POLITECNICO DI MILANO

School of Urban Architecture Construction Engineering- MI
Master’s degree in Built Environment – Interiors (BEI)

USE GREENHOUSE BUFFER SPACE STRATEGY TO BUILD A SUSTAINABLE ROOFTOP NEIGHBORHOOD

Retrofitting of a Social House Design in Giudecca, Venice

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I would like to express my deepest gratuities to my tutor Professor Alessandro Rogora who have been patiently guided me during recent seven months to complete this Master thesis and help me to better understand the thought of “*Design with Climate*”. I also appreciate the impressive materials Prof Rogora introduced during the Final Studio A, including *Building form and Energy, Climate and Architecture, Urban Evolution and its shortcomings and Self-Construction.* I remember the responsible attitude that the architect has two clients, the project clients, and the society, which impressed me. I aware that an architect must take the responsibility to help to solve the energy crisis and climate change, to control our narrow addiction of showoff, to realize that the design of relationship is more important than aesthetics: the relationship between environment and people and the relationship between people and people.

My further thank is to School for permitting me to commence this Master thesis, for supports on the facilities include reference materials and computer to conduct necessary research work.

Special thanks to my wife who is always encouraging me and support me mentally!

I am, of course, the only person responsible for any accidental omissions and all the inevitable mistake.

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Abstract

For a long history, we human build buildings to provide a comfortable sub-environment and protect ourselves from extreme weather. Before the air conditioning and equipment invented, people from various climate zone have developed many passive strategies to adjust the local climate. However, after the invention, our desire to create a permanent, stable indoor environment becomes more unrestrained. People even build an indoor ski slope in Dubai, desert area without considering the energy consumption. The evolution of passive strategies partly stopped, although there is still much potential to help to reduce the building energy load. This thesis is an attempt to research on the passive strategy, greenhouse as buffer space to help to reach adaptive comfort. To figure out how the greenhouse as buffer space in residential house design of Mediterranean climate helpful to reach adaptive comfort and find out some guidelines of this passive strategy to ensure its performance.

1. Introduction

This thesis is an attempt of using and evaluating passive strategies to reach adaptive comfort. The structure combines two majoring parts: The Survey Phase and The Design Phase.

In the survey phase, firstly, the article mainly discusses about the adaption and the thermal comfort. It is the background and the premise of the next phase. Then the different types of buffer space in different climate zones are learned and briefly describe its performance and effect. Then, the knowledge of greenhouse: the history, the development in Italy, the principle, and its use in architectural design are surveyed. Finally, similar case is listed to help us understand the situation.

In the design phase, based on the design in the Final studio, we chose Venice as the research location. The proposal is to modify the rooftop of the existing buildings to create a sustainable social community which provides affordable houses. In this proposal, we use the greenhouse as the primary passive strategy to reduce the energy load. Then analyze the context, climate, and the local environment. Then an appropriate proposal is given. Finally, we use Archisun to figure out the effect of the greenhouse. Based on the result of the evaluation, we can get a conclusion about whether the greenhouse is helpful.

1.1 The aim

The aim is to get qualitative knowledge of the greenhouse as buffer space in residence design.

1.2 The objectives

1.2.1 to know whether the greenhouse capable to reduce building energy load;

1.2.2 to know what behavior to support the performance in a day, night, summer and winter

1.2.3 to know the covering materials difference

1.2.4 to know the opening principles

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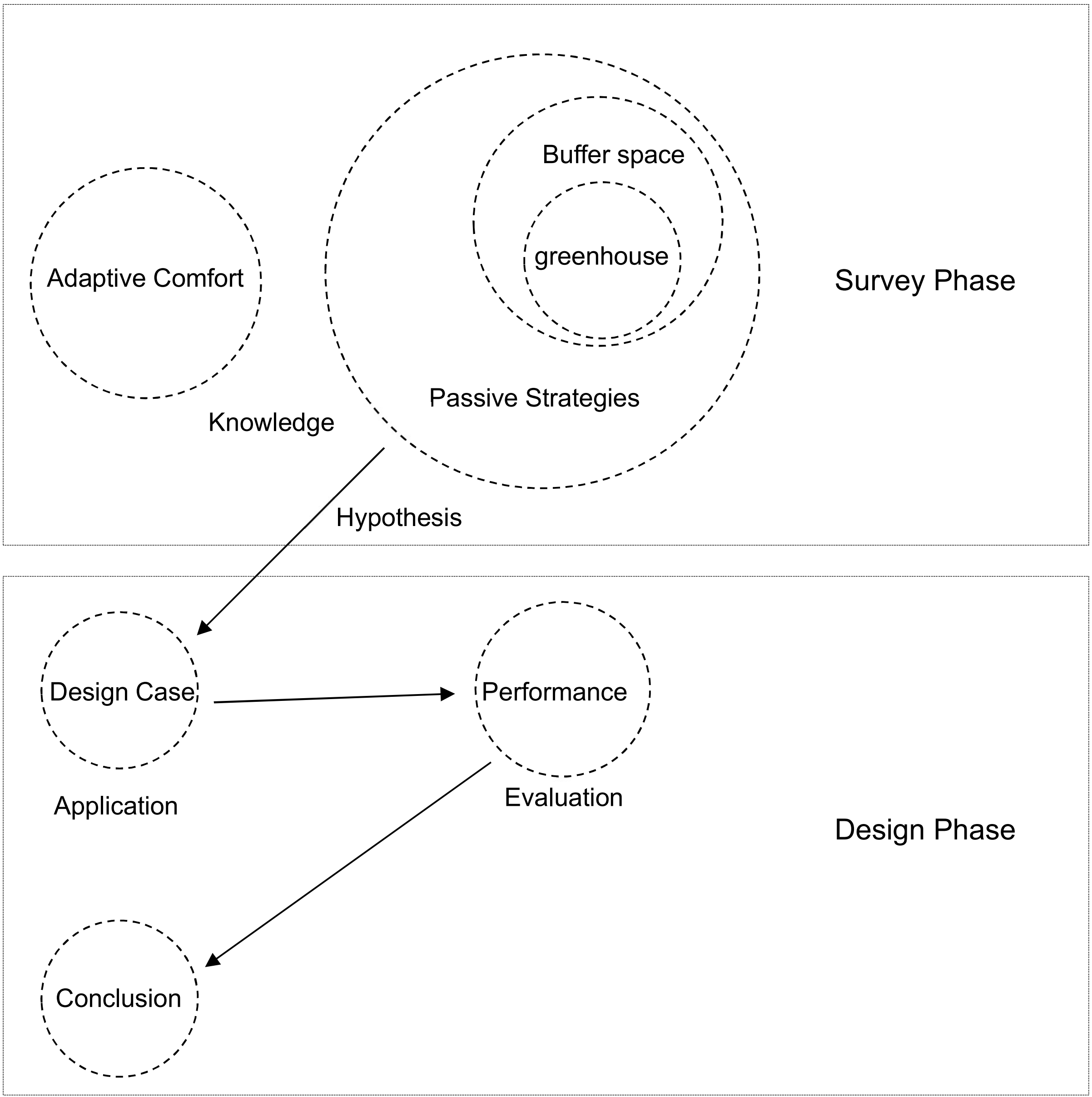
1.3 The methodology



2. Survey Phase

2. Survey phase: Adaption; Buffer space; Greenhouse

2.1 Introduction

Before going deep into the specific topic of the greenhouse as buffer space to reach adaptive comfort, background research should go-ahead to help us know the foundation and framework. According to the Methodology path drawing in page 12, firstly we have to discuss adaptive comfort, which is the final aim and measuring standard for all the things we discuss, we should know the definition, the foundations, the principle, and the focused point to realize it. Then the buffer space as a strategy of passive ones to reach the adaptive comfort should be analyzed, the mechanism, the types, and the comparison between different climate zones. The greenhouse, which is one way of buffer space strategies has similarity with other ones. Its mechanism, history development, and the cases that show its application in building comfort design should be studied.

Through this phase, we should understand the knowledge: what the standard of building thermal comfort we want to reach? Which field the greenhouse strategy belong? What attempts or experience others have done through history? What other strategies are similar we could compare? Finally, we could draw a general hypothesis about the effect that greenhouse as a buffer space to help to reach adaptive comfort and analyze it in the next phase.

2.3 Adaption

2.2.1 Adaption to The Climate

Adaption

All the spices on the earth must adapt to its living environment for surviving and flourishing. Climatic adaption means specific biological characteristic caused by a specific climate. In order to adapt to the daily or annual properties of their living environment, including seasons, temperature, precipitation, the organisms change their behavior, physical structure, internal mechanisms, and metabolism. It is evident that the more effective means a spice has developed in adaption, the more inhabit will it seize. Plants and animals rely mainly on bodies, behavior, and slightly on shelters, mostly they can live in a specific climate area, while human rely more on their inventions like clothes and shelters, which helped us spread almost all over the planet.

Animals' Adaption

Animals, closer to human race, have developed various ways to adapt to the environment.

Animals can live in many different places in the world because they have special adaptations to the environment. （*Design with climate, Victor Olgyay, 1963*）

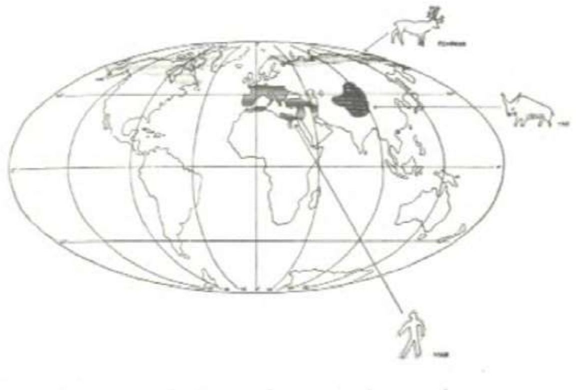


Figure 1, Early inhabitants of men and animals.

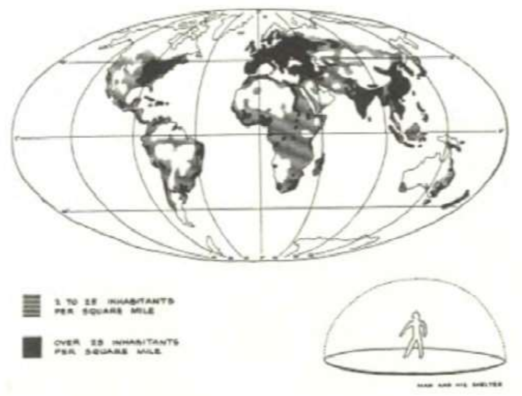


Figure 2, Present population density.

Animals depend on their physical features to help them obtain food, keep safe, build homes, withstand weather, and attract mates. These physical features are called physical adaptations. They make it possible for the animal to live in a place in a particular way. For example, camels have many adaptations that allow them to live successfully in desert conditions. Deserts are hot and dry. Winds blow sand all around, so a camel has long eyelashes, and nostrils that can open and close. Camels can go a week or more without water, and last for several months without food because they can drink up to 32 gallons of water at one drinking session, and store fat in the hump. Unlike most mammals, a healthy camels' body temperature fluctuates throughout the day from 34°C to 41.7°C. Such skills allow the camels to conserve water by not sweating as the environmental temperature rises. A polar bear lives in the cold, snowy Arctic lands. A polar bear has a layer of fat under its skin which helps it stay warm. It also has a thick layer of fur. In the Australian Outback, pooled water can be tough to come by. To deal with this issue, the thorny devil has developed skin that can absorb water like blotter paper. According to Schwartz, 'the way the scales on the body are structured, it collects dew and channels it down to the corners of the mouth', where the lizard drinks it. we can watch the lizard's skin darken as it soaks up whatever liquid remains from even the murkiest of puddles.

Also, some spices have developed skills of building shelters to adapt to the climate like us human. As introduced in Olgyay's book '*Design with Climate'* that birds and ants have extraordinary skills in building nests. The forms of the nests always adapt to the specific surroundings, like an open nest, hanged nest. The use of grasses can prevent the wind. The clay and straw nest prevent the direct sun and rain because of its steep entrance. The nest built by mud and straw have multiple openings. Each one is individual comprised of two chambers. The first is the entrance. The second is the place for eggs. This form prevents vertical sun rays, also minimizes the effect of precipitation. Earth is a useful material which could relieve extreme temperature differences and keep a more stable heat condition inside.

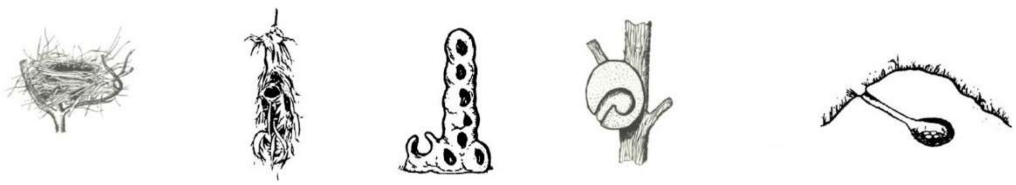


Figure 3, Birds' nests react to climate.

The ants' nests are more remarkable than the birds'. In order to catch the warm temperature in the morning, the Anthills usually located on the southern slope and elongated on a northeast-south-west axis. （*Design with climate, Victor Olgyay, 1963, P1~2*）

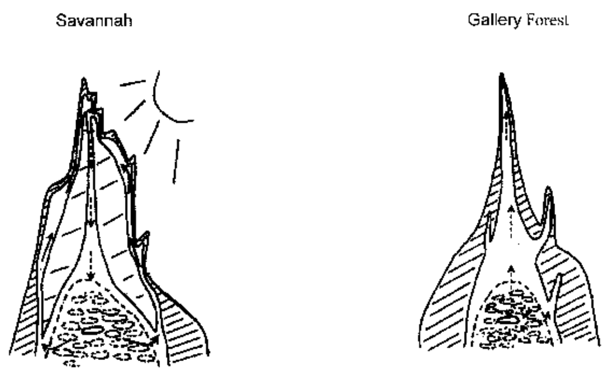


Figure 4, thermal and ventilation of ants' hill.

