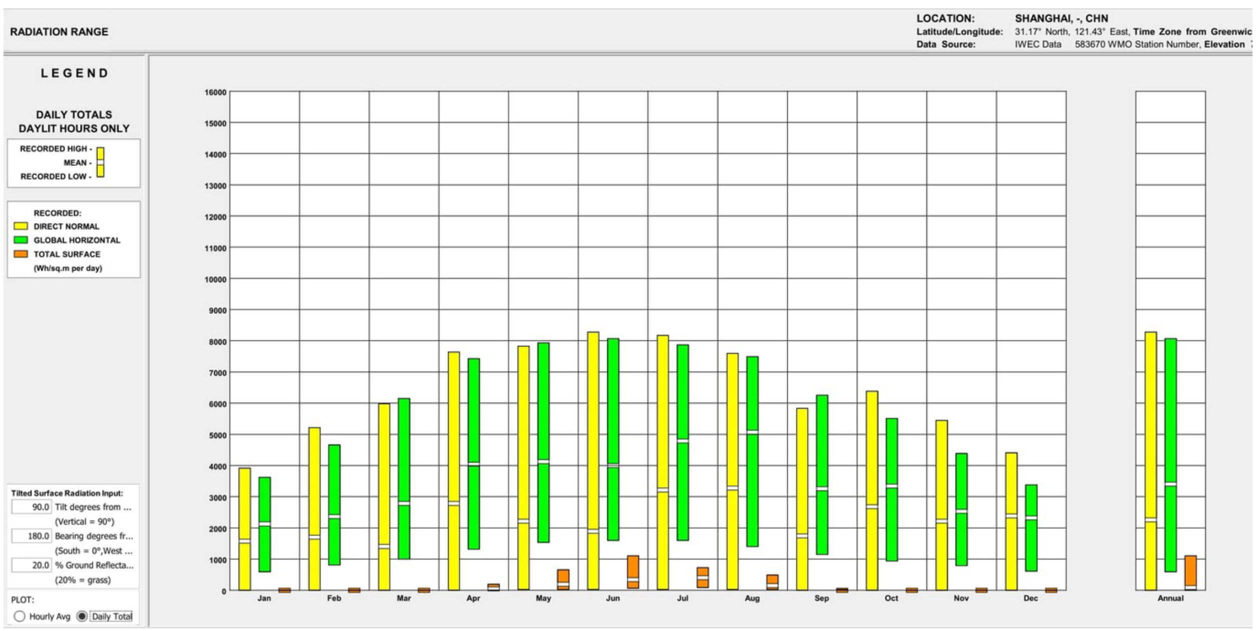

Figure 12: **Shanghai** North Surface

CHAPTER I

Starting from the cities of La Paz (Bolivia) and Shanghai (China), some examples of Vernacular Architecture have been collected and analyzed not only considering the specific reference cities but rather taking into account more in general their culture and their traditions which have affected the entire countries to which they belong.

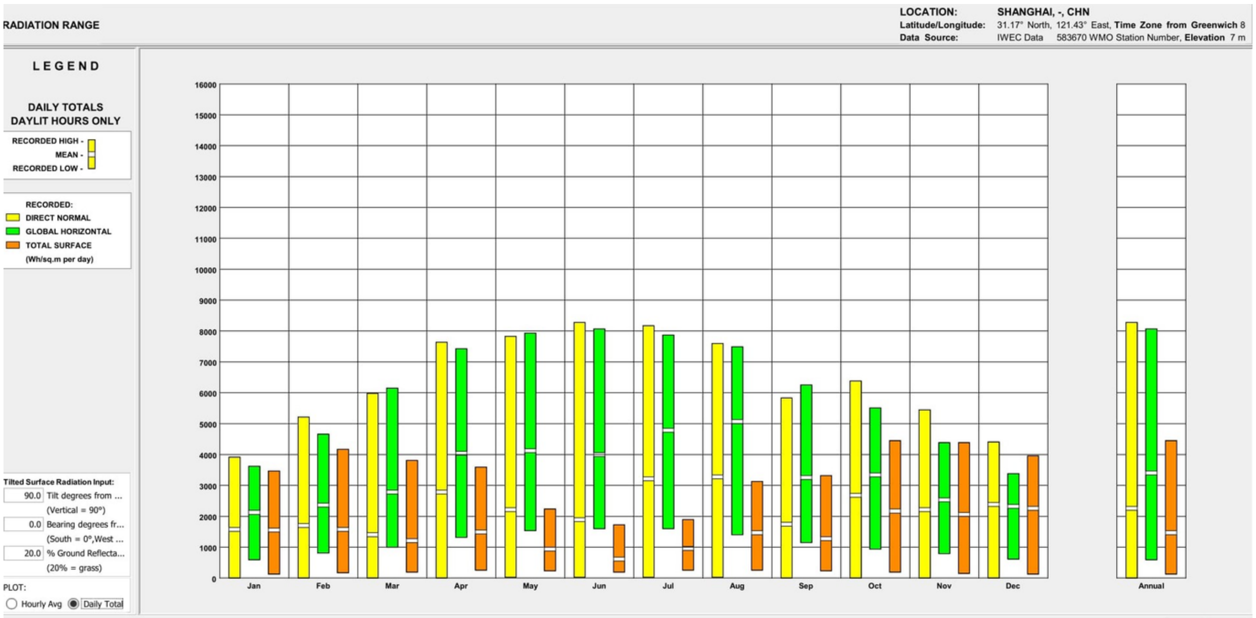

Figure 13: **Shanghai** South Surface

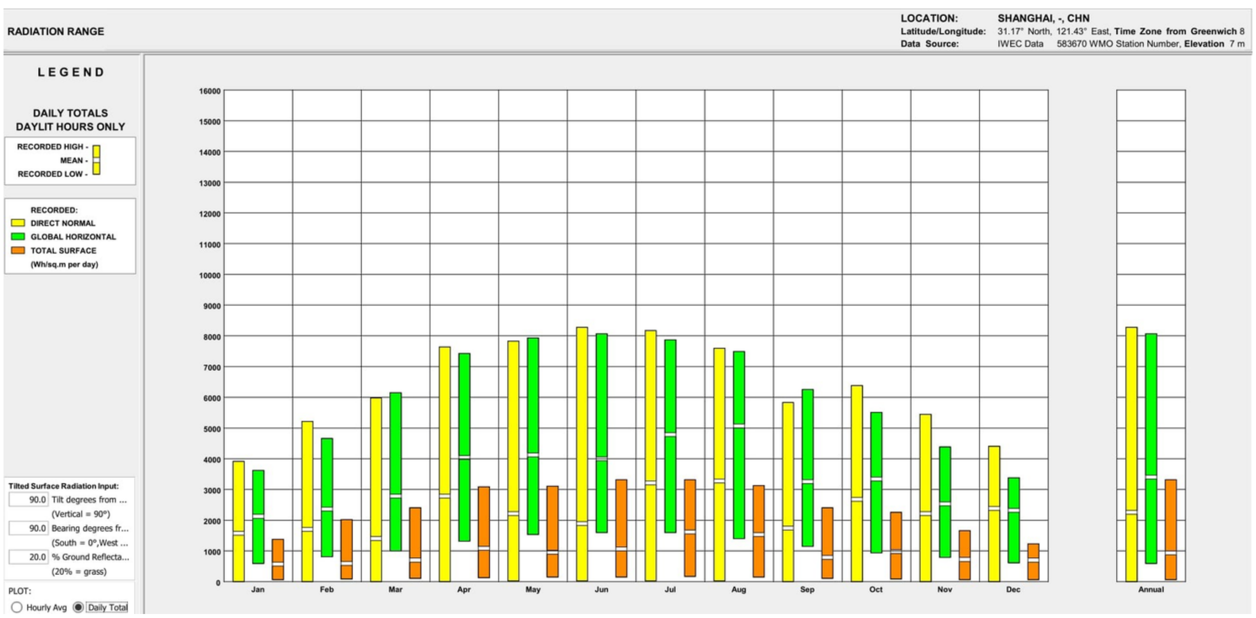

Figure 14: **Shanghai** West Surface

1.1 China vernacular architecture

As far as Shanghai and, more in general, the whole China, different examples of typical vernacular architectures have been found in relation to the different climates that characterize the various regions. Those types

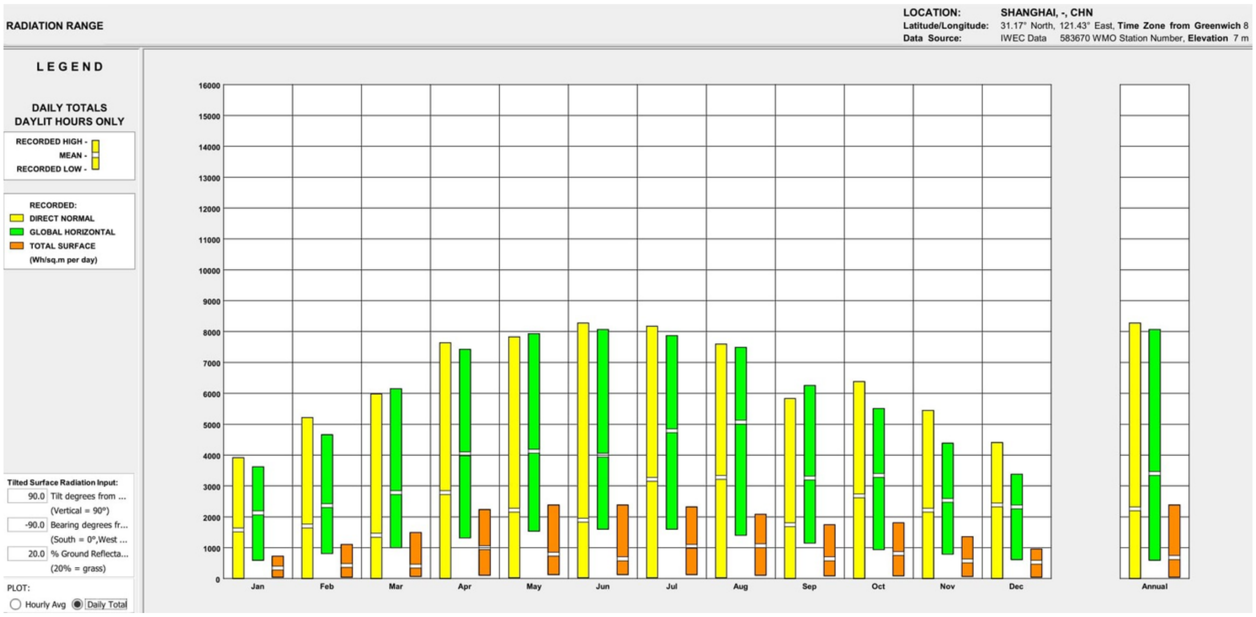

Figure 15: **Shanghai** East Surface

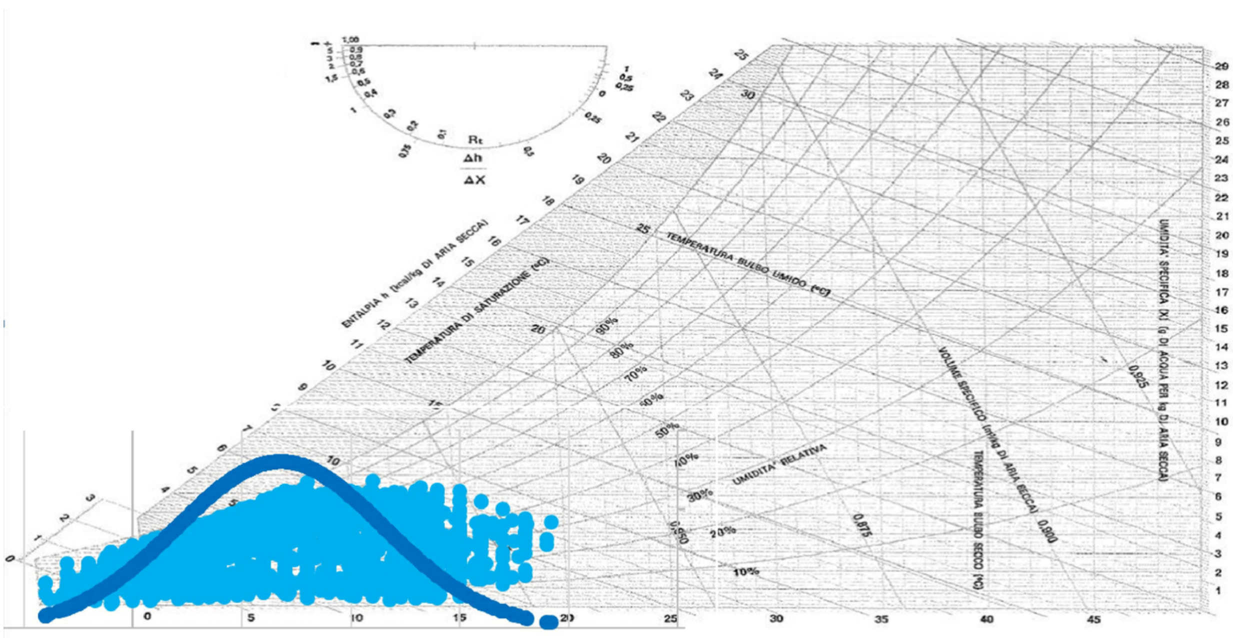

Figure 16: Psychrometric chart of **La Paz**

of constructions are focused on energy balance in the sense that they are capable to deliver a correspondingly sufficient thermal performance making it possible to achieve comfort throughout the whole year. All those types are differently spreas in China in function of the different climate regions.

Source : Review Chinese Climate and Vernacular

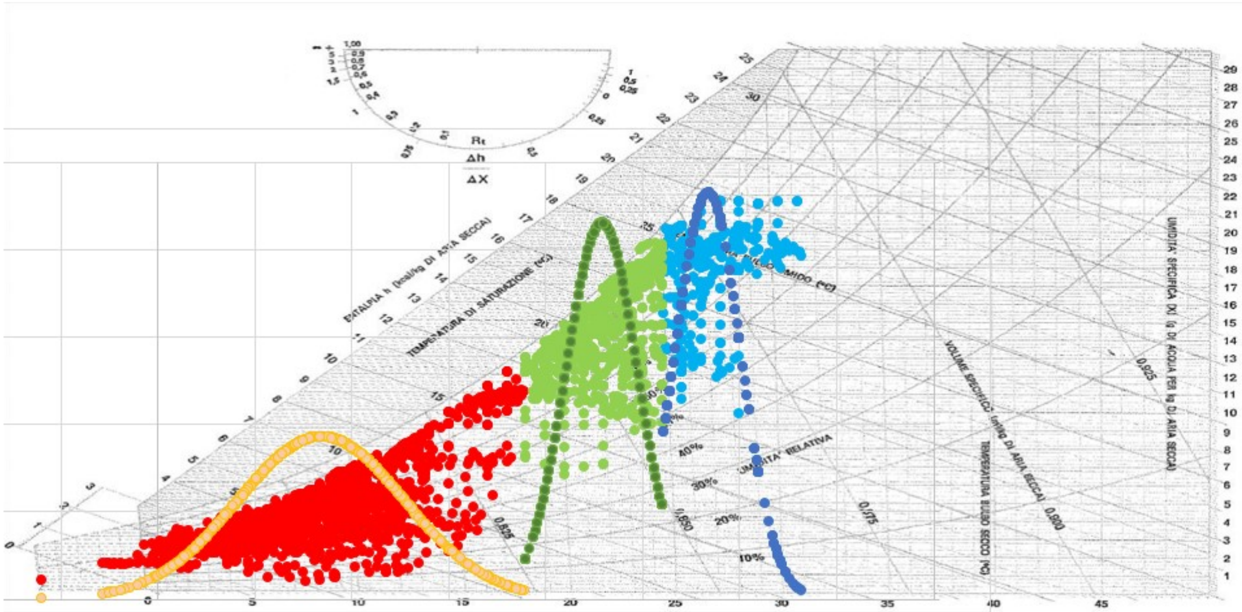

Figure 17: Psychrometric chart of **Shanghai**

Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

1.1.1 Rise pulp technique

Since 900 CE, when the first Chinese settlers inhabited this area, the people have been struggling against the severe cold climatic conditions. Different tecniques have been adopted such as the use of **south facing low-rise** houses with high solar access., constructed with quadrangular brick courtyards . Those constructions were characterized by 500 mm thick **mud walls and and two layer of windows.**

Before the introduction of glass, windows were made from a combination of **small wooden partitions** with **rice pulp stuck** from the outside and then treated with oil.

Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

Specification about construction technique of rise pulp window:

The **pulp** was attached from the outside in order to allor the wooden partition to **withstand windy conditions** and to protect the partition from **snow accumulation** . The practice was to boil local produced glutinous rice in water until it became a thick liquid that was kater used to stick several layers od paper onto the frame joining and window adges. This “rice paper seal” would last for the whole duration of the winter. When the next spring arrived the paper would be torn off and then cleaned with water.

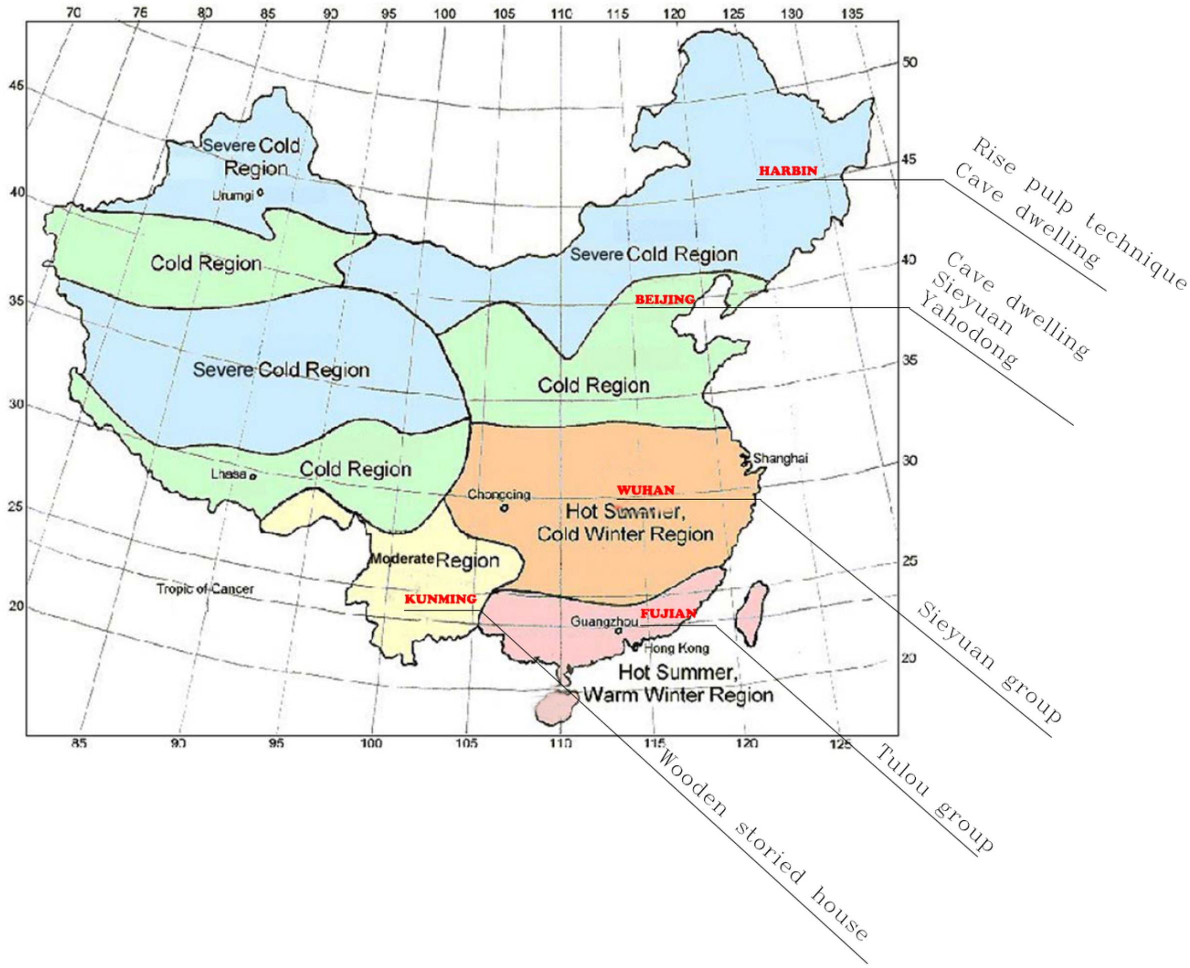

Figure 18: China climate map

1.1.2 Siheyuan

Siheyuan consists of a square housing compound with rooms enclosing a central courtyard. This courtyard often contains a pomegranate or other type of tree, as well as potted flowers or a fish tank, they are used in **cold regions of China,** where representative city is Beijing.

Siheyuans usually form alleys, which link together the interior of a city. Since alleys are usually straight and run east-to-west, houses can face north and south. As in the severe cold region, the houses are low-rise, but some of them have first floors. The central courtyard is usually big enough to allow ample solar access, and provides wind protection during the winter. Efficient ***insulation*** *has also been used for houses as there are commonly 370 mm thick brick walls and single glazing with sealed window frames made of rice paper. The Siheyuan's summer is pleasant too, the openings on the walls allow airflow to cross, while the verandas, overhanging roofs and trees create* ***sufficient shading and semi-open space*** *for afternoon tea and evening gatherings.*

Figure 19: Inside rice pulp window

Figure 20: Outiside rice pulp window

1.1.2.1 Siheyuan group

A different kind of Siheyuan has characterized regions affected by **hot summers and cold winters** where the construction is much more compact than it was in the north of the country, and, moreover, usually appear in compressed groups so as to control solar gain.

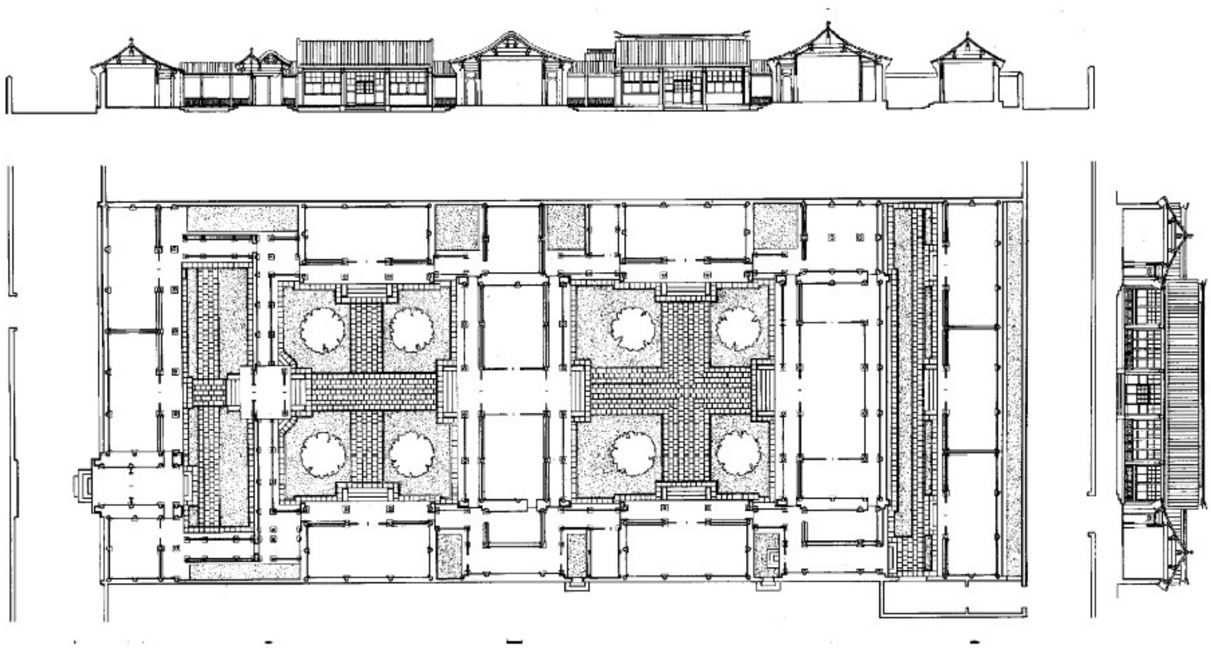

Figure 21: *Siheyuans* plan *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

CASE STUDY : Zhai J.W. Village (Wuhan)

The perfect example is the Zhai J.W. Village, built 90 years ago for a merchant; it is 11 m wide, 24 m deep, with a total floor area of 400 m2 (two partial stories).

If looking at the thermal conditions of the city Wuhan (30°35' N, 114°18' E) it is possible to see that the applied passive strategies should have be effective against **warm and humid summer**.

Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

The building is facing the main road, where the shop has been arranged at the front and residential area at the back. The house is mainly north—south facing with a small deviation to the east; it gets **adequate shading** from the east and the west side benefiting from its intermediate location. The small courtyard is the **key functional space** within the entire building that connects the front shop and the residence.

This compact site layout demonstrates effective solar control as the grouped buildings create narrow streets with walls and shaded veranda places in order to **deflect solar rays** thus enabling it to **cool down during hot weather**. Moreover being a deep plan, the skylights bring **sufficient daylight** into the house, allowing **hot air to escape** through the top so as to **ventilate** the building.

Source : Review Chinese

Figure 22: *Siheyuans* entrance *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

Figure 23: *Siheyuans* patio *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

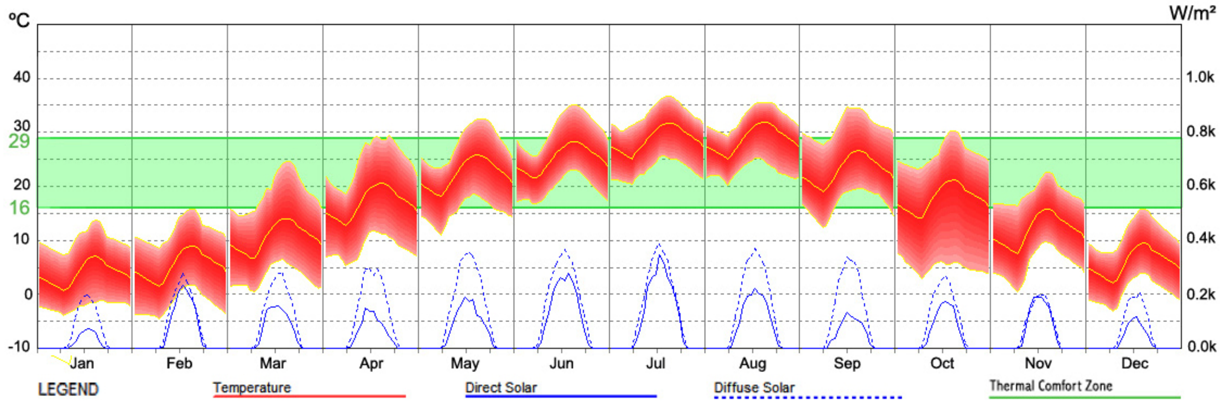

Figure 24: Wuhan thermal conditions

Figure 25: *Siheyuans* group *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

CASE STUDY : Chuxi village (Fujian)

Chuxi Tulou cluster is a Hakka village inhabited by Xu clan and is a total of 36 tulous which represent another different kind of Siheyuan is that one which is typical of regions characterized **by hot summers and mild winter which is the so called tropical moist monsoonal climate.**

The priority of the vernacular architectures is the **natural ventilation** and the **shading**, and it is often characterized by big **overhanging roofs** that are usually made from plants. Also in this case the buildings are made of groups of constructions as it is possible to see from Tulou group. Round Tulous normally have only one fortified door. Behind the door is the foyer. This is not only the major access, but also the public space for the occupants and the **natural ventilation is ideal**.

Most round Tulous are three or four storeys. The first floor becomes a storage room for food and furniture: while the storage room does not have any windows, the second one and above are bedrooms. They have **small windows**, which open to the outside, and a **larger widow opening to corridor.** The corridors are built on the extension of the beams of the lower floor. As a result, the ground floor is free of columns, and creates a large open space. The is small eaves on the second or third floors, wich function is of drainage: the under space created can be used as a storage place.

The Tulou group demonstrate another interpretation of climate-responsive buildings in a hot climate, when traditional **passive cooling strategies** such as solar control and cross ventilation are not prospective due to security reasons, and this include the use of thermal mass. The several meter-thick clay walls have a **high**

Figure 26: Roof lights

capacity for heat storage, where heat can be stored during day time and released at night, allowing the indoor environment to be maintained at a relatively stable and pleasant temperature.

Source online : http://amazingfujiantulou.com/how_a_tulou_was_constructed.html

The large, high, soil earthen buildings came from the most common, unattractive earth: red soil, rubble and the new earth that came from below the plowed soil.

Figure 27: Tulou group *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;* **.**

Figure 28: Tulou group inside *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

The **rammed earth wall** was made up of ordinary soil, as well as mature **fermented earth, sand, and lime**. There were three types of ramming that used a special formula. The main strength of the damp ramming came from sand; lime was next most important; and soil, third. The core of the dry ramming came from soil and around this core was placed a mixture of sand and lime. According to historical code in China, the ratio between the height of rammed wall and its thickness is aroung 3:1 to 4:1. However, this ratio in Tulou is almost 6:1 to 7:1 and a five stories Tulou has a wall thickness of 1,5-2m. A wall that was rammed with well-fermented earth was unlikely to produce significant cracks or problem with tilting. There was no uniform standard for this process.

Specification about construction technique: brown sugar, egg whites, and glutinous rice into

Figure 29: Tulou group inside *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

Figure 30: Interior of a singleTulou

the mixture of earth.