Human's Adaption

While talking about survive, the human race faces the same pressure as animals do. The difference is: as a spice originally lived in African grassland, the physical adaption is limited that human cannot live in a too hot area like desert either too cold zone like Siberia. However, outer inventions and tools helped human becoming one of the most popular spices on the planet, including the using of energy, the invention of clothes, the skills of building shelter. All this invention helps to create a relatively safe and stable microenvironment no matter what the outer climate is, which have much led to our flourish beyond survive. Among them, the building is the key means. Similar to physical adaption or animals' nest, building forms present specific characteristic in different climate zones through long term evolution.

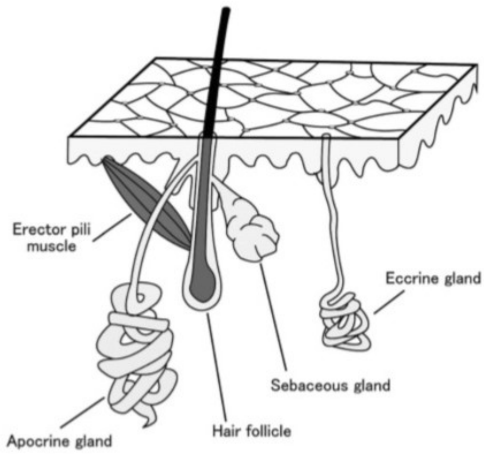


Figure 5, Anatomy of sweat glands.

Figure 6, Human's skills in building shelter.

As discussed in Olgyay's book '*Design with Climate',* this phenomenon is obvious when we study the American Indians' tribes' forms in different areas.

The American Indians moved from Asia through the Bering Strait in the Last Glacial Maximum age. Then the Indians spread over the North American in different climate zones. It was apparent that they developed different types of tribes through they had the same origin.

Figure 7, Indians' migration in American

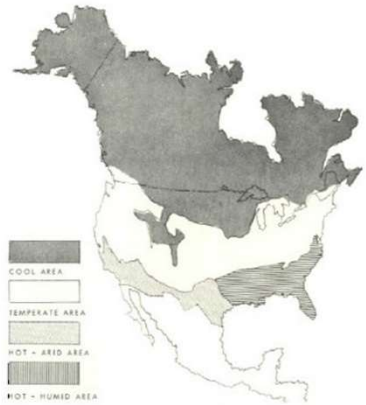


Figure 8, Climate zones in American

The Indians in the cold zones experienced extreme cold and lack of fuel. Keeping heat became the key focus of their shelter. The tribes in this zone were compact and with a small exposure surface. The Ice building of the Eskimo igloo is famous for its wisdom in an extreme cold area. The hemispherical dome could deflect the wind, make use of the snow to be insulation. The ice in the interior surface acts as an effective seal preventing the airflow. The tunnel entrance away from the prevailing winds can prevent the air heat leak. All of this consideration successfully made the indoor temperature higher than the outdoor.

On the Pacific Coast, the climate is less extreme, the tribes of British Columbia are much different from the cold zones. However, it is still necessary to keep the heat in order to realize the aim. Firstly, the Indians reduced the exposure surface by joining the living space together in the winter. They used double layer wood with an air gap as the outer surface. In summer, the double layer wood surfaces could be demolished to let the vents go through. The climate in the temperature area was friendly, without too strict thermal demands on the shelter, so the building styles had diversity and freedom. The eastern woodsmen and plains dwellers were different from the tribes of the Pacific Coast. The villages here were freely organized and dispersed merging with the landscape. The tribes in these areas lived as a nomad. They traveled now and then. The building shelter should be easy to be transported. The typical building unit here named wigwam, which is a conical shape covered by skin. The wind and rain could be effectively shed, and circle space could be easily heated by a center fire.

The hot-arid zone characterized in extreme hot and glaring sunshine, the shelter should be designed to protect people against the heat and the solar radiation. Like the northern tribes, the southwestern tribes used communal structure to protect from the heat. The shelters of San Juan called pueblo, combined with massive adobe roofs and walls, which can delay the heat effect with good insulation value. The windows were small. By join the unit together, the ratio of surface/volume was largely reduced. The shelter usually extended on an east-west axis. The heat of the morning and afternoon was reduced in this way in summer, while in winter received the maximum tropical sun radiation for good.

The hot-humid area was characterized in extreme hot and glaring sunshine too. Besides, the humidity became a problem in this climate zone. Occupants built the shelter to protect them from the extreme heat and sun radiation, like the hot-arid inhabitants, and to increase the ventilation on the other hand. The villages built here allowed free air movement, the units were scattered mixed into the shade of surrounding. The Seminoles used large gable roofs covered by grass to protect from the sun and created ample shadow space without walls under the roofs. The roofs with steep angle and ex-tensive overhang protected against rainfall. The floors were elevated to protect from the ground humidity, to allow the air circulation underneath. (*Design with climate, Victor Olgyay, 1963, P3~5*)

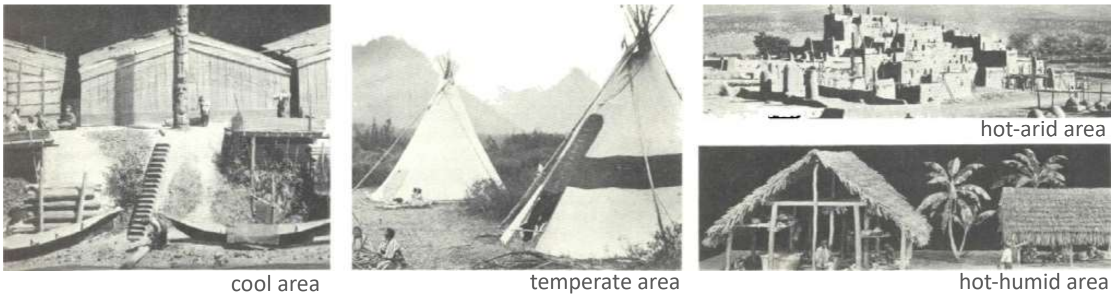


Figure 9, different shelters of American Indians in different climate zones

We can see from this study that human have remarkable abilities to develop the shelter according to the specific climate. We can also verify this if we study regional rural architecture all over the world. We can find various examples in Bernard Rudofsky’s book ‘Architecture Without Architects’.

For example, the people in the oasis of Swiwa, build their living space underground and leave an irregular hole on the ground as entrance, just like typical animal's shelters in this area. Another radical solution of an underground village is in the Chinese loess belt. Loess is soft and has high porosity, can be easily carved. Ten million people live in dwellings made by loess in Honnan, Shansi, and Kansu provinces in China. This kind of dwellings is clean and free of vermin, warm in winter and cool in summer.

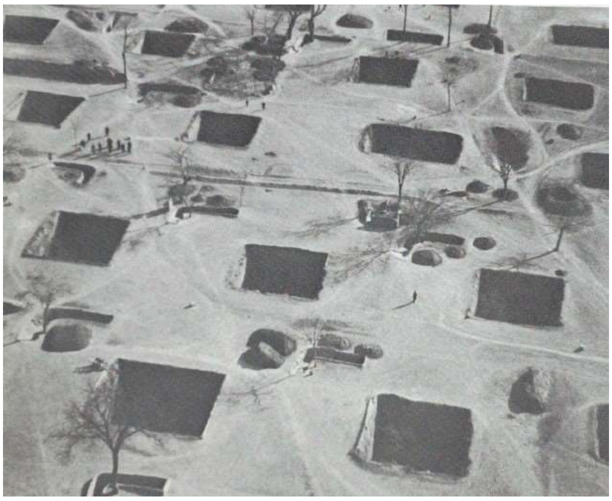


Figure 10, Underground village in Honnan, China

Before the air conditioning invented, through a thousand years, human have developed remarkable adaption building strategies all over the world. Such building forms are climatic sensitive. The air conditioning tech gives us the ability to ignore climate brutally and build the same forms spreading globally. In an extended period, architects no longer pay effort to use and develop the former strategies because of air conditioning. However, the increasing crisis of the energy and climate change force us to rethink the building forms, the local strategies' wisdom to reduce the energy use in the building. It is smart to study the passive adaption achievement we involuted before and try to develop it in a new way.

Figure 11, a typical building relying on the air condition

2.2.2 Thermal Comfort

Introduction

As mentioned above, shelter as a primary method for human adapting to the environment is aimed to create a relatively comfortable microenvironment for the occupants. It is necessary to understand what 'comfort' is? It is the measurement of our building activities. How we describe and measure it? What is the principle in creating comfort? We can trace the development of the thermal comfort studies and learn how step by step, finally forming the wide-accept standards today as adaptive comfort.

Principle

The fundamental assumption we should mention of the adaptive approach is the adaptive principle: "*If a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort*" (Humphreys and Nicol 1998).

The occupants in the building have two basic adaptive actions according to this principle:

- Adjustments to the optimal comfort temperature by changes in clothing. activity. posture. etc. so that the occupants are comfortable in prevailing conditions.
- Adjustment of indoor conditions by the use of controls such as windows, blinds. fans and in certain conditions mechanical heating or cooling. Occupants may also migrate around the room to find improved conditions

Brief History

Dr. Thomas Bedford, from the UK Medical Research Council, is the pioneer of the thermal study, who laid down the Methodological foundations in the 1930s. His report 'The warmth factor in comfort at work' in 1936 was the first large- scale systematic collection of thermal comfort field-study data. Then a vital department called BRS from the UK came into history. Edward Teddy Danter, who developed the Admittance Method to estimate temperature in unheated buildings in summertime; Charles Webb, whose work on thermal comfort became an evident of what temperatures were acceptable; Michael Humphreys who tries to understand statics and computer programming and became familiar with thermal comfort literature, with thermal physiology, human heat exchange with the environment, and also with the psychophysics of subjective sensation, and build a simple model to representing the heat flow from the body core to surroundings. Webb explained the origin and development of thermal comfort indices, and Humphreys explained the simple thermal model and how it gave insights into the way a thermal environment might be expected to affect the occupants of a building. A field study to obtain the index is critical. Charles Webb's comfort research team at the BRS formed in response to the need to define acceptable temperatures in increasingly lightweight and highly glazed office and school buildings, a need that required a better understanding of the thermal comfort. Two papers the first presenting the simple heat flow model and the second the experimental work and its results.

First international conference on thermal comfort was held in Sep. 1972. Participants like A Pharo Gagge, Ralph G. Nevins, Baruch Givoni, Milos Jokl David Wyon, Don Mclntyre, Ian Griffiths, were essential scholars of the human thermal research in the coming decades.

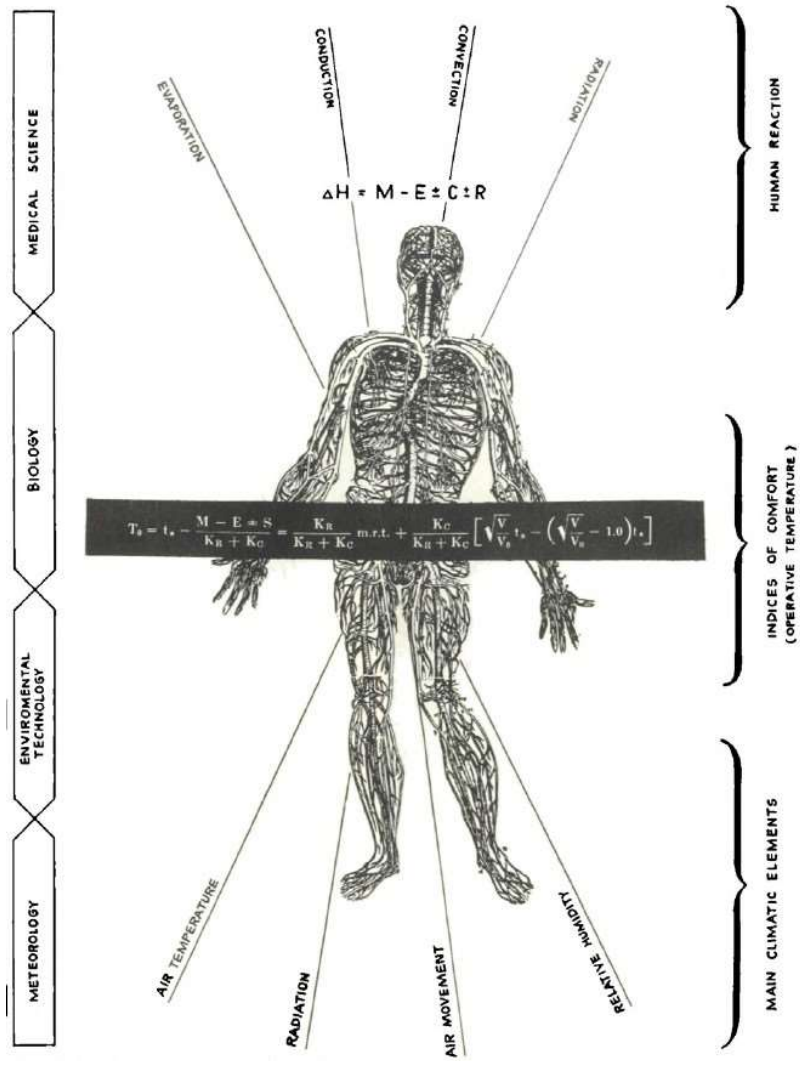


Figure 12, relation of the human body to the climate elements.