The three ingredients were not added directly into the mixture: Brown sugar and egg whites could easily *attract ants and insects, and this would have jeopardized the stability of the wall. Thus, they could not be added in directly. The Hakka had strict* ***rules*** *for this process: the glutinous* ***rice was first ground into powder****, and* ***cold water was mixed*** *with it. Then a large amount of* ***hot water was added****, so that the* ***mixture became very runny****. Next,* ***brown sugar was added****. Finally, this specially created paste was poured into the three types of earth and turned over with a hoe so that it would be thoroughly combined.*

[Source online: http://amazingfujiantulou.com/how_a_tulou_was_constructed.html *]*

1.1.3 Cave-dwelling

These structures also provide reasonable comfort and indoor air quality without having the benefit of modern day air-conditioning systems, and they are used especially where the **climate is cold and dry** and the soil is firm, as fot the city of **Harbin**, located in the subarctic climate zone. This is also a typical local residential form that can be dated back to the Neolithic age, when people excavated the soil from hillsides, and made caves available for them to live in. This residential architecture is common in **North Shannxi Province** and even the entire **Loess Plateau.**

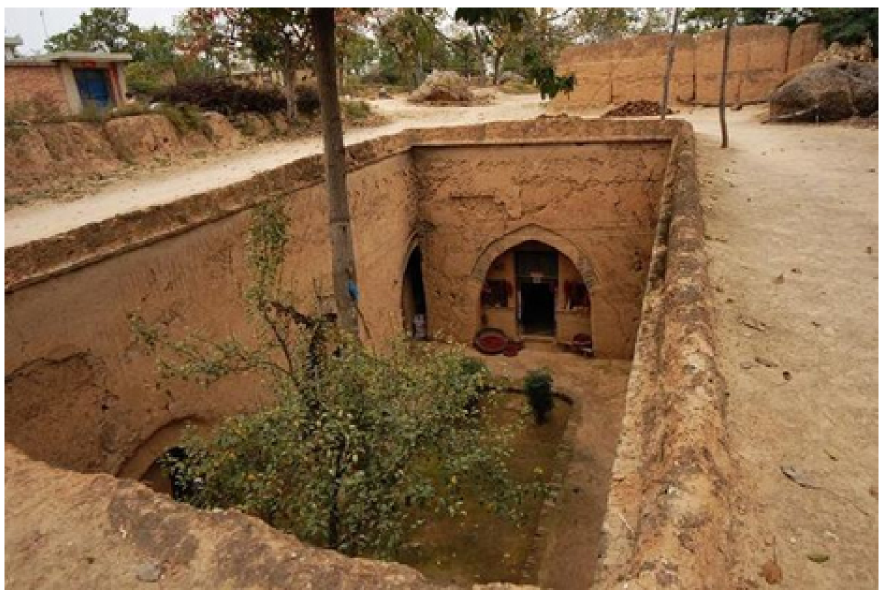

Figure 31: Cave dwelling system *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

Because of the capacity of the heavy mass, the cave is ***cooler during the summer and warmer in the winter****, which is an ideal solution for achieving thermal comfort. Although it is not practical to house a population of 1.3 billion in caves, cave–dwelling demonstrates local people's understanding of the environment in which they live and their ability to adapt current resources and put them to practical use.*

The first type of cave dwellings are those carved out of the side of a cliff. Cliffside dwellings are often south-facing, and the facades are sometimes faced with bricks or stone.

Figure 32: Cave dwelling system *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

Figure 33: Cave dwelling inside *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

Another unique feature is the Kang arrangement, which has been used for heating homes in Northen China

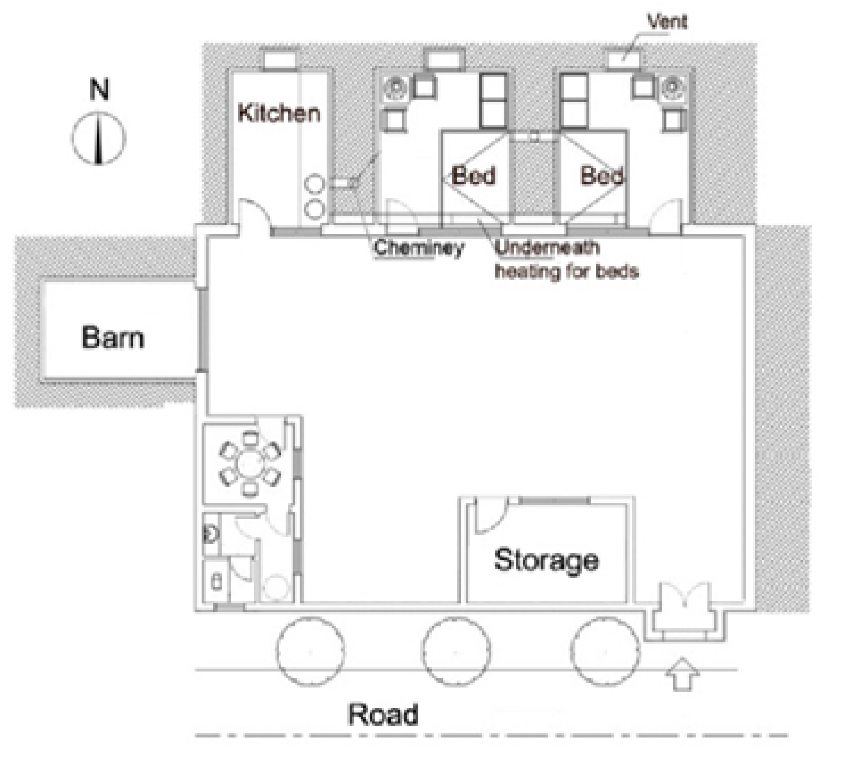

Figure 34: Cave dwelling plan *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

for more than 2500 years.

A kang system consists of a stove, a kang (bed), channels and a chimney. **This system has been used for sever cold regions of China**

Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

One end of the bed is connected to a stove in an adjacent room, while another end is connected to a chimney. The kang itself is hollow, thus allowing heat and smoke to travel from the stove to the chimney, and in the process heating up the bed and the room. Of course the system implies residual heat of smoke from adjacent cooking stove is used: form this stove biomaterials are burned and the bed release heat to the bedroom so that finally the smoke is exhaled via the chimney. It allows four different home functions of cooking, sleeping, domestic heating and ventilation. The ventilation is integrated into one system and moreover, it harnesses biomass burning for both cooking and space heating and thus reduces the use of commercial energy.

The system is not used any more and this is of course related to the fact that has a **negative impact on global warming**.

1.1.1.1 Yahodongs

Figure 35: Cave dwelling system *Source online: Photograph courtesy of Ronald G. Knapp 1984, Qianxian, Shaanxi Province*

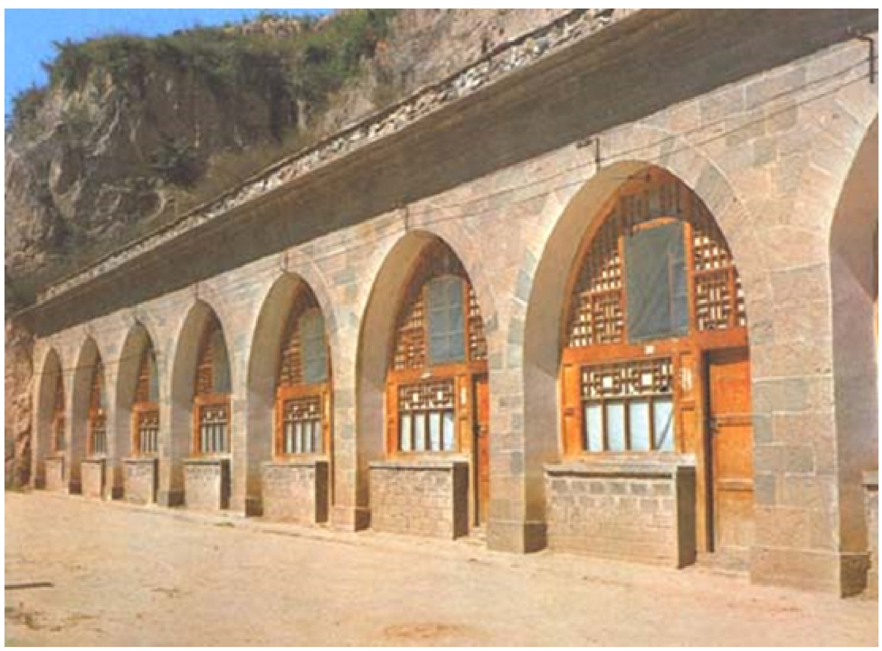

Figure 36: Cave dwelling external wall *Source online: Photograph courtesy of Ronald G. Knapp 1984, Qianxian, Shaanxi Province*

A centuries-old tradition in central China, characterized by a general **cold climate,** has seen indigenous people living underground in ancient 'pit yards'. The courtyard homes, called Yaodongs, have had six generations living under their roofs for over 200 years and are currently under conservation. However the tradition itself in China is thought to date back over 4,000 years and have housed thousands of residents in

Figure 37: Kang system chimney system

the hills. Today, the homesteads are much more modernized and many of them are equipped with electricity and other utilities.

Yaodongs can be divided into different types, depending on the topography of the regions in which they were built. Where hills are available, Yaodongs may be built into the slopes, and a hill may contain several stories of Yaodongs but where hills are not available, Yaodongs are simply built into the ground. Rectangular wells about 5 meters to 8 meters deep are first dug into the ground and after that, Yaodongs are built into the walls of these wells which serve as a courtyard for the inhabitants.

The two main typologies are :

Cliff cave dwelling which are dug in loess cliffs, on the side of the valley.

Ground cave dwellings which are dug around an excavation conducted at the surface, serving as interior courtyard, called yaodong-well or sunken courtyard.

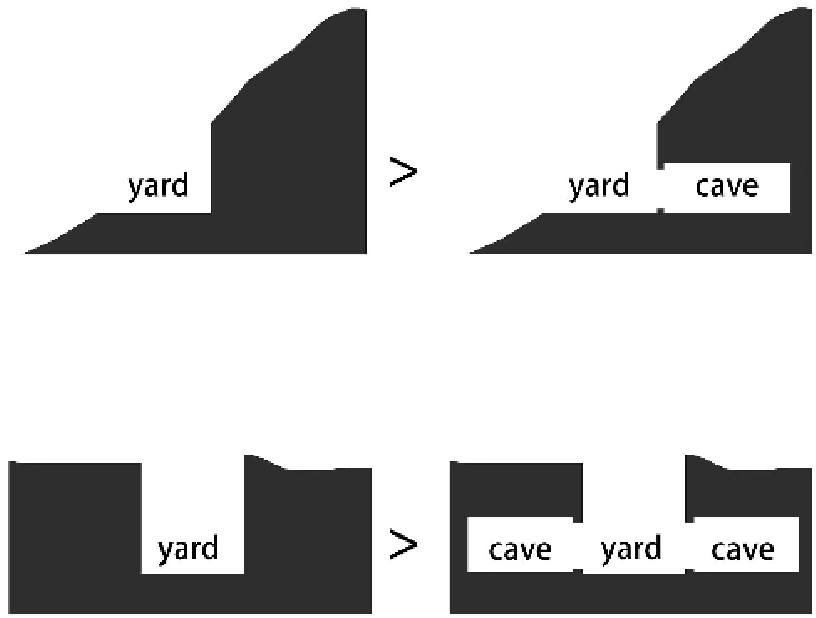

Figure 38: Tipologies of Yahodongs

Source: Thesis The Renovation of Traditional Cave Housing in China - New Ecological Design for Old Yaodong Thesis supervisor: Alessandro Rogora - Authors: Cao Yonghe

Yhodongs caves are normally located on the slope of the mountain. The arrangement is not planed but according to the natural layer structure of the Leoss earth: this is the name for special local sediment that has been deposited by wind storms on the plateau over the years. The layer structure of the Loess plateau is quite typical geological landscape in China and it elped to build Yaodong caves because of the natural terrace type.

Traditional Yahodongs are one of the most eco-friendly and economical dwellings in China because they are made of materials for building which can be found in local area: they merely produce waste to the environment. Moreover Loess soil is a **good insulator of heat** so its use allow to take advantages of a design strategy which include **thick earthen walls that are able to keep the interior of the Yaodongs cool during the summer and warm during the winter.**

As far as the shape, due to the big openings of the window on the façade, the natural **lighting condition is quite good** near the window, while less daylight can go deeper into the cave.

Figure 39: *Yahodongs* top view *Source : ONLINE www.dailymail.co.uk/china By GABRIEL SAMUELS and VICKI CHENG FOR MAILONLINE* - PUBLISHED: 16:11 BST, 5 April 2016 | UPDATED: 17:40 BST, 9 April 2016

Figure 40: *Yahodongs* top view *Source : ONLINE www.dailymail.co.uk/china By GABRIEL SAMUELS and VICKI CHENG FOR MAILONLINE* - PUBLISHED: 16:11 BST, 5 April 2016 | UPDATED: 17:40 BST, 9 April 2016

Advantages

In winter while the air temperature outside is 0, the temperature in a cave might be 18. It is because the **earth stores the great solar energy during the summer,** and slowly release the heat in winter, even

Figure 41: *Yahodongs* top view *Source : ONLINE www.dailymail.co.uk/china By GABRIEL SAMUELS and VICKI CHENG FOR MAILONLINE* - PUBLISHED: 16:11 BST, 5 April 2016 | UPDATED: 17:40 BST, 9 April 2016

Figure 42: *Yahodongs* top view *Source : ONLINE www.dailymail.co.uk/china By GABRIEL SAMUELS and VICKI CHENG FOR MAILONLINE* - PUBLISHED: 16:11 BST, 5 April 2016 | UPDATED: 17:40 BST, 9 April 2016

there is very l**ittle solar gain in winter**. While in summer, the air 22 temperature outside is 30, it might be only 20 in a cave. Because the e**arth stores little solar energy in winter** and it did not change much the temperature, meanwhile it stores **enormous solar energy from the sun in summer**. In fact as

Figure 43: *Yahodongs* in mountains *Source:* ***The renovation of traditional cave housing in China. New ecological design for old Yaodong*** **- CAO, YONGHE , ICAR/12 TECNOLOGIA DELL'ARCHITETTURA, 23-apr-2013**

already said leoss is a good material for thermal mass, so Yahodong caves become a natural **Solar-passive house** if properly built. The earth has big mass and high value of conduction and can store a great amount of energy due to this big mass, so this particular kind of buildings are really good for cold climates where is it necessary to **store energy** in order to guarantee thermal comfort without the use of an heating plant during winter: those systems are actually not used any more but the a renovation of the traditional Yahodong can be seen as something useful for future architecture in those areas.

Disadvantages

The arrangement of traditional Yaodong is not as good as its ecological construction: the rooms in the cave are usually mixed use. The main living room works as well as the kitchen and the dining room, sometimes bedroom. The toilet is outside of the cave as an individual unit which makes it so not convenient in a cold or rainy day. Moreover the interior of the traditional Yaodong **cannot resist the humidity** in the earth and is sometimes very **wet**.

Because of the mixed use of the cave, there is not an individual kitchen in the Yaodong cave: there is only stove without an effective chimney is installed in the living room. When people cook in the cave, the salt particles and oil particles which harm the health of people, will rise and float in the air. The **high relative humidity** in the traditional Yaodong cave makes the situation worse. The floating particles easily combine with the vapor and precipitate to the surfaces of the interior space. Moulds and **some harmful bio-gas would grow from the chemical particles**, doing damage to the quality of the air in the cave.

Moreover the temperature inside the Yaodong is not equal on every area: it changes according to the depth of the cave so that in a normal winter day, the interior temperature is higher where the tested area is deeper in the cave. The structure is **weak against the earthquake**.