In the 1970s, Scholars found the factors relating to the thermal comfort. All of the studies finally led to thermal comfort standards called ASHRAE 55, by Ole Fanger and his colleagues from Kansas State University. The ASHRAE 55 has its limits and was challenged by more developed one called ASHRAE 884.

After the 1970s, because of the oil crisis, the architectural field realized that it is urgent to improve the build energy efficiency. After the air conditioning invented and widely applied, the capability of the indoor environment controlling improved largely, which led to more immense depth and scale architecture. The trend caused that the responsibility of the building energy efficiency improving handed over from the architect to the mechanical engineer. It caused that human could ignore the environment in the design to some extent by using HAVC. It directly slows down the former passive strategies' development. As the energy shorting and global warming became more and more severely, the awareness that there is still much space, we can develope the passive strategies which is a benefit to the environment shifted gradually. In the last two decades, the standards ASHAE has generated. Studies in climate and architecture emerge in large numbers, completed our knowledge about building energy efficiency and thermal comfort.

Adaptive Comfort Model

The current accepted adaptive comfort model is European EN 15251 and ISO 7730 standard, ASHRAE Standard 55. Though the derivation methods and results are slightly different between different standards, the sustainable aim is the same. The ASHRAE adaptive standard is suitable in buildings without mechanical cooling installed. The EN15251 is suitable for mixed-mode buildings.

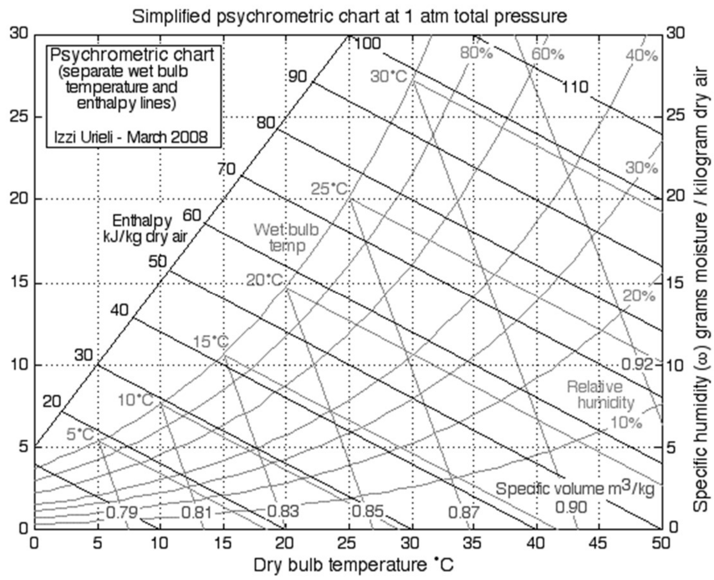


Figure 13, The psychrometric chart.

ASHRAE is a model defines thermal environmental conditions for human occupancy. It is an American National Standard, which establishes the ranges of indoor environmental conditions to achieve acceptable thermal comfort f. The standard was first published in 1966. The most recent version of the standard was published in 2017.

Occupants can adapt to different situations according to different seasons and weathers. It is the base of the Adaptive Model. It also bases on the hypothesis that numerous factors can affect occupants' thermal expectations and preferences, such as thermal history, the ability to control the environment. Numerous field studies revealed that occupants preferred temperature according to the outdoor, which naturally ventilated buildings are better than sealed, air-conditioned buildings.

The ASHRAE-55 2010 Standard, the standards introduced the prevailing mean outdoor temperature as the input variable. The mean outdoor temperature is based on the average of the mean daily outdoor temperatures over no fewer than seven and no more than 30 following days before the day or is calculated by weighting the temperatures with different coefficients. This model can only apply where the outdoor environment can affect the indoor environment, so it should be a natural conditioned space with no mechanical equipment. Studies by de Dear and Brager revealed that occupants could tolerate a broader range of temperature in naturally ventilated buildings, due to behavioral and physiological adjustments. ASHRAE Standard 55 includes the recent findings in the study field. Recent thermal experiences, availability of control options, changes in clothing, and shifts in occupant expectations can change occupants' thermal responses.

There are three types of thermal adaptation, behavioral, physiological, and psychological. These are the fundamental three aspects of adaption.

Psychological Adaptation

Due to the Psychological factor, in a specific environment, comfort can change according to the time. The subjective awareness of thermal comfort could be affected by the historical experience in occupants' memories. Historical experience can change the thermal expectation. This principle explains the difference between the observation in natural ventilated building and the PMV still model. In this observation, the relationship between indoor comfort with the outdoor mean temperature is twice more than predicted.

Psychological adaption is different in a still PMV model and adaptive model. In a still model, the observation in the experiment stated the factor without the influence of the psychological. The adaptive model revealed the difference between the statics and the real result described by occupants caused by the psychological factor.

Thermal comfort is a state described in the psychological field defines the factor that influence the psychological state. The factors related to the psychological state is the sense of control over the temperature, knowledge of the temperature and the appearance of the environment.

It is also widespread in daily that the sun will cause different feeling in different seasons because of the thermal experience. The sunlight in summer will cause fretful and uncomfortable when in winter, it is regarded as pleasant and helpful even in a room where the temperature is the same. Similar to this, bright and dark can affect in the same way in different seasons.

Physiological Adaptation

Like the animals and plants, the human body itself is the first line of defense to the environment. The biometric mechanisms can help the human to survive even in an extreme environment. If the environment is cold, the body uses blood vessels to shrink, in order to reduce the blood flow to the skin, which at the same time reduce the skin temperature and dissipation. On the other hand, blood vessel dilation can increase the blood flow to the skin, which causes the skin temperature rise and dissipation increase. If an imbalance happens, sweat will be helpful to increase the evaporation and take the heat away. If all of the above react are not enough, the temperature increase over 40 degrees, a heatstroke may occur. While in a cold environment, tremors will force muscles to work involuntarily and produce heat by ten times than regular. If this cannot be effective enough, too low body temperature can be fatal. Days and months adjustment can lead to a more deeply adjustment, the total cardiovascular and endocrine adjustments. Hot climate can cause the blood volume increase; blood vessel dilation will be more effectiveness; the sweating mechanisms' performance will be improved. Also, psychological preference will be changed. In a cold climate, the shrink of the blood vessels will be permanent, cause a decrease in the blood volume, the body's metabolic rate will increase.

Behavioral Adaptation

Behavioral adaption is the next level adjustment after physiological adaption. Most common behaviors like different clothes in different seasons, like stay in a shadow and ventilated place in the summer and sunshine place without wind in the winter. Before the air conditioning invented, the occupants will react through different behaviors against the uncomfortable indoor environment. For example, turn on or turn off the window and the fan to control the ventilation, turn on or turn off the blind and shelter to control the light and sun. Among them, the window is a common strategy. The people who take the behavior in a hot climate feel cooler than people did not do it. Occupants may adapt to the hot summer even by becoming more nocturnal, change the main daily activities tonight. Behavior significantly affects energy simulation input. Behavior model has been developed to improve the accuracy of the energy simulation.

After the air condition invented, the building is encouraged to be close, and occupants need not adjust the climate through behavior. The building components related to adaptive behavior deteriorate. Since sustainable trends become essential, the critical change we should refocus and develop the behavior strategy in building design. It is also the main topic in the discussion.

Figure 14, The behavior adaption. The solar radiation was so intense that these people opted to be farther away but comfortably in the shade of the palms.

2.2 Buffer space as a method to reach adaptive comfort

2.2.1 Definition of buffer space in building design

When we talk about the buffer space, the word 'between" is essential for us to define the concept. If we look at the human's adaption from the first stage biological mechanism like skin, to the second stage the clothes and to the third stage a simple envelope, the buffer space belongs to the building envelope, a more complex part between indoor and outdoor. When the outdoor temperature becomes hot, the buffer space can function to decrease the effect and made the indoor not directly face the temperature increase. When the outdoor is cold, the buffer space can function to prevent the cold and make sure the pressure to indoor reduced. In conclusion, the buffer space is a space between indoor and outdoor to improve the building envelope's ability to adaptive comfort.

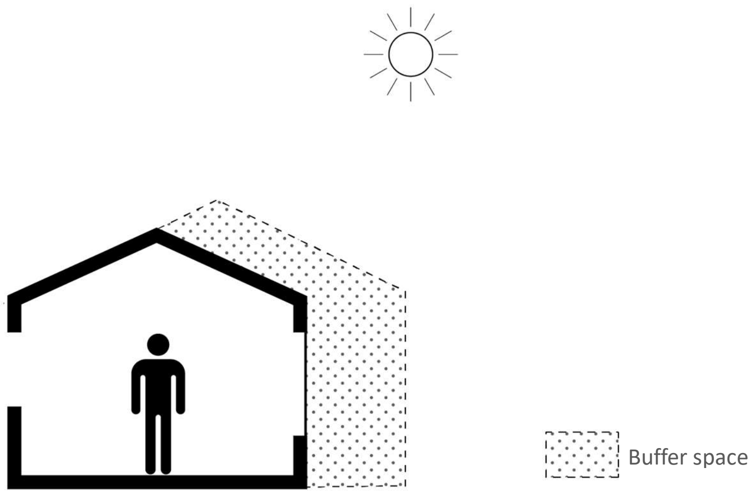


Figure 15, The relationship between buffer space and indoor to outdoor

2.2.2 Different types of buffer spaces in different climate zone

The flourish architecture heritage shows in different climate zones, and under different civilizations, human has developed remarkable building systems adaptive to the climate. Such forms or structures are stimulated and improved through a long evolution. If we study the different regional architecture, we could find various designs that function as buffer space. For example, the porch, the alley, the different types of the inner court, semi-outdoor space on the ground floor, all these forms play an important role in building comfort. It is just like the various animals and plants all over the world. Every specific buffer space form is unique and could be regarded as a treasure, which offers local wisdom of adapting to the climate. It is an essential element of civilization. There are two characteristics: different climate zone has different strategies to adapt to the climate; the different region under the same climate type may have similar strategies.

Hot humid

In the tropical hot, humid area, the climate characterizes by high humidity and temperature, the difference between seasons, day and night are weak and unclear. In the rainforest, because of the frequent rainfall, the humidity is stably high throughout the year. In such area like Thailand, Brazil, Indonesia, the ideal buffer space here is the flyover floor and huge hangout roof. The large roof protects against the frequent rain and creates a semi-outdoor space under the eaves. This space functioned as the intermediate space between indoor and outdoor. It offers an ideal shading place enjoying the ventilation, meeting, or even the kitchen. The space created by the flyover floor worked as the humidity insulation against the ground. The ventilation will take the humidity away. This buffer space is used as service space for livestock or warehouse, too.

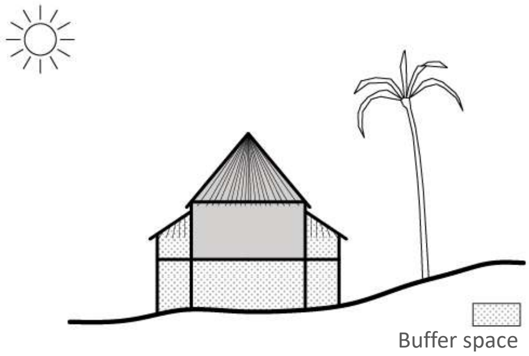


Figure 16, Buffer space in hot humid

Figure 17, Typical buildings in hot humid

In the subtropical area, the climate characterizes in a humid, warm climate. The summer is always long, warm, and humid. The winter is short with strong, cool winds. Protecting from the humidity and heat in summer and cold winds in winter are the main aim of this area. The common buffer space in this area is largely covered terraces, for example, the traditional Japanese house. This kind of buffer space offers a place protected by the roof from the rain and sunshine, provide a semi-outdoor space for daily activities. In some cases, the covered terrace joined together to form an entire walking path through several buildings. Occupants could walk through without rain and sunshine. Such buffer space is usually combined with a courtyard and garden to functioned as a leading aesthetic space of nature, a kind of psychological comfort, which functioned as semi-outdoor living room.

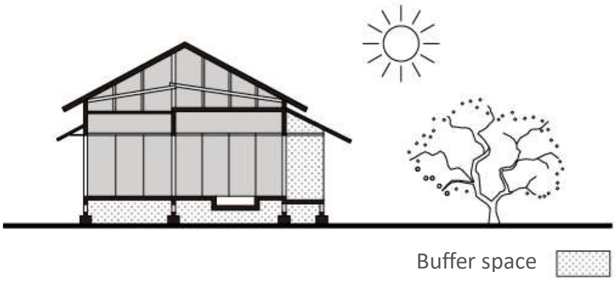


Figure 16, Buffer space in subtropical area

Figure 17, Typical Japanese terrace under roof

Hot dry

In the hot, dry desert area, the sunshine is sufficient, and the precipitation is rare. Summer is very hot, and the winter is warm. Because of the ground is majorly sand, the difference between day and night is sharp. There are permanent residents and nomads in this area. For the nomads, the Bedouin tents are typical, which rarely have strategies of buffer space. Permanent residents use great mass and heavy materials, which can delay the effect of the day-night temperature variations of the day. The typical building like in Morocco, designed as a protection to the outside, makes the small shaded inner courtyard spaces as the main buffer space. The small shaded inner courtyard spaces as the core of a typical Morocco residential building, with a width/ height around 1/3, aimed to motivate the inner heat to move out and reduced the amount of sunshine. A water pool is shared in the court to supplement the humidity in the dry climate and use evaporation to cool. The other rooms are organized surround the inner courtyard to share the benefit of the buffer space. Besides, we can also find the street in Morocco could be covered even in winter to prevent from the sun radiation.