Influence of the tradition on new construction

Yaodong cave houses are the typical house style of the vernacular tradition but many new projects for New Yaodong cave were born since 1980s.

As a typical example the *new Yaodong house in Dan village of Shaanxi* was recently complete but in this case the "face" of traditional Yaodong cave is the only thing that can recall the memory of traditional Yaodong cave.

Although, the new structure was located besides the mountain, it is a very independent building without any connection to the mountains behind. All the materials of the building are ***moder, for instance, concrete, steel, glasses and bricks.*** *Since the whole structure was completely created, it has n****othing to do with loess and earth.*** *Generally speaking, the building is not a earth sheltered building but some conventional apartment building. The project copied the "face" of the traditional Yaodong cave, yet lost the most important spirit of it*

1.1.4 Wooden storied house

The vernacular architecture for moderate region is primarily based on timber construction as timber is the most common and locally available building material. This type implies a **mild climate** with a high incidence of sunshine and precipitation. The outdoor environment should be reasonably pleasant throughout the year with an average annual air temperature close to the comfort range, as for the city of Kunming.

Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

As it is possible to see from the graphs in this city utdoor air temperatures mostly remain within or **close to the comfort range** or slightly cooler for a short period. Although the diurnal temperature is 5 °C for those mild months and 10 °C for cooler months, possessing an annual mean temperature of 16 °C, the climate itself becomes a comfort factor that requires few passive design strategies.

CASE STUDY : Traditional house (Kunming)

Usually these houses consist of a small structure with three to five rooms, where all aspects of daily life and activities are carried out at the first floor level. The housing material is a combination of **bamboo and wooden frames,** steep, thatched roofs with broadly sloping eaves, bamboo mats for floors and sitting area, and wide, open corridors in which to dry clothes.

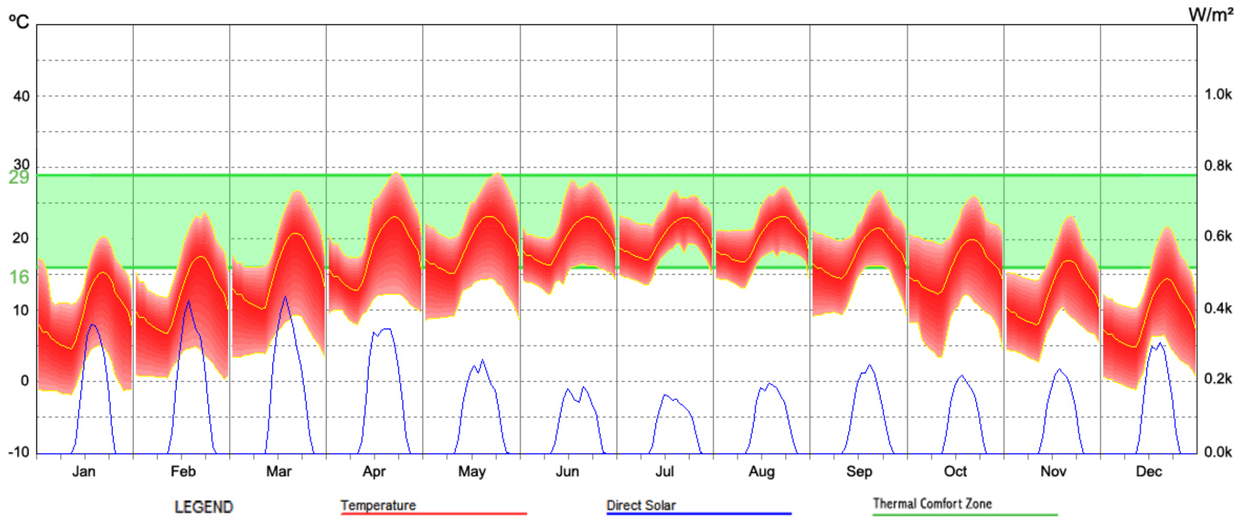

Figure 44: Kunming cllimate data

Figure 45: Wooden storied house *Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;*

This type of the house gives **protection from intensive solar radiation** as well as **rainfall**, and also allows a prevailing **breeze to cool the dwelling**. Indoor comfort can be easily achieved by utilizing this solar radiation in cooler months, although **overheating possibilities remain** if they are not effectively controlled, trought the use of a correct cooling strategy, such as the **Natural Ventilation.**

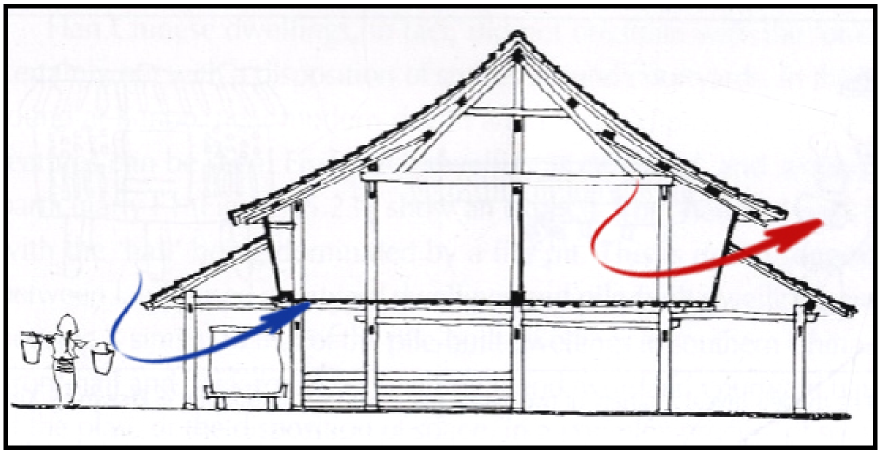

Figure 46: Section of the house

Source : Review Chinese Climate and Vernacular Dwellings Feifei Sun, NPS Group, Earle House, Colonial Street, Kingston upon Hull, HU2 8JY, UK;

Considering the fact that the **groungfloor is empty** this solution of **sub-floor ventilation** can be considered a good strategy to avoid overheating and control solar radiation in hot months.

The aim of this system is to provide crossflow of air in both directions, ie. from side to side and end to end of the dwelling. Vents shall be placed in all walls that enclose the sub-floor space. Corresponding openings shall also be placed in any internal walls in the sub-floor space.

1.1.5 Summary conclusion of the analysis in function of regions:

As far as **cold and severe regions**, all the analyzed systems (cave-dwellings, siheyuan and Kang arrangement) combine Chinese architectural techniques and human comfort which is reached through some passive strategies used for both winter and summer, including solar controls, adequate ventilation and control of the outdoor microclimate. In conclusion, the vernacular architecture in those regions tends to have a general solar access in winter, but is controllable in the summer. It combines with adequate thermal mass capacity, and a manageable building envelope that ensures both airtightness and natural ventilation. From the analysis of those architectures it can be deduced that in China there is a climate in which both winter and summer comfort needs to be addressed. In other words, the climate is cooler than the comfort range in winter and warmer in summer. As a conclusion the best strategy in response to those climates, the building should firstly harness as much solar gain as possible through the whole year, and then protect it by heavy thermal insulation and airtight building envelope so as to reduce the heat loss to the cold outdoor environment. Additional protection against snow and winds should also be considered in the design.

As in the cold region, for **climates with humid and hot summers and cold winters**, passive building designs should focus on energy balance with special regards to summer comfort, as evaporative cooling will not be an effective prospect during hot months. Apart from obtaining passive solar gains and reducing heat loss during the winter, sufficient solar controls, promoting effective ventilation and passive cooling by natural means should be the priority for climate-responsive buildings.

Regarding **moderate climate**, he priority for passive building designs in this mild climate is to provide sufficient solar access during cooler seasons whilst taking into account the potential for overheating. Thus, passive cooling strategies observed from vernacular architecture such as solar control and natural ventilation should also be considered.

For those regions characterized by **hot summers and mild winter** a sustainable building designs should emphasize passive cooling practices only. Solar controls and ventilation are the key contributors and prospective evaporative cooling only occurs from October to April. In situations where traditional passive cooling is difficult to achieve, heavy insulation should be compensated.

1.2 Andean vernacular architecture: Bolivia and Colombia

Starting from the analysis of vernacular architecture of **Bolivia**, it has been later consider to take into account what is it the so called Andean style of the highlands. The most ancient ethnic groups usually used carved stone to build their houses, temples and other structures as can be seen in ruins such as Tiwanaku and others. The common classes built their houses of mud and straw with straw roofs.

In order to better understand this kind of vernacular architecture, it has been later analyzed the expression of rural vernacular housing in the Andean highlands of **Colombia** which is the result of a combination of American native's labour, materials and construction systems, and the techniques and spatiality of the European conquerors that arrived in the territory in the sixteenth century.

Figure 47: Geographic location of Colombia and Bolivia

Online source: https://it.pinterest.com/pin/155374255867621584/

More recently, with the influence of the Spanish, they began to use adobe. These materials are still the basic construction materials used in the Andean highlands today, except that the huge carved stones used by pre-Colombian cultures are no longer used. Throughout the major cities of Bolivia (La Paz, Cochabamba and Santa Cruz) most houses are of modern architecture similar to homes in North America and Europe and typical native or Colonial style Bolivian houses can now only be seen in rural areas where native groups continue, even today, to build their homes as they have for several hundred years, as it possible to see from the pictures.

Taking into account Colombia, until today, from the indigenous population there still exist a few examples of wattle and daub, adobe walls and straw roofs, while from the Spaniards stems the adobe masonry and clay tile as the dominant expression, in which both building systems always appeal to the use of available raw materials (clay, wood and vegetable fibres).

Online source: https://en.wikipedia.org/wiki/Climate_of_Colombia

1.3.1. Wattle and daub, adobe walls

Figure 48: Vernacular house Tiwanaku ***Source: online site http://www.boliviabella.com/bolivian-houses.html***

Figure 49: Vernacular house Tiwanaku ***Source: online site http://www.boliviabella.com/bolivian-houses.html***

In the picture below there are two of those examples, located in the Rain Forest in the municipalities of **Tinjacà** (left) **and Arcabuco** (right) where it is visible the use of the wattle and daub walls and where the wood is taken from local zones. The wattle is used as the application surface for the daub, either between the wall cavities in post and beam constructions, or as stand alone walls with stronger vertical supports.

Everything we expect in a modern wall is there. A heavy thatch roof and the lime whitewash act as our exterior rainwater controls. Several inches of daub would be the insulating thermal controls. The daub would be fairly vapor permeable, allowing drying in both directions, ideal for the **temperate climates** in which most early cultures developed. That same layer of hardened daub probably would produce a respectable air barrier as well. Moreover suppose the builder erected the building frame, wrapped it in wattle, then applied exterior daub (with some structural supports). No thermal bridge: a 2000-year-old mud hut could meet aspects of modern energy codes better than houses build in the 80's or 90's.

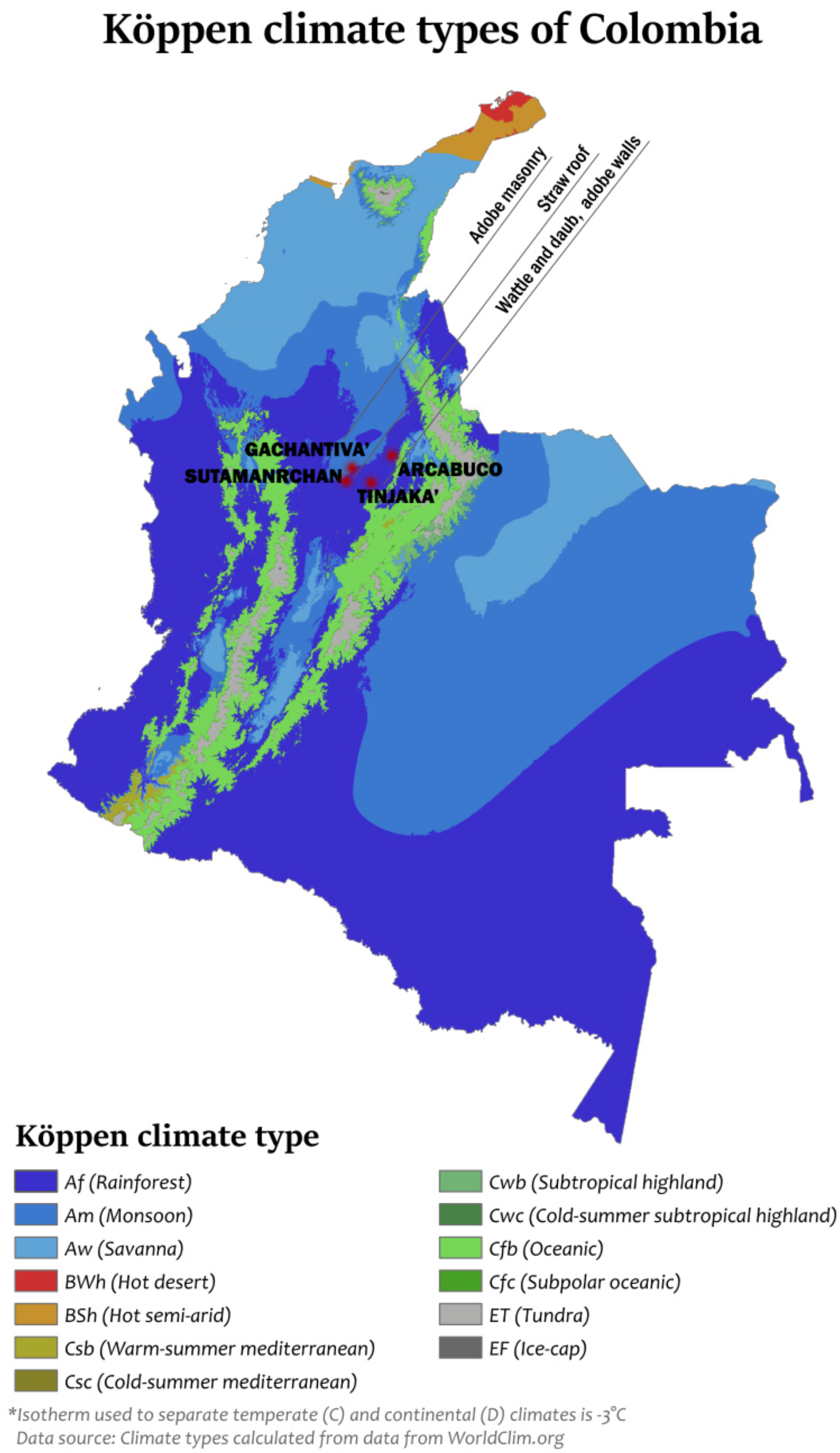

Figure 50: Colombia map with typical vernacular Architectures

Figure 51: Wattle and Daub wall *Source : MATERIALITY OF RURAL VERNACULAR HOUSING IN THE ANDEAN HIGHLANDS OF COLOMBIA: ENVIRONMENT AND BUILDING SYSTEMS* **www.witpress.com, ISSN 1746-4498 (on-line)**

1.3.2 Adobe masonry

In **dry climates**, adobe structures are extremely durable, and account for some of the oldest existing buildings in the world. Here it is possible to see daub masonry combined with industrial materials in the Dry Forest of the municipality of **Gachantivà.**

Figure 52: Adobe masonry *Source : MATERIALITY OF RURAL VERNACULAR HOUSING IN THE ANDEAN HIGHLANDS OF COLOMBIA: ENVIRONMENT AND BUILDING SYSTEMS* **www.witpress.com, ISSN 1746-4498 (on-line)**

Adobe buildings offer significant advantages due to their greater thermal mass, but they are known to be particularly susceptible to earthquake damage if they are not somehow reinforced. Thus, in addition to being an inexpensive material with a small resource cost, adobe can serve as a significant heat reservoir due to the thermal properties inherent in the massive walls typical in adobe construction. In climates typified by **hot days and cool nights**, the high thermal mass of adobe mediates the high and low temperatures of the day, moderating the living space temperature.