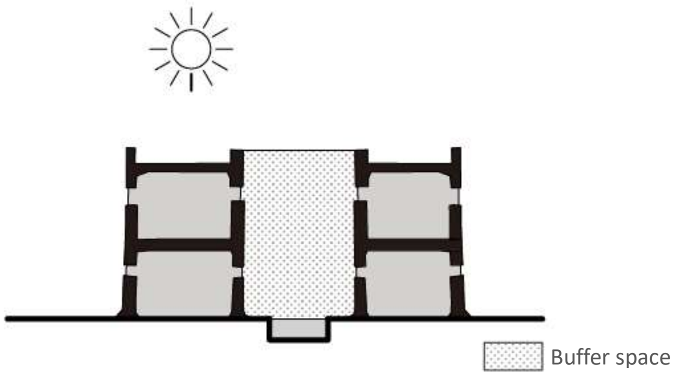


Figure 18, Buffer space in hot dry area

Figure 19, Morocco inner court

Mediterranean

In the Mediterranean area, the climate characterizes in mild and little variation between day and night and a contradict situation between summer and winter. The summer is short and warm. The winter is cold and humid. The architectural heritage in this zone is remarkable. From Greece, Rome and the medieval age, plenty of high-level building system has developed through ages, which even largely influenced the global. We can immediately notice that the primary material in this area is stone. The stone and brick house can provide a stable indoor climate through the long summer. Heating is needed in the winter, from the simple ancient fire to typical element like a fireplace and the modern centralized heating. Buildings are often whitewashed on both the inside and the outside. Typically, a few, small sheltered windows are popular. There are several types of buffer space in this area. In the city scale, narrow alleys provide proper ventilation and shading in the summer. It is prevalent in Italian historical cities and towns. Mainly Venice is characterized in water alley which brings cooler ventilation through the city.

In the architecture level, porch and inner courtyard are two typical strategies. A porch (from Old French porch, from Latin porticus "colonnade", from porta "passage") is a term used in architecture to describe a space located in front of the entrance of a building forming a semi-outdoor space. Porch offers a space for people to pause, wait, or relax without or before entering to the primary indoor environment. The porch on the south side of this climate zone ensure that in the hot summer, while the sun angle is very high, the space under porch is totally under the shading; in the winter, the sun angle is lower, the porch could be in sunshine and provide a place for the occupants to enjoy the sunshine. Bologna is famous for its continuous porch along the street, which people even could walk through without suffering the hot sunshine in the summer or the raining day.

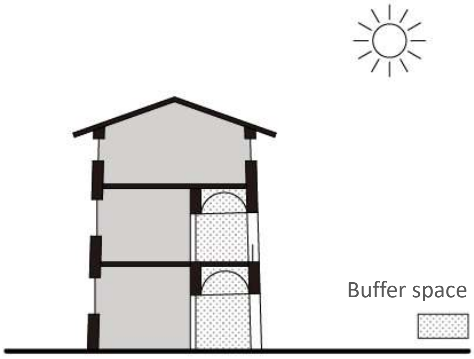


Figure 20, Buffer space in Mediterranean area

Figure 21, Continuous porch in Bologna

Another buffer space in this area is the inner courtyard or called atrium. A courtyard or court is a circumscribed area, often surrounded by a building or complex, that is open to the sky.

It is very impressive when people travel in Italian cities that we can see from the street through a big iron door a beautiful garden or fountain inside. Roman atrium houses were built side by side along the street. They were one-story homes without windows that took in light from the entrance and the central atrium. The hearth, which used to inhabit the center of the home, was relocated, and the Roman atrium most often contained a central pool used to collect rainwater, called an *impluvium*. These homes frequently incorporated a second open-air area, the garden, which would be surrounded by Greek-style colonnades, forming a peristyle. It creates a colonnaded walkway around the perimeter of the courtyard, which influenced monastic structures centuries later. This image is very appealing in that specific hot summer climate zone. Also, in Florence and other cities, such type of space organization is very common.

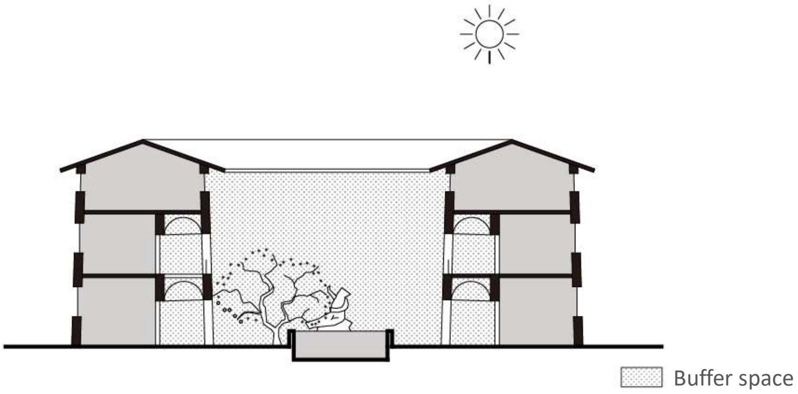


Figure 22, Buffer space in Mediterranean area

Figure 23, the courtyard of Ospedale degli Innocenti, Florence.

For example, the Istituto degli Innocenti, we can find several courts which organized the main indoor building rooms. The court with an effective width and height ratio, pool, or different kind of gardening can have a different effect on the microclimate adjustment. When the width/height <1:3, the court affects as a heat pump help to exhaust the heat out. When the court has pool, fountains, or plants, the evaporation can reduce the temperature of the buffer space.

It is widespread to combine Porch and inner court in this area. Recently after the techniques improved and the commerce became a focus. The court is covered with a grass roof to give the place an adaptive capability to different seasons. For example, typical case are the famous Galleria Vittorio Emanuele II in Milan and the T Fondaco dei Tedeschi luxury Mall in Venice.

Figure 24, the courtyard of Fondaco dei Tedeschi, Venice

Continental climate

Continental climate characterizes in seasonal temperature differences. Also, there are many variations during the day. The summer is long, warm and dry, while the winter is long and cold. Besides, the humidity is low; the wind is always strong. We can find two typical adaption building style in this zone: North American plains Indians' conical tepee and the Turkish country house. The former one is a nomad tent. The shape of the tent is adjusted to the aerodynamic, which weaken the influence of the strong wind. On the top, the tent has flaps to adjust the ventilation. In the winter, central fireplace and the tent skin made from animals' fur could keep the heat effectively. The traditional Turkish dwelling handles is an excellent example of successfully adapt to seasonal differences. It uses heavy materials for the substructure and a superstructure made of an insulating timber structure, stone-faced roofs with a low pitch and overhangs that protect against the summer sun. The centrally heated room solves the winter comfort problem. In this climate zone, there is no obvious buffer space strategy.

Moderately humid-Temperate coastal climate

Moderately warm, humid, rainy and changeable are the keys in this climate. Half of the coastal area between the Equator and the North and South poles is under such a climate. The summer is short and cool, while the winter is mild. The adaption of the climate demands the building to protect against humidity and wind. The gable faces the sea and the wind. The porch is a prevail buffer space in this climate zone. In order to keep the heat in winter, the heated room is usually in the core surrounded by unheated room. It is a typical buffer principle, from porch, unheated room to heated room. Winter garden is another common buffer space in this climate zone. It is very common along the coast of Southern England, Northern France, and Northern Spain, which is a space protected against the wind using a light structure with a lot of glass. The greenhouse effect will make the winter glass room warm. Also, in the cooling season, shading the glass room or with properly opening to remove the greenhouse effect. As this was the main topic of this article, we will go detailed in the next chapter.

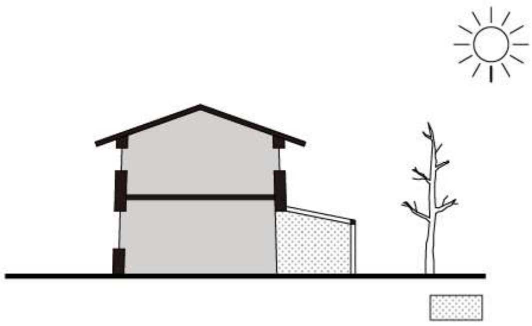


Figure 25, Buffer space in temperate coastal climate area

Figure 26, green house in residential unit

Cold humid-Subarctic

In the subarctic area, the climate characterizes in changing between quiet, dry period and humid period and very windy weather. The summer is usually cool. The winter is cold and dark with long snow-covered period. The typical subarctic areas are Scandinavian, Siberian, Canadian, and mountain area. Heating and winter are the main topics of such areas. The fireplace is the core of the house, while the house is normally sloped because of the snow. When snow settles on a roof with low slope, it helps to retain the heat in the house. The Swedish log house and Icelandic peat house are the typical buildings in this area. In Sweden, the forest protects against the wind during winter. The Swedish log house is built by the timber and with a brick chimney as the heating core in the middle. In contrast, the Icelandic peat house always built into the earth because there is no forest. There is no obvious buffer space strategy too. However, when we study a famous rural world heritage in Japan named Shirakawa historical village, where the winter and snow are similar, we can find the attic or space under the sloped roof could be the buffer space in such climate zone. If the attic well located with the chimney, it will keep the heat longer and release the heat continuously. With the heavy snow as nature insulation, the heat could be kept in alone time. In the summer, if it is needed, with a simple behavior, open the windows of the attic, the ventilation will take the heat away, turning it to a contract function component. It seems the attic is a general strategy could be used crossing the climate zone.

Figure 27, Buffer space in cold area.

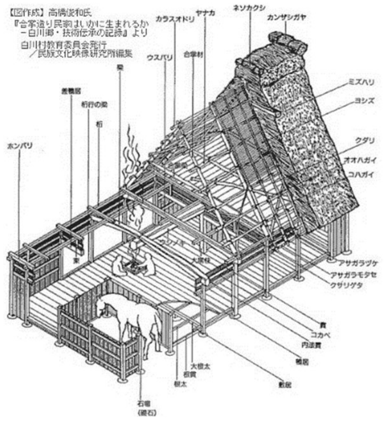


Figure 28, attic as a buffer space, Shirakawa historical village, Japan

Cold and dry- Arctic

The Arctic area is extreme cold, long, dark winters, and short, bright, cool summers. The temperature changes are very little. Similar to the hot, dry desert, the environment is very difficult for human's survival. The building must protect the occupants against the cold and the wind. Eskimo igloo and yurt-Mongolian nomad dwelling are typical shelters in this climate zone. The Eskimo igloo shows man's wisdom to develop shelters in extreme climatic conditions. They use snow blocks to build a domelike house. The snow block is full of air between and is a natural insulating material. Also, the shape of the dome is optimum with the volume and surface ratio. The yurt, an advanced, portable dwelling for nomads in Siberia and Mongolia has a similarly optimum shape, surrounding a central fireplace. There is no buffer space found in this kind of building.

In conclusion, all types of buffer space surrounding the compact main indoor room is popular in each climate zone. Porches, courtyard, winter garden, attic, stilt floor, and covered terraces are typical buffer space strategies around the world. Some of them are applied even in several climate zones, like the courtyard, porch, attic. In this article, we try to apply the winter garden strategy, which is popular in cold zones to Mediterranean climate to lighten the cold winter problem.

2.3 Use the Greenhouse as a buffer space

2.3.1 Why greenhouse can be a buffer space

The greenhouse effect is famous for the global warming crisis. Originally a greenhouse is used in agriculture field to create a stable environment for the vegetation in order to plant anti season, or for the botanical garden to make sure the plant from the tropical area can survive. In the residential area, a greenhouse or called winter garden or sunroom, is popular in the cold area like Scandinavian, German and Britain usually is a light skeleton glasshouse in the south to create an indoor warm place for winter. The main reason for the greenhouse is widely used based on its greenhouse effect (GHE). In a transparent and closure space, the solar radiation can heat it and be warmer than the outside. Through hundreds of years of development, the greenhouse has fully developed in many techniques and styles. With windows, equipment, or shelters, it is very easy to control the indoor temperature through behaviors. For example, for residential building, solar could heat the greenhouse warmer than outdoor, if there is no air condition, the indoor temperature may be lower than the greenhouse and a transfer will occur from greenhouse to the indoor. If the indoor has heating equipment, the temperature higher than the outdoor can still reduce the energy load of the heating. In summer, the opening and other components like shading could detract the greenhouse effect by changing itself to a semi-outdoor space like a porch. Through a simple behavior, the greenhouse could act as a climatic buffer space efficiently

2.3.2 The brief history of greenhouse globally

To understand the evolution of the greenhouse, we study the brief history of the greenhouse. The initially start point can been traced back to Roman time in order to supply a vegetable that the emperor Tiberius likes to eat. The gardeners invented a prototype of the greenhouse to plant the vegetable and ensure it can grow over the whole year. The prototype was a wheeled cart put in the sun at day and keep it indoor at night. According to the description by Pliny the Elder, the vegetables were stored under frames or in a house with oilcloth called specularia or sheets of slenite glazed.

The first record of a heated greenhouse is found from the Sanga Yorok, an essay on husbandry compiled by a royal physician of the Joseon dynasty of Korea during the 1450s, focused on planting vegetables during winter. The detailed construction of a greenhouse was given in this essay, in which could plant vegetables, flowers, and ripening fruit. It utilized ondol, a traditional Korean underfloor heating system, to supply heat and control the humidity. Also, it used cob walls to insulate the heat and oiled windows to control the light. Another material confirms this technique, the Annals of the Joseon Dynasty, in which showed greenhouse-like structures with ondol were constructed to supply heat for orange trees growing during the winter of 1438. In the 17^{th} century, the concept of greenhouses for plants used in the Netherlands and England. When the techniques about the envelopes were not so advanced, the closure of the greenhouse could not be ensured. The heat keeping was always a severe problem in that time. The first heated greenhouse in the UK was completed at Chelsea Physic Garden by 1681. During the 1800s, Charles Lucien Bonaparte, a French botanist, built the first practical modern greenhouse in Leiden, Holland, in order to grow tropical medicinal plants. Then the greenhouse spread to the universities because of the growth of botany science. The first greenhouse called orangeries by French, for the function to protect orange trees from freezing. During the 17^{th} century, the development of the greenhouse continued as the material and construction tech developed. The typical one built at the Palace of Versailles was more than 150 meters long, 13 meters wide, and 14 meters high.

Figure 29, The Crystal Palace, London, 1851

With the glass and iron techniques developing and the favor of the botanical garden by the upper class, the Victorian era in England was the golden era of the greenhouse, both the scale and the elaboration were broken through. The pioneering Kew Gardens. Joseph Paxton experimented the usage of glass and iron to build large scale greenhouse at Chatsworth, in Derbyshire, working for the Duke of Devonshire. His work included the Crystal Palace in London. The Crystal Palace was a cast-iron and plate-glass structure originally built in Hyde Park, London, to house the Great Exhibition of 1851. More than 14,000 exhibitors globally gathered in its 990,000 square feet (92,000 m2) exhibition space. It was 564 m long, with an interior height of 39 m. Chance Brothers introduced the sheet glass method into Britain by in 1832 made it possible to produce large sheets of cheap but durable glass. Its usage in the Crystal Palace first time created a large percentage transparency building never seen. Other large greenhouses included the New York Crystal Palace, Munich's Glaspalast and the Royal Greenhouses of Lueken (1874–1895) for King Leopold II of Belgium was also famous in the 19^{th} century.

In the 20th century, the greenhouse was used in many field and area, like zoos, science, agriculture, residence, and public buildings. For example, the Eden Project, in Cornwall, the Climatran at the Missouri Botanical Garden in St. Louis, Missouri, the Rodale Institute in Pennsylvania, Toyota Motor Manufacturing Kentucky, the winter garden in northern Europe, the glass-covered inner court in commercial building and museums. Still, the development of the material and construction techniques reduced the difficulty and the cost of building a greenhouse, which made it widely spread in the 20^{th} century in many areas. New covering materials like polyethylene film, PVC, polyethylene carbon, plastic panel, lighter glazed glass. New construction methods like wood and steel frames, which is lighter and stronger and cheaper. It resulted in the fast development of greenhouses and wider utilized in different areas. The environment control capability became accuracy and advanced with more technique and equipment through these years, which caused the energy efficiency improved. Nowadays, many commercial glass greenhouses or hothouses are high tech production facilities. With the help of equipment like screening lighting, installations, cooling, and heating controlled by a computer optimize indoor conditions. In the building area, companies focused on offering mature system of winter garden developed easy construction, high performance, acceptable cost solutions. The origin usage of greenhouse in the residential building could trace back to the 17th to 19th centuries. The prototype was constructed with masonry and large glass windows and roofs.

Then in the 19^{th} century iron skeleton and glass became popular. As to public space, the first large public winter garden in Regent's Park in London was built in 1842–46 for evening occasions, large flower shows, and social gatherings. Nowadays, there are numerous companies do the business in the winter garden design and construct. The structure can be built with wood frames, aluminum frames, and steels. Covering materials could be glass, fiberglass, double sheets of polyethylene film, polycarbonate, and acrylic materials.

2.3.3 The greenhouse in Italy

Italy is the origin place of the greenhouse, as mentioned above. The Cucumis described by Columella and Pliny was grown in prototype of greenhouses. It was a wheeled cart, which was put in the sun at day, and keep it indoor at night. In medieval, the botanical gardens were associated with university faculties of medicine and were founded in Northern Italy at Orto Botanico di Pisa (1544), Orto Botanico di Padova (1545), Orto Botanico di Firenze (1545), Orto Botanico dell'Università di Pavia (1558) and Orto Botanico dell'Università di Bologna (1568). Figure 30 shows a 16th-century print of the Botanical Garden of Padua. On the right part of the print, we can see a greenhouse in the garden.

Figure 30, a 16th-century print of the Botanical Garden of Padua

Compared to the cold northern Europe, the Mediterranean climate is not so cold as the north. The greenhouse was not very prevailed in Italy. In public building field, the usage the glass skylight in commercial buildings spread from north. For example, Galleria Vittorio

Emanuele II, the famous shopping district in Milan, built in 1877, characterize in a huge semi-outdoor glass-covered commercial street. The prototype is the Burlington Arcade in London. Galleria Umberto I of the same style was built between 1887-1891 in Napoli.

Figure 31, Galleria Umberto I, Galleria Vittorio Emanuele II, Burlington Arcade

In the modern public buildings, some peer architect develops the greenhouse prototype to more advanced type, which aimed to create a fresh experience. For example, Carlo Rotti proposed an experimental concept named the four-season pavilion in 2018 Milan design week, where in one corner there are snowball fights, while in the next room an ice-cream melt. Visitors can experience the four seasons housed inside the 500 square-meter, 5-meter high greenhouse. It is an extreme concept of use greenhouse to control the climate, not so practical but impressive.

Figure 32, Four-seasons Pavilion in 2018 Milan design week.

In residential field, unlike the sunroom or winter garden typical in Germany, Dutch, Britain, there was not many greenhouses buffer space used in Italian residence. The summer is hot, and sunshine is strong, which makes the shading and ventilation the most important strategy. While the winter is cold but with a fireplace, it is tolerable. It is why we cannot find many greenhouse examples in traditional Italian residence. If there is any, the way is different from the northern Europe type. The exposure area glass would be smaller than the north. Typically, it may only close the porch with glass or cover the inner court with a glass skylight.

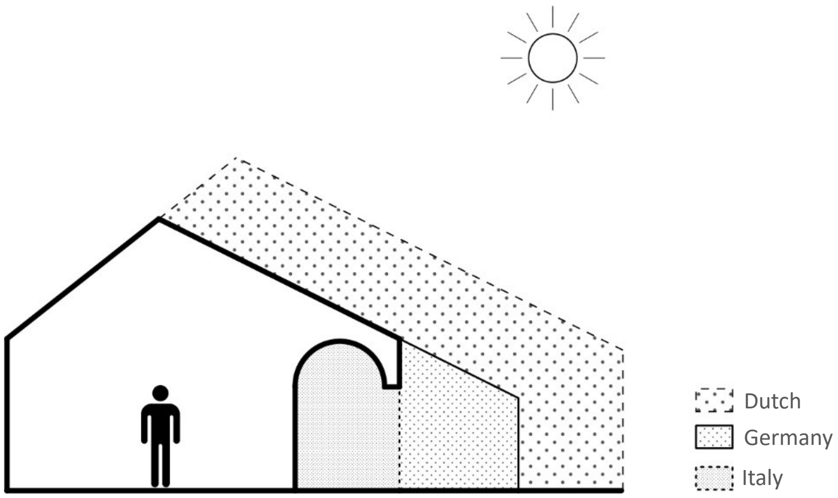


Figure 33, Different greenhouse north to south.

As the building techniques developing and the globalization, the skills and products can quickly transfer between regions. The global trend of sustainability and energy efficiency pursuit make the traditional fireplace step out of the common heating. On the other hand, the invent of the air condition and the massive heating supply have changed people's thermal expectation about comfort in winter. Therefore, the greenhouse utilizing in buildings which is common in the north begin to spread to Mediterranean area. Some companies founded to provide services for installing a greenhouse. For example, the Sunroom, a company founded in Cattolica, Italy, can provide various solutions to the greenhouse buffer space in building. A lot of complete examples are showed on the company's website. The three series they provide, like Puro, Clima, Motus, are different types of residential greenhouse product. For example, the Motus series the description is: *The Motus mobile coverage for solar greenhouses and winter gardens is the only system that opens in two-thirds of its surface, with motorized or manual opening. This special solution provides the opportunity to experience the sensation of living at home in the open sky, "sunbathing inside the house". The system consists of a modular structure of large section aluminum profiles such as crossbars, wall anchors, eaves gutters and support columns.* (www. sunroom.it). The products for residential greenhouse today are complete and mature system with portable easily installed frames, durable and well energy performance coverings, motor-controlled shading system, and even mechanical cooling systems. It is affordable and well functioned in the Mediterranean area, though not yet so popular.


Figure 34, Projects done by Sunroom.

2.3.4 Hypothesis of the performance of greenhouse used a buffer space

The greenhouse widely applied based on the simple principle: the greenhouse effect. This principle helped greenhouse can function as an organ where the indoor temperature and other properties can be controlled. The greenhouse is used to a dwelling, workplace, or commercial building to provide a temperature buffer and insulation between indoors and outdoors as well as provide heating and induce airflow to assist cooling. In a cold climate zone, the greenhouse is commonly regarded as a warm, sunny, peaceful environment to sit. How is the greenhouse effect works? When sunlight goes through the greenhouse, short wave radiation passes through the glass. Then converted to longwave radiation when absorbed by a solid object, such as the ground. The infra-Red radiation from plants and infra-Red thermal radiation from soil and air, the sunlight reflected by soil as the heating source of the indoor. Glass reflects long wave radiation, so the heat is trapped. Warm air by convection from the heated surfaces is also trapped. Also, the closure protects against the wind cooling effect, too. The process causes the result that indoor temperature is warmer than outside. And with properly located openings and fans or facilities can be worked as the coordinator to control the process. With the understanding of the process, the key point we should focus on can be discussed.

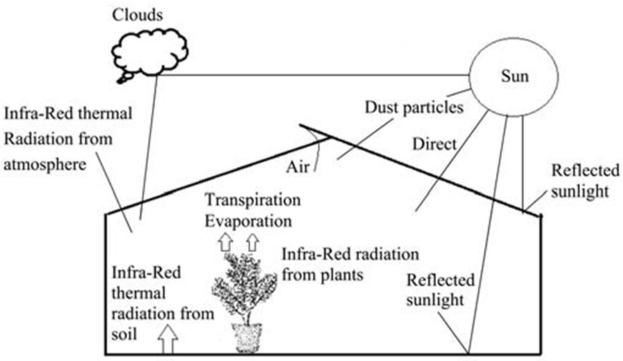


Figure 35, The principle of greenhouse effect.

The first point is to make the most of solar energy. In order to the conversion of light to heat, maximize light exposure, and heat absorption will be the first point. The orientation is vital to solar exposure and absorption. Oriented to the leading solar direction may be the best choice, including the surrounding context. Many commercial glasshouses prefer north-south orientation to achieve light exposure throughout the day, but generally east to west orientation ensures higher thermal efficiency. Because in the most important season winter, north to south orientation exposures the least area directly to the sun.

The angle of the surface and the solar light is important because maximum transmission occurs when the glass is perpendicular to the light source. So, in the design, we should maximize the solar gain in winter and minimize it in summer according to the comfort demand. The optimize angle in different latitude which will be different. A generally finding is to place the glass perpendicular to the sun for the winter by taking the latitude and adding 15°.

After ensuring maximum light transmission, another focused point is to convert the light as much as possible to heat and to be stored and reradiated at night. The principle is that light converts to heat through being absorbed by an object. The absorbing factor of the material is related to the color of the material. If we set an ideal black object to absorb light as 100%; other color's absorbing factor will base on its comparison to black. A white surface can reflect up to 96 percent of light. Quantitative studies suggest that the absorbing factor that smooth white surfaces are 0.25 - 0.40; grey to dark grey is 0.40 - 0.50; green, red and brown is 0.50 - 0.70; dark brown to blue is 0.70 - 0.80; dark blue to black is 0.80 - 0.90. It is better to design the interior surface of the greenhouse to be dark for solar absorption. The envelope of the greenhouse should be well insulated to reduce heat loss. Heat will lose through the glass by conduction. Insulating shutters or blinds or better still, double glazing could be helpful to reduce the loss. Using an internal liner or polyethylene film to form an air insulating layer is another economical method. While in the winter day, the greenhouse can produce heat, making the space warmer than outside. How to keep the heat is a key point if we want the greenhouse to be helpful at night in a residential house. Maybe a low- tech heat storage device can be helpful in such a situation.

As to the summer, cooling will be the main aim. According to the basic principle that the warm air is always moving upwards and the cooling air is always sinking. If we want to form effective vents and take the heat away, the entrance of the vents should face the main wind direction in summer to let the cool air in, and the exit of the vents should be on the deep top to ensure the escaping of the hot air. Other strategies like a solar chimney or exhaust fans are also useful. Extra shading or even re-brush the wall to be light in summer are also helpful.

2.4 Case study

2.4.1 IBN Institute for forestry and nature research Wageningen, The Netherland.

The IBN institute designed by BEHNISCH ARCHITEKTEN in Netherland is a typical case for the buffer space strategy application in modern design. The huge agricultural greenhouse between the buildings functioned both as a main microclimate adjustment organ and a pleasure semi-outdoor space for transportation, informal meeting and daily leisure activities. The big controllable windows on the top give the buffer space a flexibility capability to adapt to the climate. It creates a passive way in modern architectural techniques. All the working place face inner gardens, and outdoor landscape shows the harmony with nature. The buffer space absorbs solar heat in the day; then draw off at night. From the strategic graph from BEHNISCH ARCHITEKTEN shows the different performance of the buffer space.