The massive walls require a large and relatively long input of heat from the sun (radiation) and from the surrounding air (convection) before they warm through to the interior. After the sun sets and the temperature drops, the warm wall will then continue to transfer heat to the interior for several hours due to the time-lag effect. Thus, a well-planned adobe wall of the appropriate thickness is very effective at controlling inside temperature through the wide daily fluctuations typical of desert climates, a factor which has contributed to its longevity as a building material.

1.3.3 Straw roof

Locally grown thatch is a sustainable material, which has little impact on the environment throughout its life-cycle. It requires no chemicals to grow, can be harvested by hand or using traditional farm machinery, requires no mechanical processing and therefore has low embodied energy and can be fixed using hand tools. At the end of its life it can be composted and returned to the land.

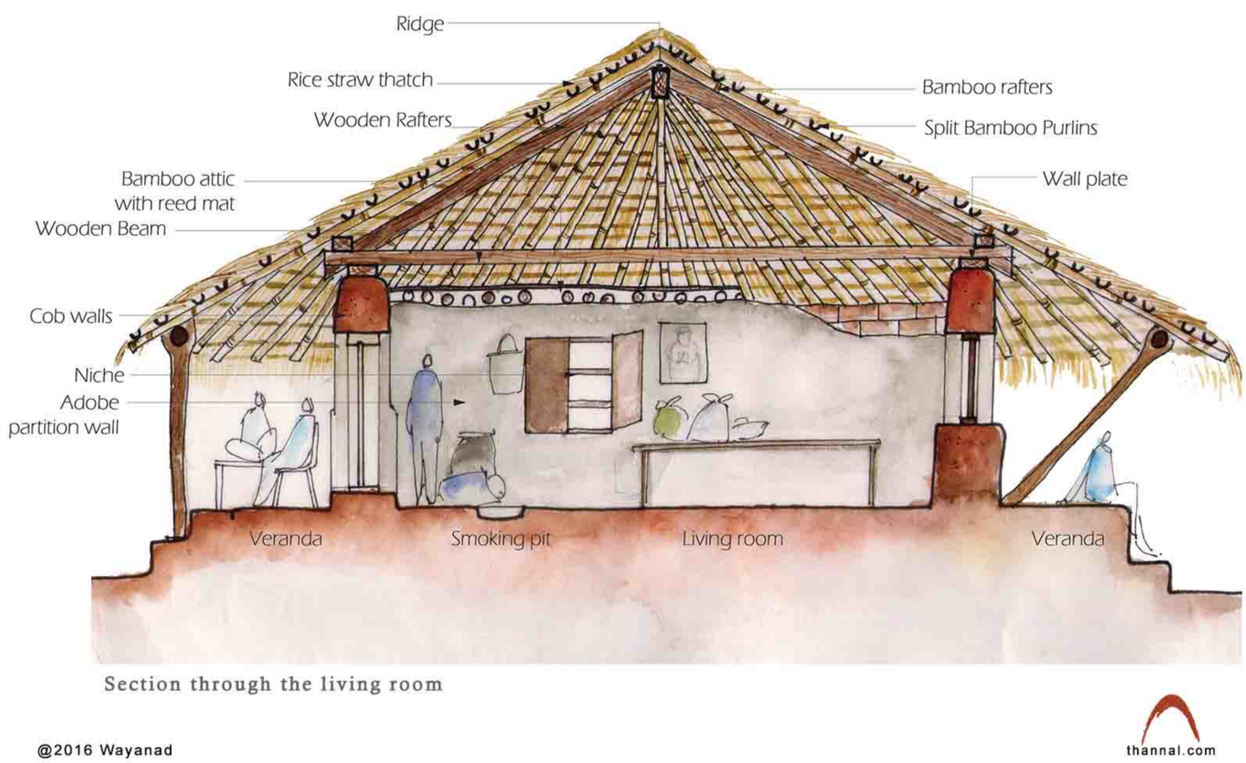

Figure 53: General section of Straw roof

Source online : http://thannal.com/150-year-old-natural-home-of-a-natural-farmer/

As an example a construction in the **Dry Forest** of the municipality of **Sutamarchàn** is adapted to the inclined topograpghy of its location and wattle and daub walls system are combined with an earth, straw and gravel roofing.

Figure 54: Straw roof *Source : MATERIALITY OF RURAL VERNACULAR HOUSING IN THE ANDEAN HIGHLANDS OF COLOMBIA: ENVIRONMENT AND BUILDING SYSTEMS* **www.witpress.com, ISSN 1746-4498 (on-line)**

Well-maintained thatch is a highly effective weatherproof coating as traditional deep thatched eaves will **shed rainwater** without the need for any down pipes or gutters. Thatch has a much **greater insulating value** than any other traditional roof covering and it is capable of **keeping buildings warm in winter and cool in summer.**

The tradition of over-coating in particular, with long straw thatch, has created very effective insulating roof coverings where extremely energy efficient can be provided if there is sufficient **thickness** of the right material, adequate **weather proofing** and it is well maintained.

CHAPTER II

2.1 Introduction

Starting from the Watson & Labs matrix, it has been later analyzed what to do in the two different assigned climates (La Paz and Shanghai) in order to minimize the energy needs for heating, cooling, ventilating and even illuminating the indoor spaces, so as to make it clear the more opportune **design strategies.**

The Watson and Labs matrix (1973)

(*) in theory ... you could

		HEAT SOURCES			
	Main strategies	Conduction	Ventilation	Radiation	Moisture transf.
WINTER (cold season)	*Increase heat gain*	*Improve heat storage when available*	Improve indirect gains from warm soil or sun	Improve solar gains	-
	Reduce heat loss	Reduce heat transfer from inside	Reduce air exchanges and infiltrations	(*)	-
SUMMER (hot season)	*Reduce heat gain*	Reduce heat transf. from out to inside Reduce heat storage.	Reduce air exchanges and infiltrations of hotter external air	Reduce solar gains	-
	Increase heat loss	Increase heat transf. from in. to outside	Improve air exchanges and infiltrations of colder external air	Increase radiant losses (cooling)	Use evaporative cooling
	SOURCES	-	Atmosphere (+earth)	Sun	-
	SINKS	Earth	Atmosphere (+earth)	Sky vault	Atmosphere (+water)

Figure 55: Watson and Labs matrix

2.2 La Paz (Bolivia) design strategies

Analyzing the city of La Paz , the first thing that can be said is the fact that for La Paz type of climate, the average monthly temperature Tdb is a good representation of the entire spectrum of temperatures all over the year, because La Paz has the particularity that its temperature is varying between a compact interval of temperatures all over the seasons, so if we consider a deviation of +/- 2σ and compare it with the scatter Tdb values all over the year, the results show extreme interval values that content almost all the temperature values all over the year. Of course in this city there is no difference between heating and cooling period because temperatures never reaches value lower than -7°C and higher than 19°C which are the maximum and minimum picks and that is the reason there would never be necessary to use a cooling system but only an heating one.

Starting from the previous analysis, it is clear that in order to maximize indoor comfort without the use of plants, it must be taken into account the fact that passive strategies must be defined so as to **increase the natural heating** during the whole year, by **increasing heat gain** and **reducing heat losses**. The result is to shorten the duration and reduce the intensity of the heating season thus diminishing the need for conventional heating. Also some studies related to daylight optimization must be kept into account.Here the aim is to sum up the main passive strategies that could be used.

2.2.1 Materials and techniques

Considering the vernacular architecture which characterizes South-America and in particular the Andean style of the highlands, the first thing than can be considered as part of the designing strategy is the use of materials with sufficient thickness and that can guarantee an **high thermal insulation**.

The first way to improve heat storage is to think carefully about the **quality of materials** of **external walls** and in particular to their **thickness** so as to make it possible to let them *keeping the solar heat* during the day and *releasing it to the inside* during the night. Nowadays, external walls are usually made with a reinforced concrete frame and lightweight brickwork, at best with a layer of heat-insulating material, so walls are too light to meet all requirements and it is thus necessary to take into account some alternative devices related to the use of the materials both for opaque and transparent susrfaces

EXTERNAL WALL WITH INTERSPACE (conduction)

Consisting of two layers between which there is an empty space (air space apart), this space allows the insertion of a **wide variety of heat-insulating materials**, including loose materials (granules of perlite, expanded vermiculite).This system has also the advantage that the bearing wall placed inside (as an inner liner) has a high **thermal inertia**, so it accumulates and **maintains heat for a long time**. The outer partition must in turn be made of exposed masonry, full bricks or clinkers, so that the supporting wall is externally **protected against the weather**. However, it is important to leave **ventilated cavities** that allow the **moisture** accumulated by the thermal insulating materials *to dry and evaporate* through appropriate openings in the outer casing.

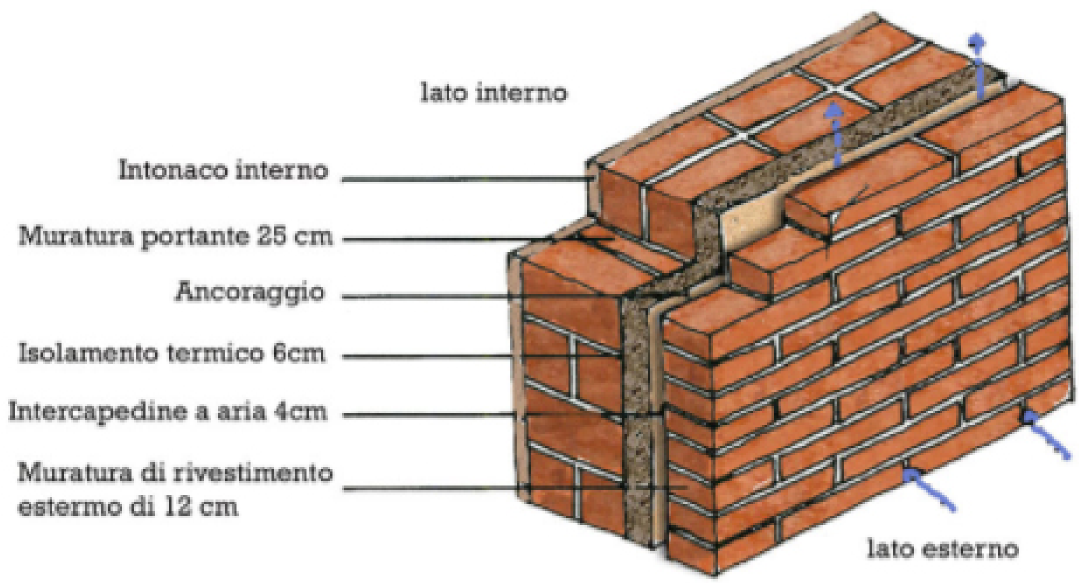

Figure 56: Wall with interpace

https://www.faidanoi.it/bioedilizia/tecnichei-muri-perimetrali/

EXTRA INSULATION (conduction+acoustic insulation)

This device might prove cost effective and will **increase occupant confort** by *keeping indoor temperature more uniform.* It can be applied not only to the external walls in relation to the type of chosen system such as that one with interspace, but also to the **ceiling/roof** and the groundfloor: an higher layer of **inslulation** p*revent from the negative effect of cold external temperatures* by **avoiding heat losses. So** An extra insulation of the roof would protect the building but it is necessary to consider that it has to be properly covered in order to stop air leakages and fire.

Source: Climate consultant

Figure 57: Extra insulation

As far as materials, in relation to the vernacular architecture, **straw** can represent an highly **effective weatherproof coating**. In addition **thatch** has a much **greater insulating** value than any other traditional roof covering.

Differential temperatures below the roofing membrane cause ice dams. There are several causes of this temperature difference – poor insulation levels, air leakage into the roof, heat sources in the attic, and solar heating of bare roofing. There are primarily two problems caused by ice dams – water leakage and dangerous ice conditions. Some solutions solve one of these problems and some solve both, and there are three broad strategies that can be used and combined.

Stop excessive heat from flowing to the underside of roof

Remove the excessive heat by **ventilation**

Provide a **waterproof roof membrane** *that will not leak under standing water and protect pedestrians from falling ice.*

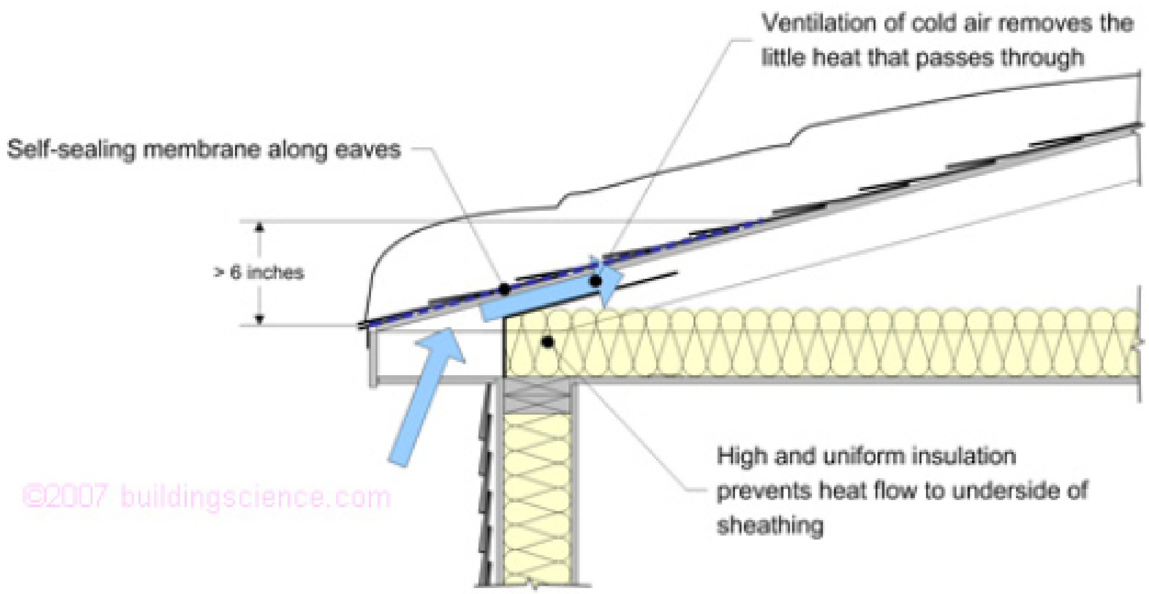

Figure 58: Roof combination of solutions

Online source: https://buildingscience.com/documents/digests/bsd-135-ice-dams

Moreover the correct positioning of insulation layers could avoid **thermal bridges,** and this can be guaranted troguh the use of thermblock, which is a brick block with high compressive strength, good static values and high **acoustic insulation** to be used in the construction of load-bearing walls.