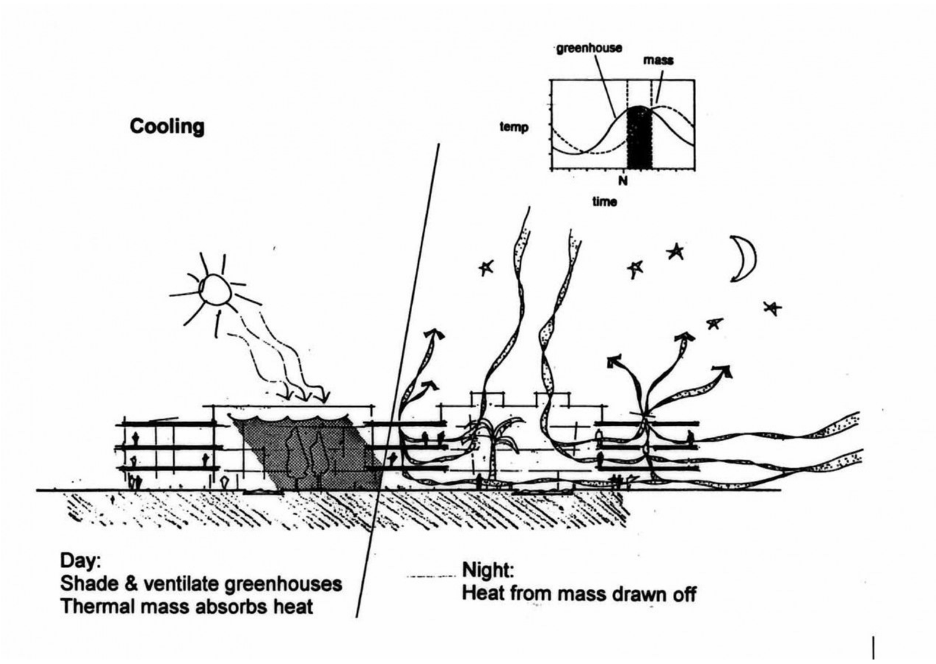


Figure 36, The strategy of IBN institute.

Figure 37, The buffer soace of IBN institute.

Figure 38, The roof and the opening of the buffer space

Figure 39, activities in buffer space

3. Design Phase

3. Design phase: Attempt proposal in Venice

Introduction

In this phase, according to the hypothetical project in Final Studio, we designed an attempt proposal in Venice, Giudecca island. The main idea of the project is creating a low rent and sustainable social house on the existing rooftop of the residential area, which can help to increase house supply and prevent the local population from losing. The greenhouse is designed as the main strategy to reduce the energy use and at the same time functioned as rooftop farm and semi-outdoor activity space for the social community.

3.1 Motivation and Background

Why rooftop?

The affordable housing crisis is a new issue that rises in recent years. The causes could be related to the increased of the Gini coefficient, the increase of tourism and short rent business, and the migration of the manufactures caused new poverty and refugee problems. Some of European most in-demand cities have seen sharp increases in housing prices over the past years. It threatens housing affordability as prices are recovering faster than earnings, and the availability of housing is low. Short-term rental platforms, which are becoming increasingly popular, may cause property prices to spiral and negatively affect local livability. According to Eurostat's 2015 Urban Europe report, most European big city residents feel that decent housing they can afford is increasingly hard to come by.

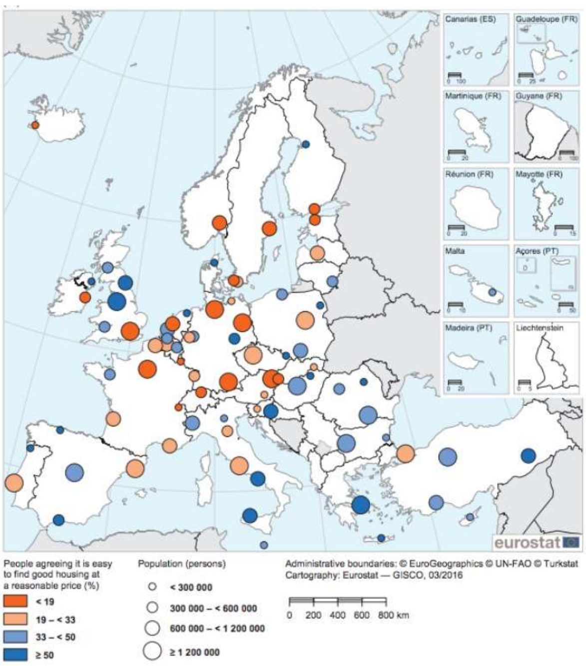


Figure 40, Proportion of people who agreed that it is easy to find good housing at a reasonable price in their cities, 2015. Eurostat.

The situation in Italy is the same. Italy is the most famous travel destination. Tourism in Italy is continuously booming, as the latest figures show another record year for the country with more than 420 million visitors in 2017.

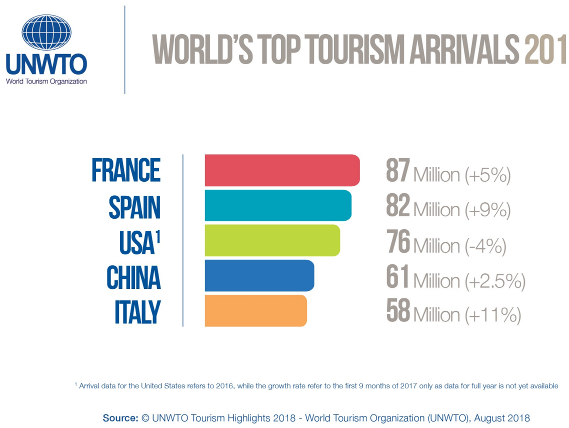


Figure 41, Tourism arrivals 2017.

From the tourism report 2017, the arrivals increase by 11% than in 2016. The increasing tourism attracts the house owners to change the house to hotels to make more money. The short-rent business platform like Airbnb helps the trends to be faster. While the living expense is becoming higher when too many tourist visits. It causes local people whose income were not so high cannot afford a satisfying house.

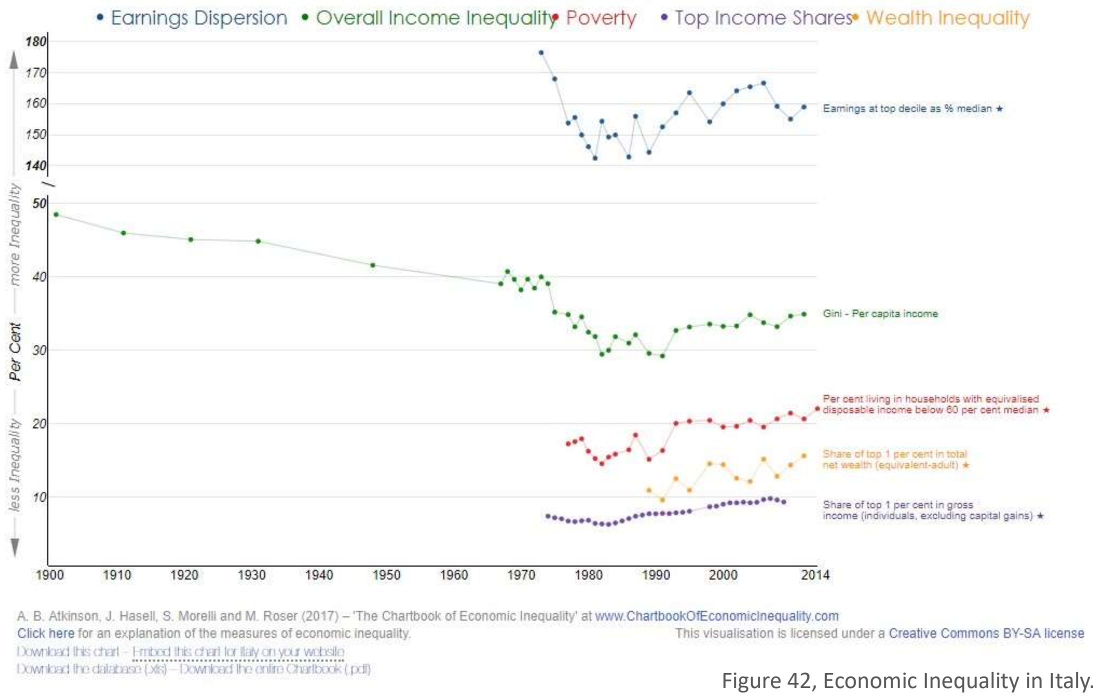


Figure 42, Economic Inequality in Italy.

The above table shows the poverty is increasing recently, and the economic inequality is becoming server and server. It means that in the same city, one rich citizen may have ten houses while the poor citizen cannot afford to rent one home. The economic inequality and tourism together lead to new gentrification of the European cities. Low-income people only can afford to live in the suburb area where the supply will be larger, and the price may be affordable. That is because, in most of the centers of European cities, the architectural heritage was protected. The density in the old city center is low, the houses' qualities are low, and the energy efficiency are low. It is difficult to invest a new supply in the main city while where is more livable. The old buildings in the cities are normally 6-7 floors with slope roof. They cannot be demolished, but there is much potential on the roof to increase the density of the existing area through a sustainable way. It is why we choose to design social houses on the rooftop to solve the affordable house shortage in big cities in Italy.

As to Venice, the house shortage problem is typical here. It drives its way ahead of a huge theme park with the local population losing. The visitors' number has increased by 135% from 1971 to 2001, while the local population dropped 45% at the same time.

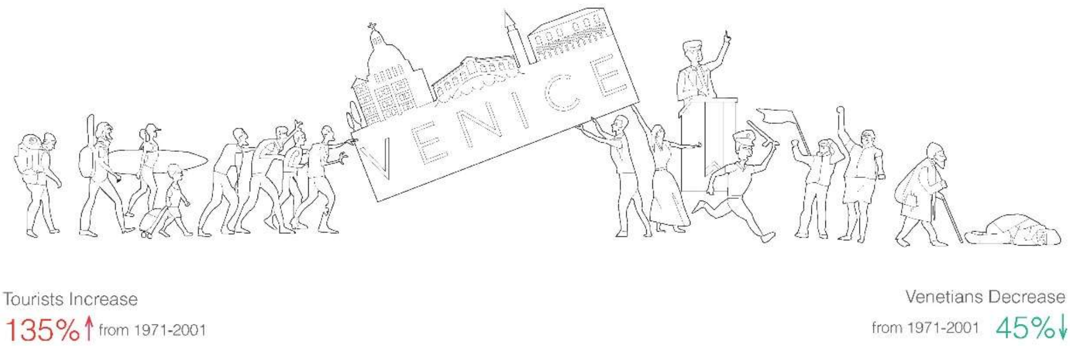


Figure 43, Tourism and population trends 1971-2001, Venice.

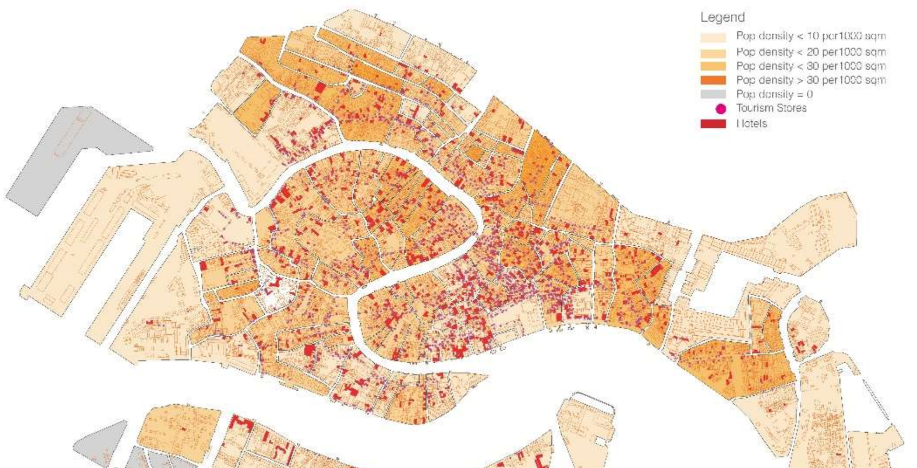


Figure 44, Tourism heat map, Venice.

Figure 45, Tourism hotels map 1999, Venice.

Figure 46, Tourism hotels map 2018, Venice.

We can see from the figure the hotel beds and the location have remarkably expanded in 1999- 2018. We can also tell from the tourist heat map that the main island of Venice is heavily influenced by the tourism. More and more householders change their apartment to short rent apartment, such as Airbnb, hotels. It becomes harder and harder for people to find a low rent long term house. Many venetians have been forced out of their homes because of the high cost of living. They move out from the historical center to Cannaregio, Giudecca, and Mestre. Some people have joined together and found organizations to protest this, such as Assemblea Sociale per la Casa, or Social Assembly for the House. These organizations helped people to occupy empty apartments in Cannaregio and Giudecca. However, their behaviors are regarded as illegal and probably will be expelled by police.

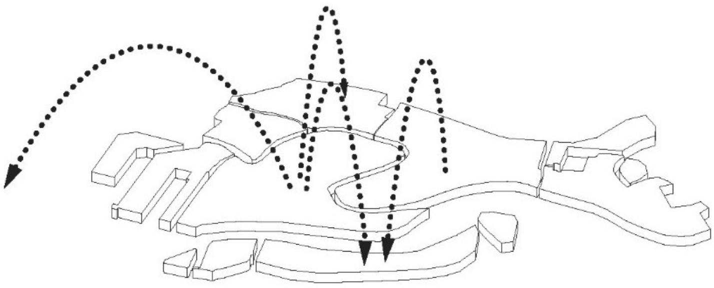


Figure 47, Local population moved out to surroundings, Venice.