Online source: http://www.hotfoot.ie/product/marmox-thermoblock-thermal-bridge-elimination/

Figure 59: Use of thermblock

HIGH PERFORMANCE GLAZING SYSTEM (radiation+conduction)

Glazing surfaces, which represent those elements that at the same time allow the **entering of solar radiation** and the **reduction of thermal insulation**, bust be studied taking into account both those positive and negative aspects and as far as the used materials, it could be a good solution to provide double or triple high performance **glazing (Low-E)** on West, East and South facades while **clear** on north for **maximum passive solar gain**. Even though it would be useful to maximize solar radiation on all surfaces since temperatures never reach thermal comfort conditions, the use of clear glass also on the other sides could create too much difference in terms of heat gain between the difference parts of the building, defining a discomfort condition so in order to ensure adequate internal comfort, low-emission (low-e) surface treatments, if properly applied, can bring significant energy saving benefits both in summer and winter, which here is the only season to be taken into account.

Online source: http://www.macotechnology.com/blog/il-comfort-termico-nelle-tensostrutture/

2.2.2 Geometry and space distribution

Not only the use of proper materials and techniques but also a correct definition of geometries and distribution of internal functions can help in the achievement of good comfort conditions, both considering the **increasing of heat gain** and the **reduction of heat losses**. Moreover the shape of building can be studied in order to have a good behaviour against **wind, snow and moist.**

GEOMETRY OF BUILDING (conduction+moisture,ice,rain)

In relation to shape and geometry, the use of compact building forms with **square floorplan** and **multiple stories** can be assumed in order to *minimize heat losses* from building envelope. A shape which is more compact can be really thermally efficient. The compactness, the use of insulation casings, the realization of spaces protected by particularly severe external agents, are the leading strategies in cold climates. The sphere is solid with the smallest surface exposed to equal volume but also the cube can be considered as a good solution.

Source: Climate consultant

Considering also the fact that in cold climates, such as in La Paz, the snow can create problems, the choice of an **inclined roof** is a good solution but other alternatives could also be taken into account, such as those shown in the picture below.

Online source: http://swinburnearchitect.com/wordpress/roof-thoughts/

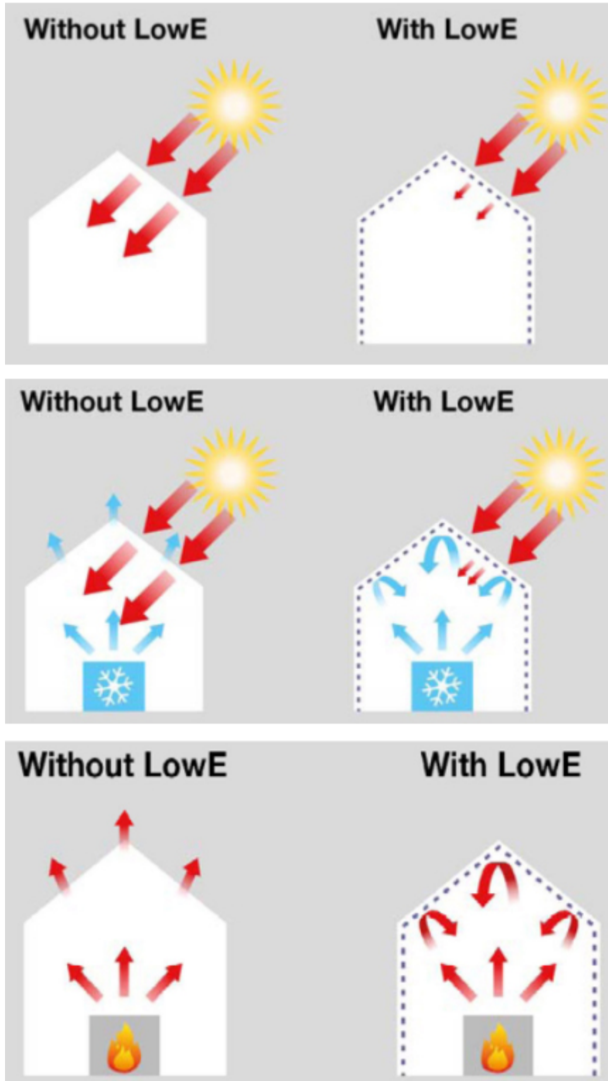

Figure 60: Effects of Low-E glazing

Figure 61: Use of compact buildings

In addition, in function of the geometry of the roof some **solutions** should also be **avoided** so as not to cope with problems of **moisture, ice, rain.**

Online source: http://www.greenbuildingadvisor.com/blogs/dept/green-building-blog/least-five-things-are-wrong-picture

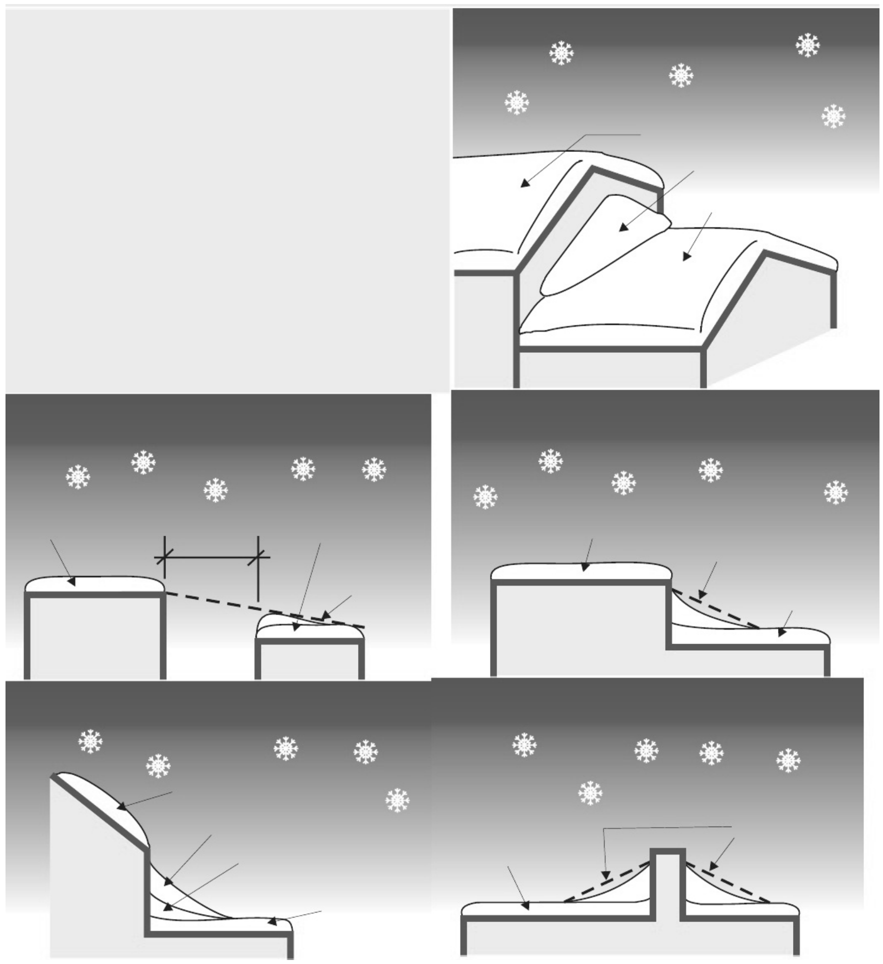

Figure 62: Different solution for roof

Figure 63: Example of wrong solutions

GLAZING SURFACE DEFINITION (radiation+conduction)

In order to take *advantages to wind sun exposure*, **maximization of north glass** area it is necessary. In this case, for La Paz, since there is not so much difference between summer and winter, definition of overhangs it is not necessary becouse also summer is an heating period and it will have no senso to minimize solar gain.

Figure 64: 7Maximization of glazing north surface

Source: Climate consultant

Regarding Solar Radiation, in La Paz the monthly average values are almost the same all over the year due to its altitude and the positioning with respect of the equator line that it has so also the definition of window surfaces should be defined so as to let enter as much solar radiation as possible, in function of orientation, remembering that those surfaces are cold so an overestimation of the needed area could **create problem related to a low thermal mass.** In fact Solar radiation is admitted in buildings through glazing, which is the building element with the **highest rate of heat loss**. Thus increasing solar heat gains also increase heat loss, as well as resulting in undesirable excess heat at times, so the design objective should be to address the *interdependence and temporality of these two strategies rather than to maximize the individual effects.*

THERMAL MASS USE (conduction)

After the sun sets and the temperature drops, the warm wall should continue to transfer heat to the interior for several hours due to the time-lag effect. In order to *reduce air exchange and infiltration* not only materials but also the **geometry** of the building must be carefully studied. The **thermal mass** is related to the geometry and to additional elements on both the interior side of the insulation, located in the floors, external walls, and walls between adjoining units but also on the exterior side. Particularly in this area, where constructions are really spread in rural area on the highlands, the **use of the earth** can be integrated in the project of the habitations. As an example, projects where constructions are **partially built underground** could provide good results in terms of passive heating *keeping heat* from the soil. The great **thermal inertia** of the soil mitigates the severity of external conditions, **reducing the peaks of temperature**.

Figure 65: Villa Vals, Svizzera

Online source: http://www.rinnovabili.it/greenbuilding/architettura-sostenibile-villa-vals-506/

In this exemple of "ipogea" architecture the help of **thermal inertia** is combined with different solutions: a triple glazing, floor heating in all rooms, heat recovery and ventilation, and wood-burning fireplaces in all rooms, ensure **home-saving energy savings** while lowering consumption. The perfect energy efficiency of Villa Vals's sustainable architecture is also completely independent of fossil fuels, using only clean energy sources: the nearby hydroelectric dam dam for electricity needs, the geothermal heat pump for thermal needs associated with a heat recovery system to minimize waste

DISTRIBUTION OF INTERNAL FUNCTION (conduction+convection)

As an additional device it can be considered the idea of **locating garages or storage areas on the side of the building** facing the coldest *wind* to help the *isolation.* In winter Sunny days provide plenty of opportunity to capture and store solar energy in a solid material such as a concrete floor or brick walls (thermal mass). This stored energy can be radiated from thermal mass into living areas of the house during the night. **Excluding cold winds from internal and external living areas**, while admitting sun through glass areas, will increase the benefits of thermal mass.

Figure 66: 57location of garages

Source:

Climate consultant

This solution is related to the fact that those empty areas can act as a kind of "buffer zone" so since there is no necessity of heating thay can protect the other parts of the builidng where temperature comfort conditions must be guaranteed and where the presence of people can represent an important aspect in the definition of the passive strategy if considering them as a source of **internal gains.**

INTERNAL GAIN USE (convection)

Since buildings are subject to neat inputs from occupant **metabolic activity** and from the use of **artificial lighting** and other appliances so the Internal Heat Gain has to be considered as an helping load that increase the temperature, so as to reduce energy needs.

Figure 67: Helping loads

Source:

Climate consultant

Internal gains depends of course on the use destination of the building and of the sigle rooms.

As an ***example*** in a residential building, the kitchen is the place where different appliaces produce high internal gains so is the place where less solar gain it is necessary in order to achieve desired thermal conditions: this place could be located on the nort-east or west-east part of the building so as to let entering as much solar radiation as possible in those room where there are no people during the day and where it would be necessary to use much more the heating system such as the bed rooms: this solution should of corse be combined with the use of materials that guarantee high themrla intertia. Generally the position of room is chosen in function of the light and it would have no sense to just make a choise in funciton of the solar radition and not of the lightning but in this case, a south-west orientation for the bedrooms and nort-east for the kitchen and the living room could be considered as a compromise.

DAYLIGHT OPTIMIZATION (lightning)

Daylighting maximizes the use and distribution of natural diffused daylight throughout a building's interior to reduce the need for artificial electric lighting and some elements that can contribute to this are: Strategic architectural features, window size and placement, **light shelves** and **skylights** and **light tubes**.

2.3 Shanghai (China) design strategies

For the city of Shanghai where climate conditions are very different from those of La Paz, it is possible to see that heating and cooling periods are both existing so it so is important to focus on the necessities which characterize **winter and summer periods**, so as to define the best passive strategy that responds to the needs all over the year.

The climate of Shanghai can be considered as a moderate one, and as before seen for the similar regions of China, the priority for passive building designs in this mild climate is to provide sufficient solar access during cooler seasons whilst taking into account the potential for overheating. Thus, passive cooling strategies observed from vernacular architecture such as s**olar control** and **natural ventilation** should also be considered.

Moreover in Shanghai the monthly average values of Solar Energy Radiation changes more or less like the season changes all over the year, so it can be assumed that the shape of buildings must be studied in function of the orientation taking into account both cooling and heating periods so as to balance the different needs of the seasons. Here the aim is to sum up the main passive strategies that could be used.

2.3.1 Materials and techniques

Starting from the vernacular architecture which characterizes different regions of China and in particular that one colled "**hot summer and cold winter region",** where the city of Shanghai is locate, the first thing than can be considered as part of the designing strategy is the use of materials and techniques that guarantee confort conditions both in heating and cooling period. Passive building designs should focus on **energy balance** with special regards to summer comfort. Apart from obtaining **passive solar gains** and **reducing heat loss reducing heat loss** during the winter, sufficient **solar controls**, promoting effective ventilation and **passive cooling** by natural means should be the priority for climate-responsive buildings. Moreover another problem to cope with is the **humidity** control and **rain** protection.

EXTRA INSULATION (conduction+convection+radiation+moisture+durability)

It should also be guaranted roof and walls to beweel insulated as an example with **reflective foil and bulk insulation** (or thermo-cellular reflective insulation) in order to **reflect heat** and **retain warmth or coolness.** Reflective foil insulation is ideal in warmer climates to keep heat out while bulk insulation is better in colder climates to retain heat within the building, but combination of those two sistems can represent a good solution for a place where it is necessray to cope with severe conditions both in summer and winter.

Bulk insulation is, as the name suggests, the bulky kind and It's mainly used to **prevent the transfer of heat through conduction and convection**, using pockets of trapped air or another thermally resistant gas to resist the flow of heat. Bulk insulation has virtually the same amount of heat resistance regardless of the direction the heat is flowing in, which makes it great for protecting ceilings and walls. Bulk insulation allows to trap heat inside home when it's cold, and prevent it from getting in when it's hot outside. In order to avoid **moisture** from bulk insulation, a vapour barrier should be used where there is a risk of condensation. This system can be used for roof.