According to this problem, our proposal is trying to build a rooftop low rent house to help them. A new social community can be built on the existing residential building rooftop, which is low cost, sustainable, and helpful to the existing community.

3.2 The Site

Giudecca island is chosen as the main location of the proposal. Firstly, the organizations mentioned above are already active on the island. They occupy abandoned houses and build DIY facilities for the community. They organize activities and procession to arouse society's awareness. It is reasonable to keep the trend and develop it. Secondly, compared to Mestre, Giudecca and Cannaregio are regarded as a part of the main Venice. People live here can keep the self-identity as Venetians. It is very important to prevent Venice losing its charming. As the article wrote by Marco Casagrande thought, the islands are more helpful to keep the Venetian island identity than Mestre. It is encouraged for local people to choose island if they want to move out of the historical center. When we study another report wrote by B. Bruso, H. Chen, A. Olm, I. Schulman, about the stores of Venice, the Giudecca island is far less influenced by tourism.

Then we analyze the condition on Giudecca island. We can see the different function distribution. It is clear, where are the main residential area, and where is the area influenced by tourism. Five main residential areas are selected as the suitable areas we can carry out our proposal, where the local identity is stark, and the rooftops of these areas are technically possible for our proposal.

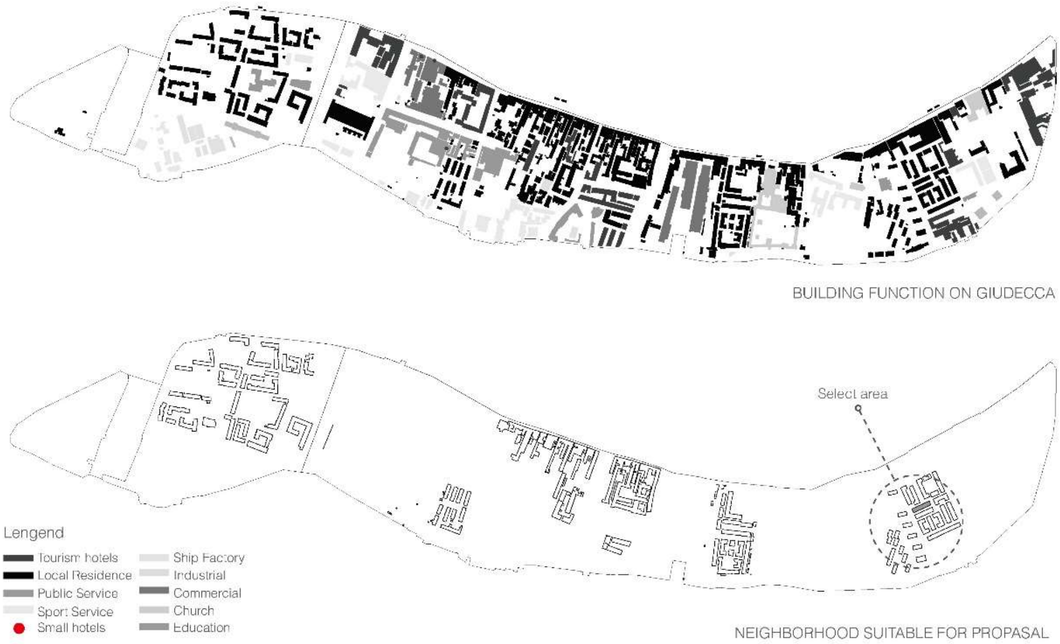


Figure 48, Analysis of the existing building on Giudecca Island, Venice.

The selected neighborhood is in the eastern part of Giudecca Island. The neighborhood called Galle Ramo Gran, consisted by 14 buildings with mainly 3 floors, and were built around 80-90s by estimating.

Figure 49, The selected neighborhood and sample building on Giudecca Island, Venice.

Based on reasonable guess, the structure of the existing building could be RC structure, with wood structure for the slope tiled roof. The external wall is painted by light yellow plaster. The design proposal includes the whole neighborhood. However, we choose a sample building as an example, which is east to west in the long direction.

According to the information from the Google Earth, the plan and section of the existing selected building is drawn. The building is 51.2m in length and 10.5m in width.

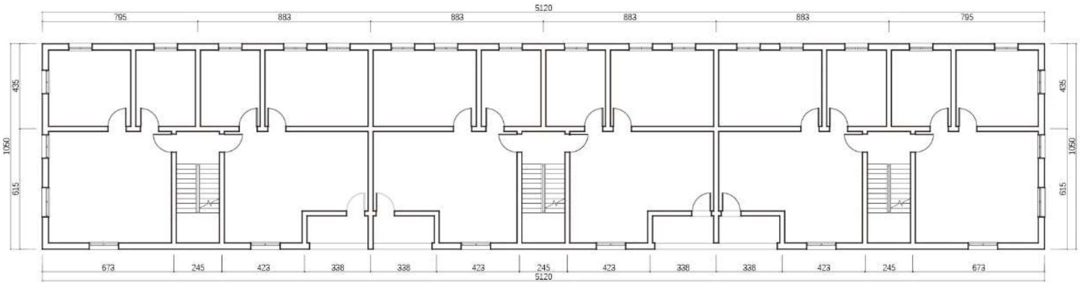


Figure 50, The plan of the sample building.

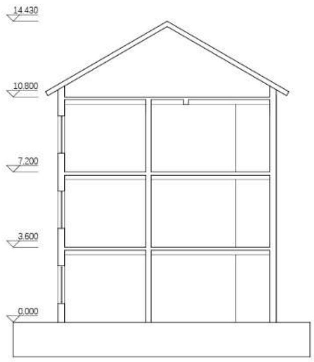


Figure 51, The section of the sample building.

The Total height is around 14.4m with 3.6m for each floor.

3.3 Climate Analysis

Introduction

According to Victor Olgyay's *'Design with climate'* methodology: Climate---Biology---Technology---Architecture. We adapt it to the proposal. Firstly, the big climate zone should be mention, and the specific site environment should be analyzed, which is helpful when we want to learn some strategies in the same climate zone type. Secondly, climate data of Venice should be analyzed, such as temperature, relative humidity, radiation, and wind effects. As a conclusion, which data we should pay more attention to should be summarized. Thirdly a biometric chart should be drawn to study the specific microenvironment. Finally, strategies will be analyzed using the software Climate Consultant.

3.3.1 Climate zone

According to Koppen's climate classification, we can find Venice is in the Mediterranean climate zone. In detail, Venice is in the humid subtropical climate zone. The Mediterranean climate is typical in the west coast of the continents. It is characterized by dry summers and mild, wet winters. It is most common in the Mediterranean Basin, such as Italy. The main cause is the subtropical ridge which extends northwards during the summer and migrates south during the winter due to increasing north-south temperature differences.

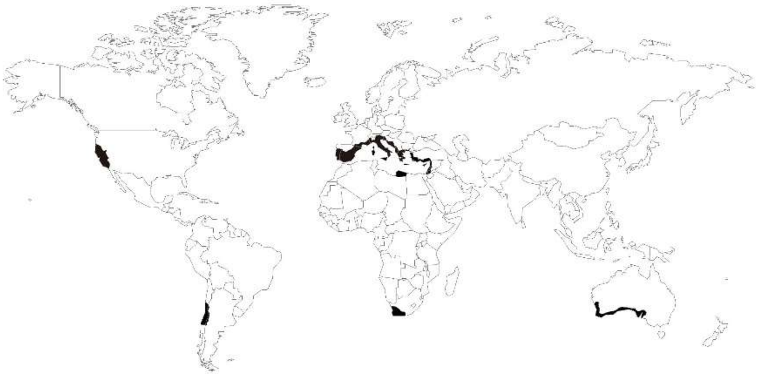


Figure 52, Mediterranean climate area global Koppen's climate map.

Figure 53, Sub-Mediterranean climate

The most typical vegetation of Mediterranean climates is the garrigue or marquis. Typical agricultural vegetation is wheat, grape, olive.

If we learn a similar climate area, we can summaries the most used strategies in the building. The first is a light painting of the façade, which can largely reflect the summer solar radiation and keep cool. The second characteristic is semi-outdoor space, such like courtyard, porch, alleys. These kinds of space can provide a relatively cooler place for occupants in shadow and good ventilation. All the typical characteristics are popular in Venice, especially alleys.

3.3.2 Climate annual data

If we study the average temperature of Venice, we can find that in winter it is cold, moist and in summer, it is hot, muggy. Average temperatures in summer (June to August) usually range between 18°C and 28°C, dropping in winter (December to February) to between 0°C and 3°C. Venice often experiences thunderstorms and rain showers which, particularly in spring and autumn, tend to cause flooding. During May, June, and September we are most likely to experience good weather with pleasant average temperatures that fall between 20 degrees Celsius and 25 degrees Celsius. On average, the warmest month is August; the coolest month is January.

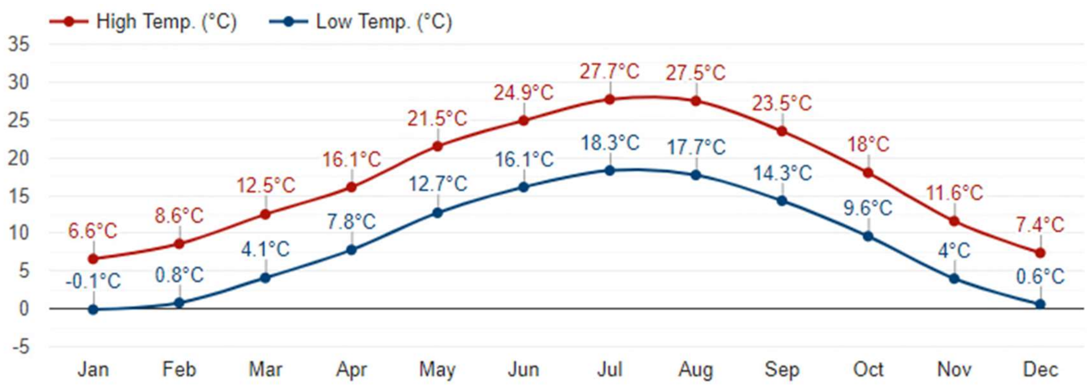


Figure 54, Annual temperature data, Venice.

Precipitation totals to 750 millimeters per year and are well distributed over the seasons. There are two relative maxima in spring and autumn when Atlantic depressions are more frequent; in these cases, the south-east wind blows, which collects moisture over the Adriatic Sea. Here is the average precipitation. Jan is the driest month.

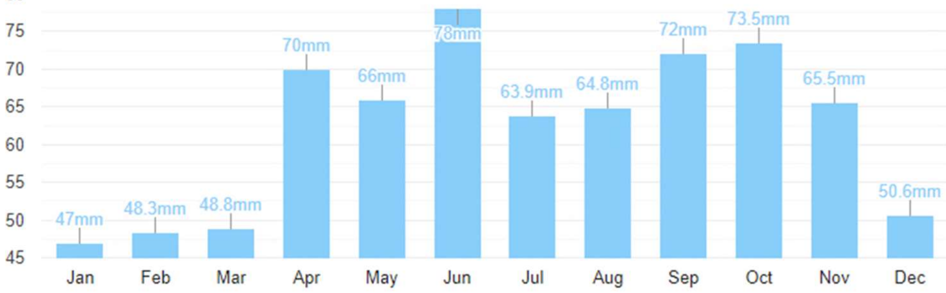


Figure 55, Annual rainfall(mm) data, Venice.

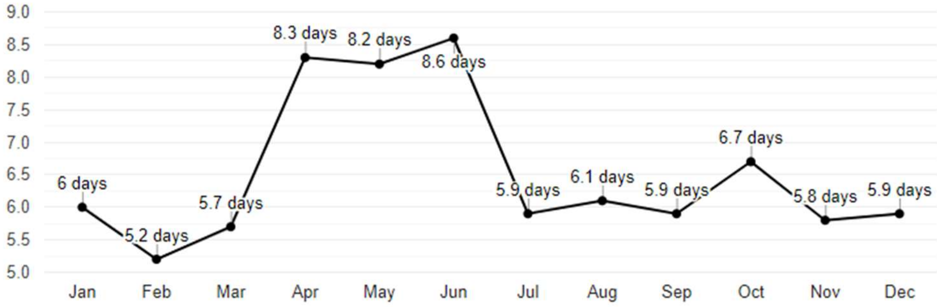


Figure 56, Annual rainfall days data, Venice.

The amount of sunshine in Venice is good in late spring and summer, from May to August, when there are many sunny days, and it is still acceptable in September. In the rest of the year, it is not high because there are many cloudy days and even a bit of fog in the coldest months. Here are the average sunshine hours per month.

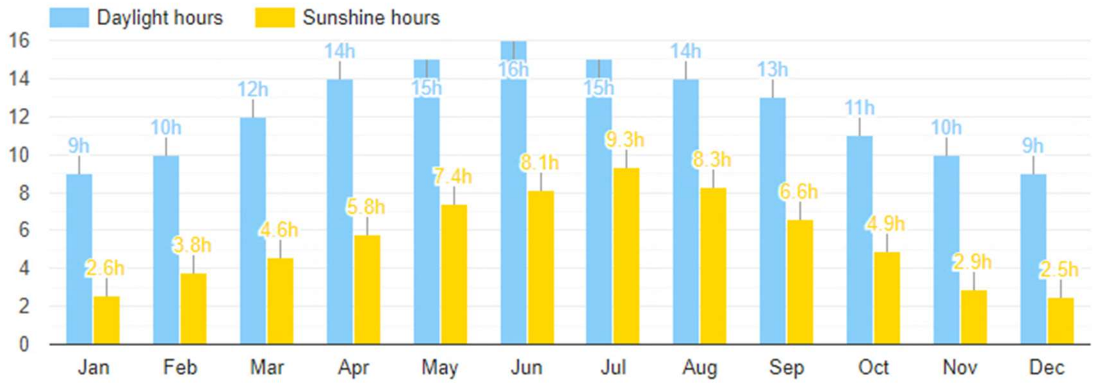


Figure 57, Annual daylight/sunshine hours, Venice.