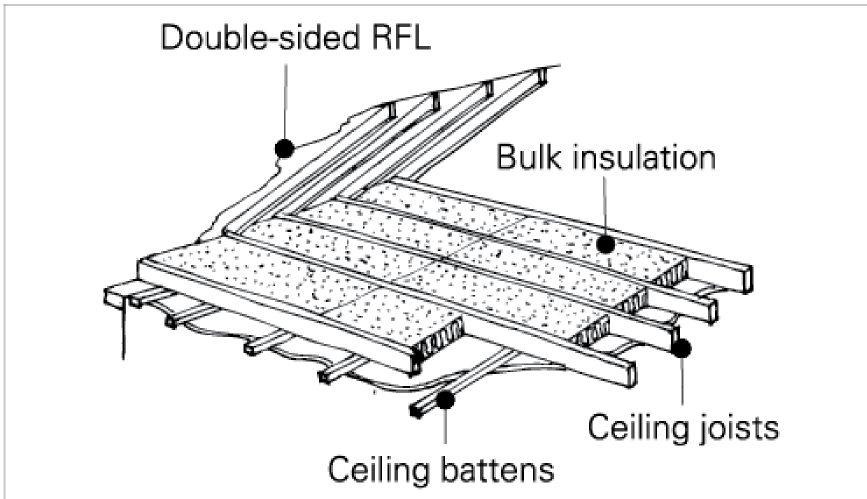

Figure 68: Bulk insulation for roof

Online source: http://www.yourhome.gov.au/passive-design/insulation-installation

Reflective insulation normally consists of a layer of foil backed by paper or plastic. It pro**tects against heat produced by radiation**, bouncing the heat back: it needs a layer of air next to the shiny side to work properly, as there has to be somewhere for the heat to go once it's been bounced back. From second low of thermodinamic it is know that heat goes to cold area. This transfer of heat to cold occurs by one of the following modes of heat transfer: conduction, convection and radiation. Reflective insulation uses a fibreglass core to slow heat transfer through *conduction and convection* but also it has an highly polished aluminium on both sides to address t*he radiation mode of heat transfer* so as to reduce energy consumption, mantaining **condensation control.**

Moreover it is important to guarantee **Durability** so Reflective insulation has to be kept **clean** to work properly too – any dust settled on it will make a big difference to how effectively it works. For this reason, the reflective side must be faced downwards or vertically. It is also important to use **perforated reflective foil** in walls when building with porous materials. The perforations **prevent water droplets** from penetrating but allow vapour through so that the insulation can **dry if it does somehow get wet**. This prevents rotting behind weatherboards, for example.

As a conclusion reflective Insulation helps to keep rooms in confort conditions throughout the seasons, greatly **reducing winter fuel bills** and **summer cooling costs.**

Online source : http://www.yourhome.gov.au/passive-design/insulation-installation

Figure 69: Reflectivee insulation

As a conclusion reflective Insulation helps to keep rooms in confort conditions throughout the seasons, greatly **reducing winter fuel bills** and **summer cooling costs,** considering the fact that it is a solution that has a good behaviour in relation not only to problems due to convection and conduction but also to radiation, to which are linked the most quantities of heat losses and gains.

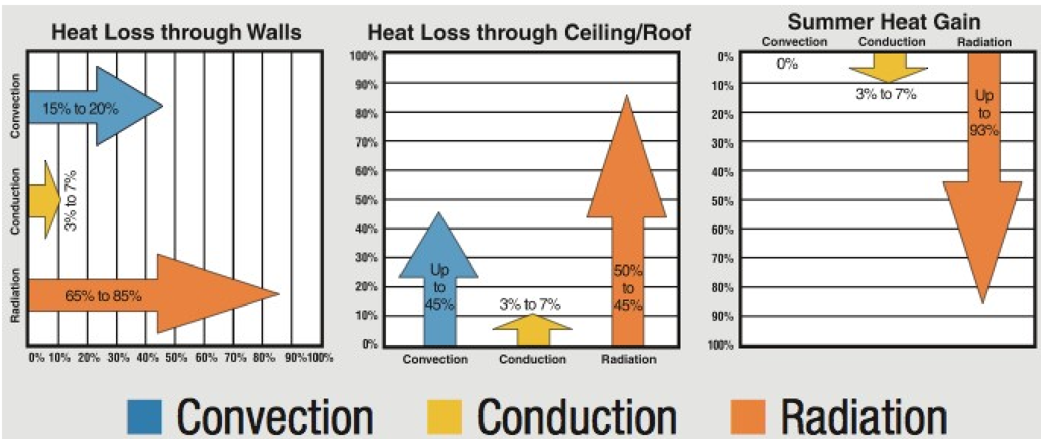

Figure 70: Mode of heat losses and gains

Online source: http://www.greenplanetinsulation.co.uk/energyguard-reflective-insulation.asp

MULTI-LAYER CASING (conduction+ventilation+moisture+rain)

Among the various trategies for improving the interior comfort of a structure, the most effective is the application of a **multi-layer casing**. Usually, each layers fulfills a specific function and the combination of two or more layers results in a net improvement in the thermal performance of the entire casing. A careful design must be able to choose the best combination of waterproof, transparent and opaque materials with low-e treatments or coupled with insulating mats and their **ventilation** to ensure thermal comfort. Ventilated external wall systems should be considered as they represent a good solution to cope with summer and winter conditions, and particularly with problem of **moisture.**

During **cooling period** the ventilated wall is a reflector of solar radiation: it provides heat accumulation on the surface layer and it can't enter reaching underlying layers. The heat then escapes the wall thanks to the free-flowing air and the air gap also helps to **prevent the water** from spreading inward to the underlying layers: this is a reasonable solution in place such as Shaghai where in summer it often **rains**. Most of the water will run down the face of the material and most of what does get into the air gap will run down the back of the panel. By this way the **water evaporate** and it is able to escape the wall thanks to the free-flowing air . On the other side during heating period since vapor pressure inside heated structures are usually higher than outside, it would be possible to have transportation of partial vapor pressure through the outside wall and actually **moisture** eliminated by the free flowing air through the cavity.

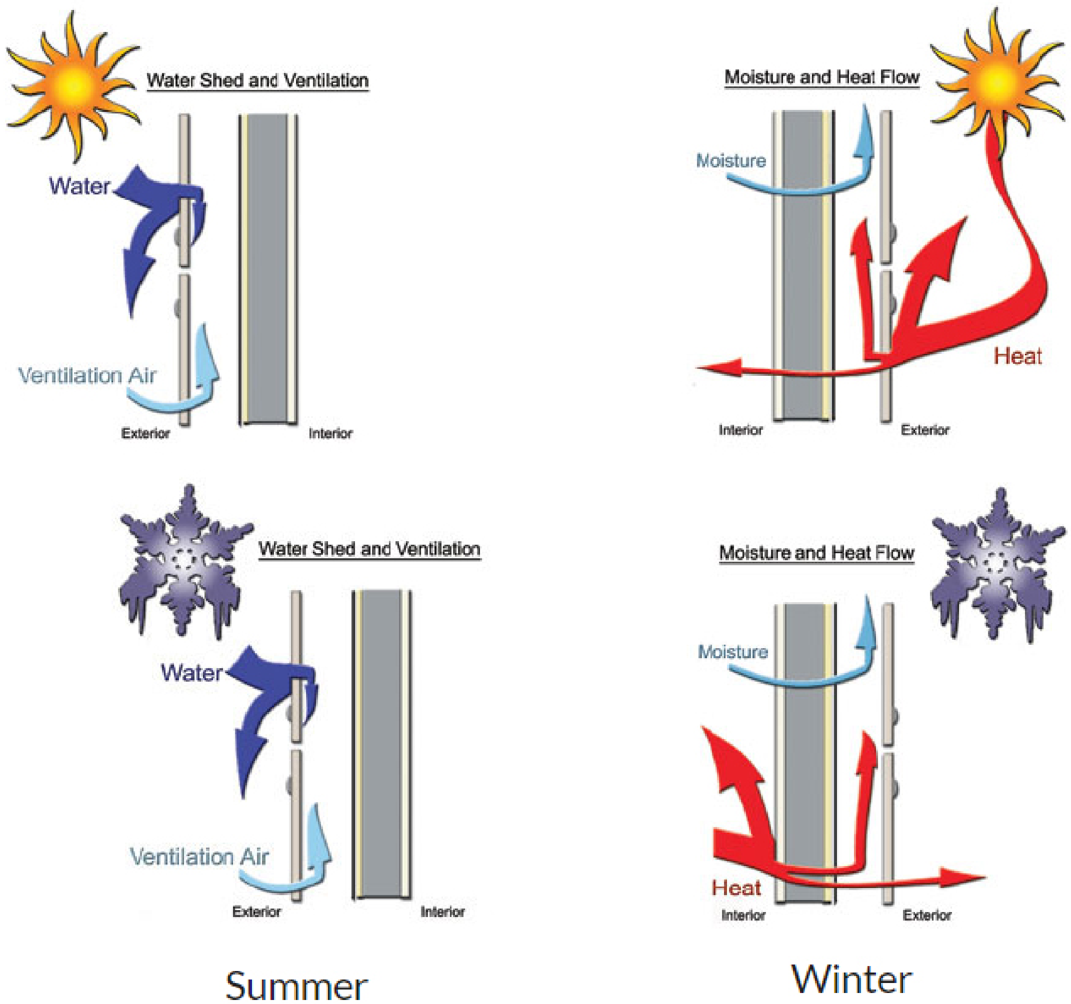

Figure 71: Ventilated wall

Online source: https://cementboardfabricators.com/ventilated-wall-system-benefits/

PASSIVE COOLING NIGHT (convection+ventilation+rain)

A good passive design strategy in summer in these regions is to shade and insulate the house against the heat of the day and flush out any stored heat during the cooler nights: windows and vents should be closed during the day and open during night so as to flush warm air out of the building and cool thermal mass for the next day: it is thus important to maximising night time cooling with **internal windows** and high level windows or **vents** in the centre of the house to let out the hot air and draw in cooler air (it is important that windows or vents can be closed in winter and during dust storms). Night-purge ventilation is useful when daytime air temperatures are so high that bringing unconditioned air into the building would not cool people down, but where night time air is cool or cold. This strategy can provide passive ventilation in weather that might normally be considered too hot for it.

Figure 72: Cooling night system

Online source: https://sustainabilityworkshop.autodesk.com/buildings/night-purge-ventilation

A problem related to the use of this system is the possibility of **rain** coming in at night, damaging property or interior finishes. Since the city of Shanghai is located in an area where rains are common during summer period, it is necessary to think about solution for this problem, as an example with the use of **overhangs, ventilation louvers with steep angles, and other structural measures.** In addition the use of high ceilings and tall openable windows can be assumed but it necessary to protect them with deep **overhangs and verandas**.

USE OF CEILINGS FANS (ventilation)

During really hot days ceiling fans or indoor air motion can make it seem cooler by 5°C or more

Figure 73: Ceiling fans

Source: Climate consultant

SHADING DEVICES (radiation+conduction)

Shading devices can be **movable and openable** so as to let **enter as much solar radiation as possible** in heating period while **protecting the glazing surfaces in cooling period**.

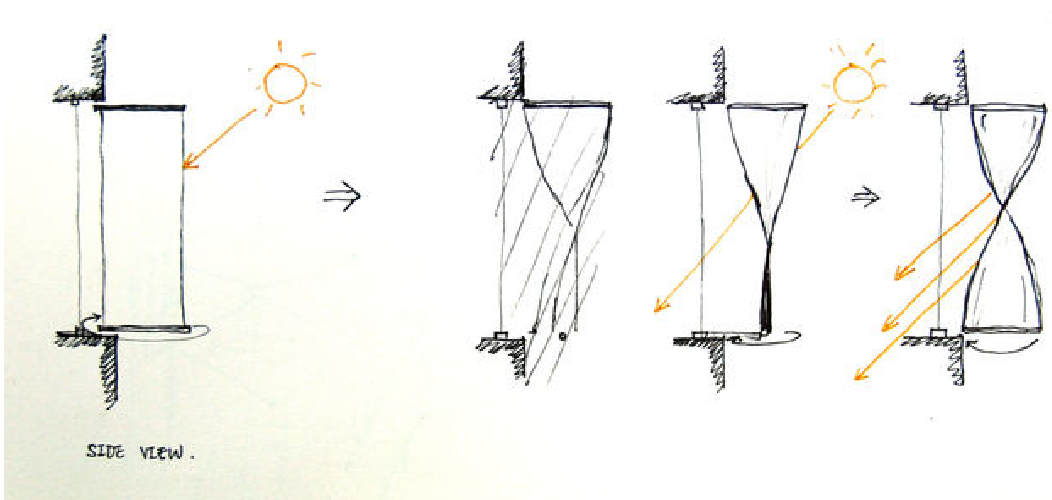

Figure 74: Kinetic shading devices

Online source: http://www.instructables.com/id/Kinetic-Architecture-Movable-Shading-Device/

The use of **plants**, especially on West side is a possible solution that guarantee the minimization of Heat Gain during summer periods. Trees that lose their leaves in the fall help cut cooling energy costs the most. When selectively placed around a house, they provide excellent **protection from the summer** sun and **permit winter sunlight** to reach and warm your house. The height, growth rate, branch spread, and shape are all factors to consider in choosing a tree.

Figure 75: Use of plant

Online source: Climate Consultant

HIGH PERFORMANCE GLAZING SYSTEM (radiation+conduction)

In addition solar gain can be controlled using either high-performance windows with low shading coefficient (tinted or reflective) or clear high-performance windows with a **low-e coating** in combination with **operable external shading** to block solar gains during summer and shoulder seasons and admit solar gains during winter. As far as the positioning of different kind of glass, it would be useful to provide double pane high performance glazing (Low-E) on west, south and east, but clear on north for maximum passive solar gain. Thissystem can be helped by an **high-performance insulation in the envelope** with minimal thermal bridging, including exterior walls and roofs.

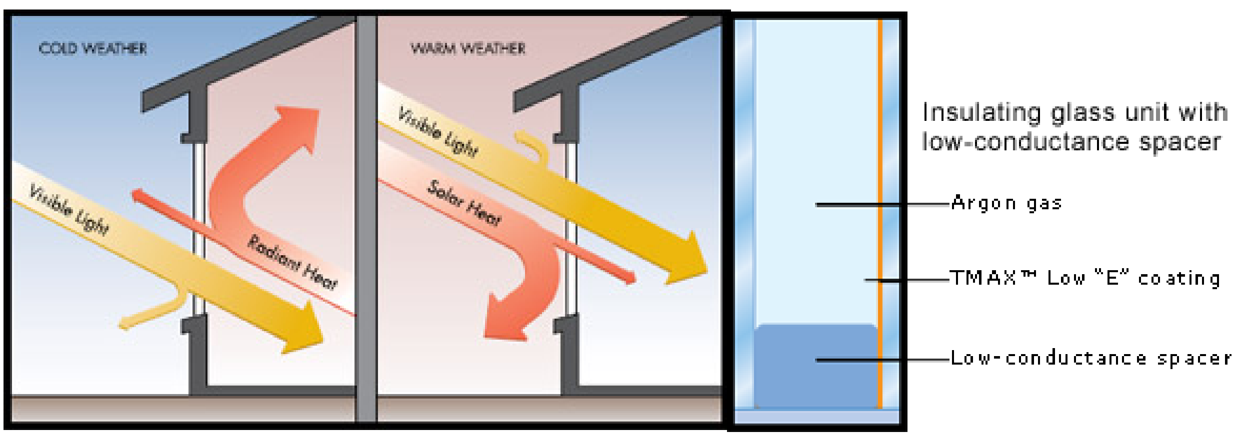

Figure 76: Glazing system

Online source: http://homeritejacksonville.com/energy-efficiency/

2.3.2 Geometry and space distribution

In order to ***Increase heat gain in winter and decrease heat gain in summer,*** control of solar heat gain is the first thing to take into account and this can easily well completed by optimizing the **shape** and the **orientation** of glazing surfaces of buildings and the design the shading devices and overhangs. Brick walls and mud plastered walls work very well by a**bsorbing the humidity** and helping the building to breathe but they have to be protected by overhangs particularly during rains period.

BUILDING GEOMETRY (radiation+ventilation+daylight+rain)

The geometry is something to be carefully projected in order to assess a whole correct design strategy, and in places where severe hot conditions during summer have to be taken into account, a building with a **protected patio** with a permanent **shading system** that distributes home environments by assessing orientation, incidence of sunlight, and aperture dimensions could be a good solution: the typical shape of Siheyuan can be considered a starting point. Moreover the use of shaded veranda , while **deflecting solar rays** and **cooling down during hot weather,** if properly studied in combination with skylights could allow **sufficient daylight** and **good ventilation.**

Figure 77: Proper geometry definition

Source: Climate consultant

Building with large open spaces can promote **ventilatio**n and cause cooling at the ground level.

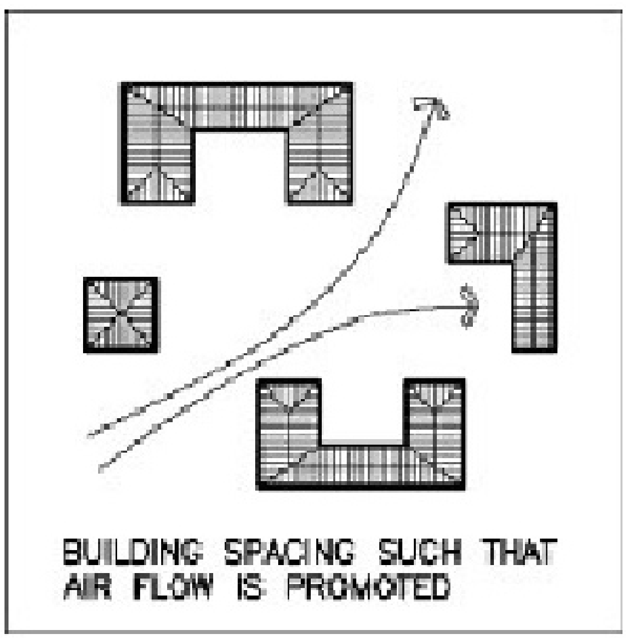

Figure 78: Large open spaces for ventilation

Online source: https://www.slideshare.net/AsmitaRawool/architecture-for-hot-and-humid-climate

In addition semi-open spaces such as balconies and verandahs can be used to give **protectioon from rainfall,** particularly during the season of **rains.** In multistored buildings a central countryyard or patio can be provided with **vents** at higher levels to draw away the raising of hot air.

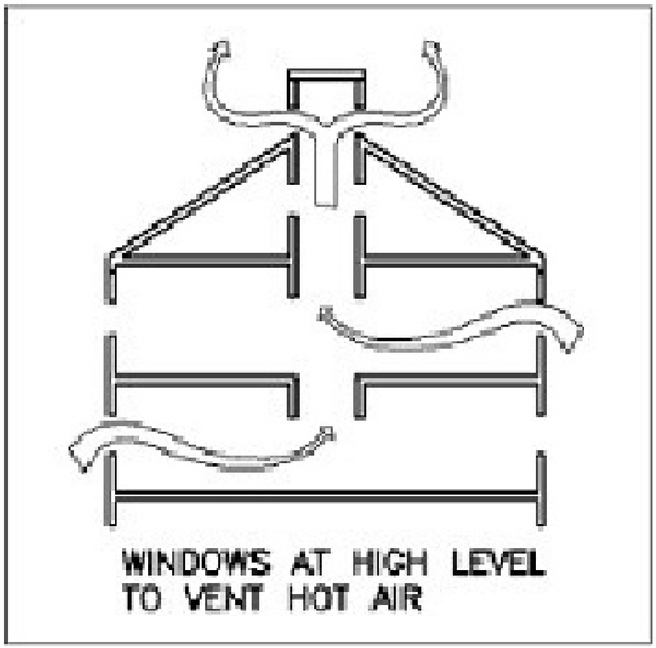

Figure 79: Vents solution in section

Online source : https://www.slideshare.net/AsmitaRawool/architecture-for-hot-and-humid-climate

The traditional solution of keeping the first floor emply to allow **natural ventilation** can represent an otherl helpful device to be combined with **patio geometry** and to a deep **overhangs and verandahs** systems that protect the building. In general brick walls and mud plastered walls work very well by a**bsorbing the humidity** and helping the building to breathe but they have to be protected by overhangs particularly during rains period.

Figure 80: Overhangs and verandahs

Source: Climate consultant

Another element that allow to **protect from rain** and **heat** is the roof and the definition of its geometry that can promote air flow. **Vents** at the top of the roof effectively induce ventilation and draw hot air out

Online source: https://www.slideshare.net/AsmitaRawool/architecture-for-hot-and-humid-climate

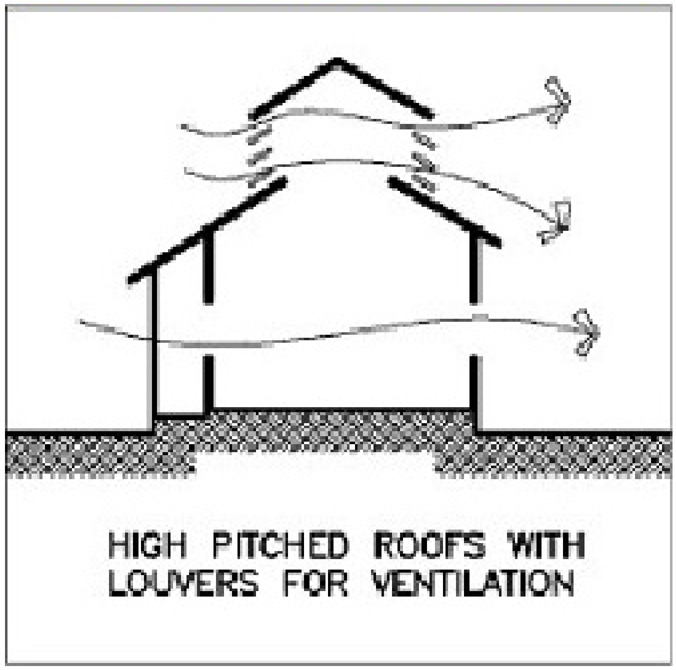

Figure 81: Roof with vents

OVERHANG ORIENTATION (radiation)

In particular window can be projected with **overhangs** studied in function of rays inclination, so as to allow the entering of solar radiation **during winter** but stopping it during summer period in order to **avoid overheating.**

Figure 82: Overhang orientation

Source: Climate consultant

GLAZING SURFACE ORIENTATION (radiation+ventilation)

In addition a good **natural ventilation** can reduce or eliminate air conditioning in this type of warm weather, if windows are **well shaded** and **oriented** to cooler breezes.

Figure 83: Orientation of of window

Source: Climate consultant

INTERNAL FUNCTION DISTRIBUTION (humiditye+ventilation)

All those area where internal activities produce **heat and moisture**, like toilets and kitchens, must be ventilated and could be separated from the rest of the structure, so as to let ventilation acting as a device to mantain confort conditions, particularly during summer period.

Figure 84: Internal disposition

Online source: https://www.slideshare.net/AsmitaRawool/architecture-for-hot-and-humid-climate

CHAPTER III

3.1 Introduction to example of Responsive Architecture

After making the analysis of the most adequate design strategies in order to minimize the energy needs in our case study, on this chapter we will provide some punctual examples of recent CLIMATE RESPONSIVE ARCHITECTURE to understand somehow in which path those vernacular architectures have been evolved into new green technologies that covers the actual needs, introducing to a new era where the common thought is the PASSIVHAUS DESIGN.

3.2 First case study: Shanghai tower

One of the most iconic green building projects in China is the recently completed Shanghai Tower. The structure, stands at 632 metres and is one of the tallest buildings in the world, second only to the Burj Khalifa in Dubai.

Figure 85: Shanghai Tower

Source online: https://www.theguardian.com/cities/2016/aug/23/inside-shanghai-tower-china-tallest-building-green-skyscrapers#img-2

The tower boasts a total of 43 different sustainable technologies, including renewable energy sources, extensive landscaping to help cool the building, and a unique shape which helps improve the building's wind resistance. These technologies have allowed the building to **reduce its total energy consumption by 21 per cent**, slash its carbon footprint by an estimated 37,000 metric tonnes yearly, and save US$58 million in material costs.

These achievements have earned the structure both the American LEED Gold certification and China's three-star Green Building award.

Impactful but invisible

Figure 86: Details

Source online: https://architizer.com/blog/autodesk-shanghai-tower/

Among the sustainable technologies implemented in the Shanghai Tower, the contributions from Danish engineering solutions company Danfoss stand out.

The company provided 6,700 water control valves, the highest number they have ever had in a single building, that contribute greatly to the efficiency of heating, ventilation and air-conditioning systems within the tower.

The control valves work by automatically securing control and **ensuring the right balance of water flow in the kilometres-long piping**. This increases efficiency and reduces wastage, while also ensuring that people on any floor can get the temperature they want quickly, regardless of temperatures throughout the rest of the building.

"More than 50 per cent of the building's energy consumption comes from the heating, ventilation and air-conditioning system. By using [Danfoss'] control valves, 20 per cent of this energy consumption can be saved, which means a lot to the owner," says Lv Guosheng, Danfoss sales engineer, who is in charge of the project.

This building is also provided with 660 variable speed drives that ensure pumps, compressors and fans never run faster than is necessary to secure the right temperature. These drives offer an estimated additional energy savings of 20 to 40 per cent. Energy efficiency in the air-conditioning system is also boosted by pressure transmitters and filter driers.

The building **collects rainwater and re-uses waste water**, has a combined cooling and heating power system. Wind turbines located near the top of the structure power its outer lighting as well as park areas, while transparent inner and outer "skins" will allow natural light to flood the building, **cutting down the need for artificial lighting**. These two layers of glass are also used for **natural cooling and ventilation**, and in total developers say a third of the site is "green space", including 24 sky gardens sitting between the two skins.

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https://inhabitat.com/8-ultra-low-energy-passive-buildings-around-the-world/

3.3 Second case study: Sun-Moon mansion (Huang Ming)

IN Dezhou City, Shandong Province, sits the largest solar-powered highrise building in the world. It incorporates enough photothermal, photovoltaic and energy-saving technologies to earn it the designation of main venue of the 4th International Solar Cities Initiative Conference, a huge expo that has everything related to solar power under one roof. Known as "Micro-Emission · Sun-Moon Mansion," this wonder of engineering is a symbol of China's rapid development in solar energy.

The Solar Valley, where it sits, is the largest research and development base for solar energy in the world now.

Figure 87: Sun-Mood mansion (Huang Ming)

Source online : http://en.jz-zy.cn/news_detail/newsId=19.html

The total floor space of the Sun-Moon Mansion is 75,000 square meters, and its dual structure features a bigger sloping arch in the north encircling a smaller one in the south. The north section accommodates an exhibition hall and the headquarters of the Himin Solar Energy Group, while the south houses the International Solar Valley Micro-Emission Hotel. The complex combines comprehensive utilization of solar energy with **energy-saving technologies**, and adopts a number of the world's latest technologies in fields like solar-powered hot water supply, heating, refrigeration and photovoltaic power generation, which boosts its energy-saving efficiency to a neat 88 percent. Its construction has perfected technical requirements for solar energy application, given rise to several solar product lines independently developed by Chinese enterprises, and provided invaluable technical support for the large-scale promotion and application of solar energy.

The building's white color implies clean energy, but the inspiration for the shape of the mansion came not only from pictographic characters for sun and moon but also evokes a sundial, a timepiece that indicates the daylight hours by the shadow that the gnomon casts on a calibrated face.

From light to power

The mansion's two sections both deploy a glass structure whose transparency makes it possible to see the sky from the atrium lobby. Such a design traps heat and captures the **best natural light**. The top layer of glass is inlaid with black BIPV (building integrated photovoltaic) modules, which serve three purposes in one: **power generation, light emission, and energy conservation**. The two buildings have 180 module sets, enough to power their neon lights at night with enough to spare to contribute to the power-collection grid. The curtain walls, doors and windows of the mansion also adopt BIPV modules – high-performance battery chips that convert light into electricity.

Presently the building has five photovoltaic power generating systems connected to its power grid, which, in addition to supplying the building's exterior illumination, also provide power for **roof lighting** and sun-shading. They produce 30,000 kwh of electricity annually.

Figure 88: Roof lighting

Source online: http://www.rightlivelihoodaward.org/laureates/huang-ming/

No air-conditioners are visible on the mansion's sun-exposed south wall. Instead its windows are shaded with shutters and eave-like devices, part of an i**ntelligent sun-shading system**. The building uses solar-powered air-conditioning for 45 percent of its refrigeration needs, saving 60 percent of the energy consumed by conventional refrigeration. And the sun-shading system further cuts the building's power demand for cooling and heating.

A five-star Green Mansion

Figure 89: Energy technology system

Source online : https://inhabitat.com/worlds-largest-solar-energy-office-building-opens-in-china/worlds-largest-solar-powered-office-building-2/

The mansion is armed with **green technologies** head to toe, inside and out. For instance, the glass developed is essentially an **insulating and sound-proofing skin** that inhibits frost or dew formation. Many other technologies and devices work behind the scenes, including the **thermal insulation of its non-transparent outer walls**, the ceiling heating and cooling technology, the aquitard (an underground system that restricts the flow of groundwater from one aquifer to another), all-season energy storage technology, and the marriage of solar and GSHP (ground source heat pump) technology. Making full use of multiple energy-saving approaches, the mansion has broken the long-standing barrier to reducing the huge energy consumption common in conventional buildings.

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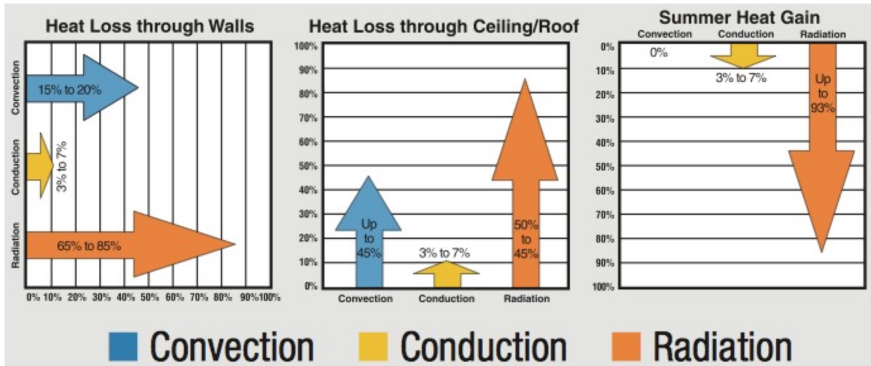

Figure 90: This is a caption