The humidity of Venice is relatively high. All the months are over 70%. Months with the highest relative humidity are January and December (81%). The month with the lowest relative humidity is July (71%). The humidity plays an important role in adaptive comfort, and it is necessary to consider the dehumidification strategies.

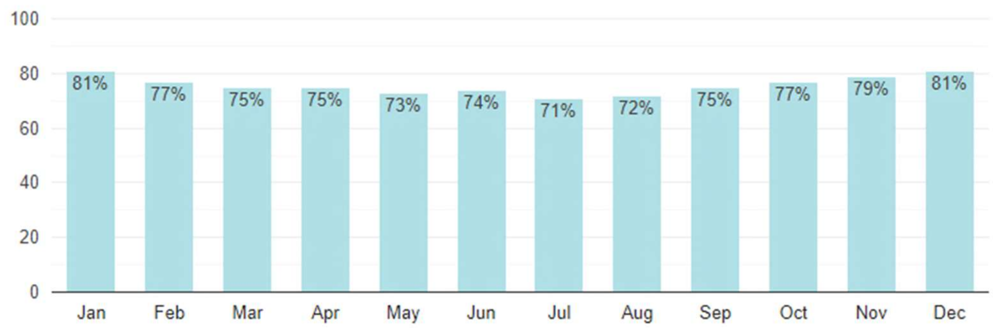
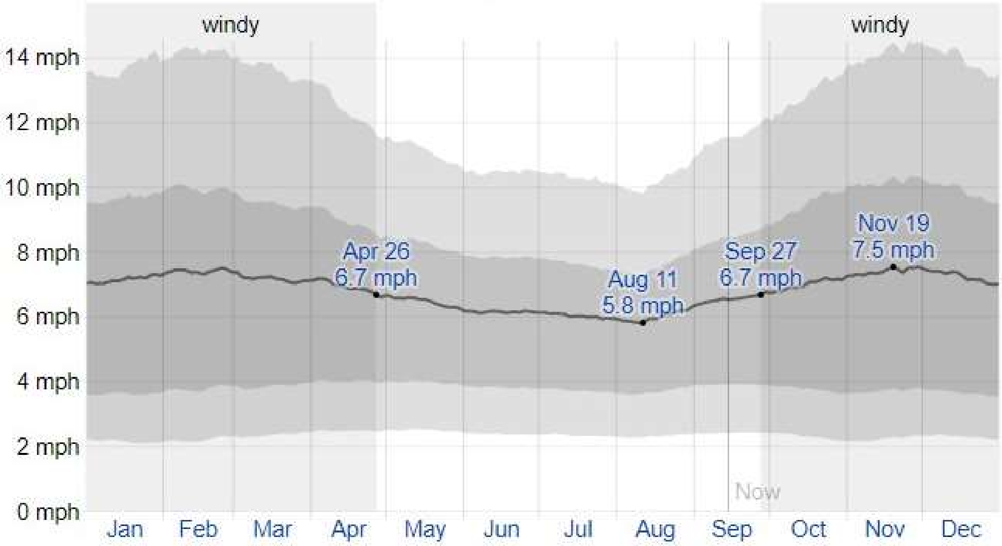


Figure 58, Annual humidity (%), Venice.

This figure below shows the wide-area hourly average wind vector (speed and direction) at 10 meters above the ground. The wind experienced at any given location is highly dependent on local topography and other factors, and instantaneous wind speed and direction vary more widely than hourly averages. The average hourly wind speed in Venice experiences mild seasonal variation over the course of the year. The windier part of the year lasts for 7.0 months, from September 27 to April 26, with average wind speeds of more than 6.7 miles per hour. The windiest day of the year is November 19, with an average hourly wind speed of 7.5 miles per hour. The calmer time of year lasts for 5.0 months, from

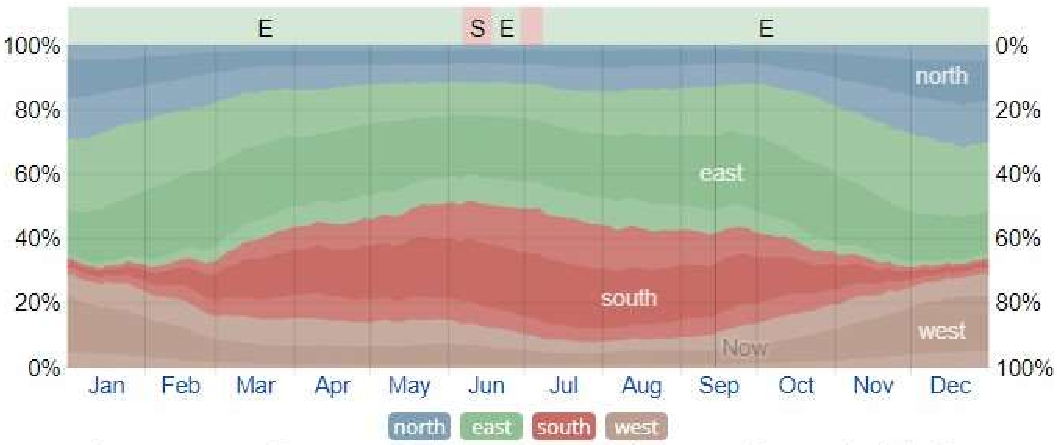
April 26 to September 27. The calmest day of the year is August 11, with an average hourly wind speed of 5.8 miles per hour.



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

Figure 59, Average Wind Speed, Venice.

The predominant average hourly wind direction in Venice varies throughout the year. The wind is most often from the south for 1.7 weeks, from June 6 to June 18 and for 1.3 weeks, from June 29 to July 8, with a peak percentage of 40% on July 6. The wind is most often from the east for 1.6 weeks, from June 18 to June 29 and for 11 months, from July 8 to June 6, with a peak percentage of 39% on June 22.



The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions, excluding hours in which the mean wind speed is less than 1.0 mph. The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest).

Figure 60, Wind direction, Venice.

The climate data above can help us to understand the climate situation in Venice, have a roughly sense of environment we face.

3.3.3 Biometric map

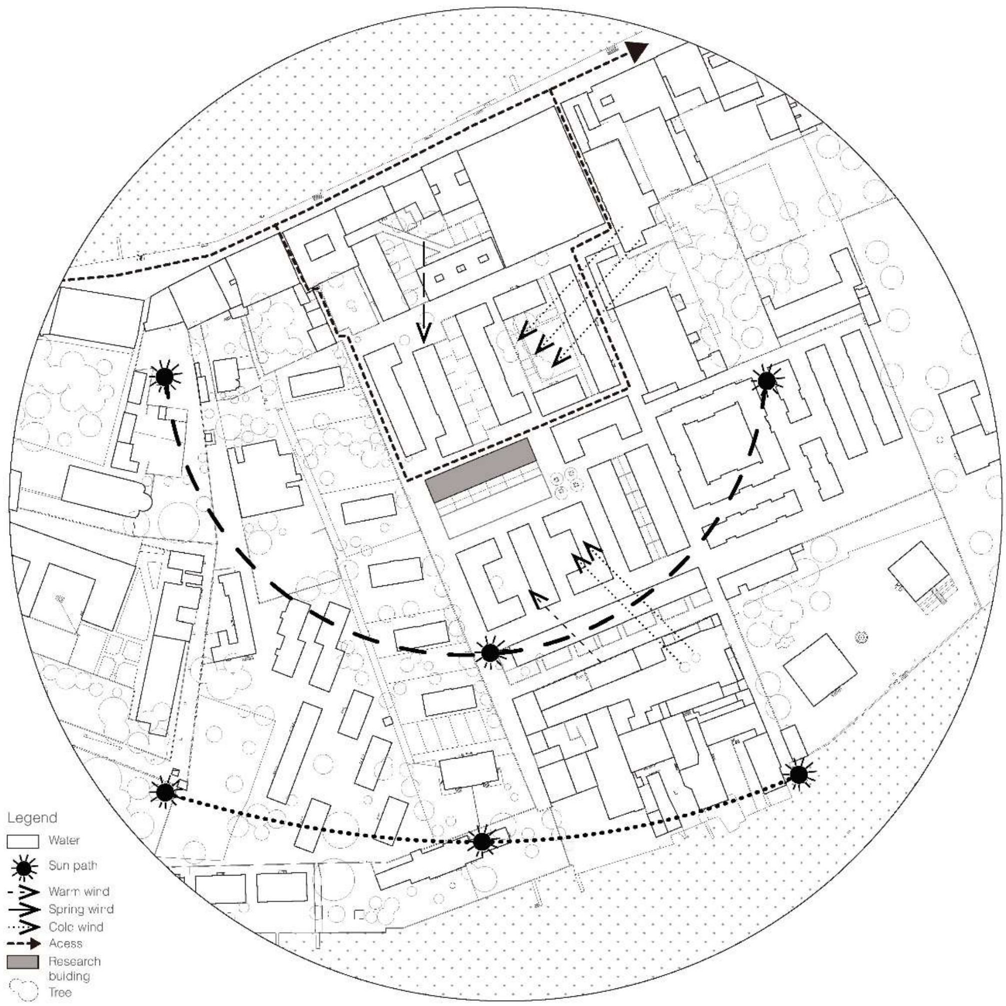


Figure 61, Biometric map.

According to climate data, combined with the site situation, a biometric map is drawn to show the environment elements overall. We can see from the map the sun path of summer and winter, the main wind direction of warm and cold, the main transportation routes to the site, the tree and green space location. It shows all of the visible and unviable elements related to our project, which should be considered in the next stage.

3.3.4 Strategies from the software Climate Consultant

The climate consultant gives guidelines to the proposal. After inserting the weather data of Venice, we chose the ASHRAE Standard Handbook of Fundamentals Comfort Model up through 2005. Then the Psychrometric chart of different time and seasons per year should be compared and learned. We can get a rough guide of the different weights on different strategies.

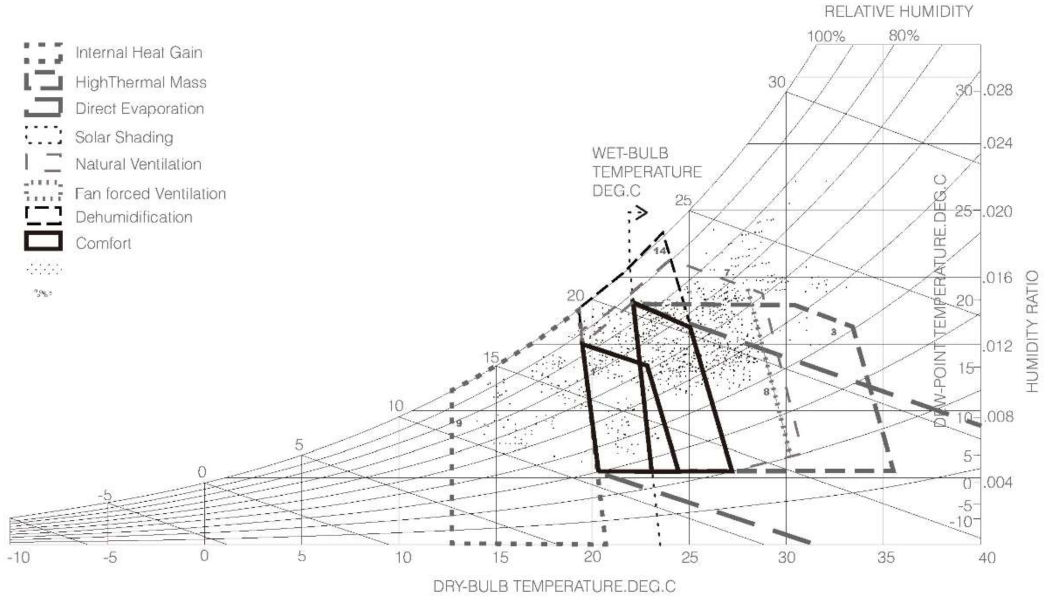


Figure 62, Psychrometric chart summer day Jun-Aug.

Design Strategies

34.6% 1 Comfort (414 hrs)

50.3% 2 Sun Shading of Windows (602 hrs)

14.7% 3 High Thermal Mass (176hrs)

19.3% 4 High Thermal Mass Night Flushed (231 hrs)

13.0% 5 Direct Evaporative Cooling (155 hrs)

17.1% 6 Two- Stage Evaporative Cooling (204 hrs)

20.6% 7 Natural Ventilation Cooling (246 hrs)

38.2% 8 Fan- Forced Ventilation Cooling (457 hrs)

10.5% 14 Dehumidification Only (125 hrs)

Total:

76.2% Comfortable hrs using selected strategies. (911 out of 1196 hours)

For example, in the summer day, the sun shading can change 602 hrs more to reach comfort. Meanwhile, fan-forced ventilation cooling can change 457 hrs more to reach comfort; Natural ventilation cooling can change 246 hrs more to reach comfort. These three strategies are the most important ones we should adapt in the summer day in Venice. While in summer night the situation turns different. In this period, the fan and natural ventilation together can change 640 hrs more to be comfortable. Besides, dehumidification helped a lot, which can turn 300 hrs to be comfortable.

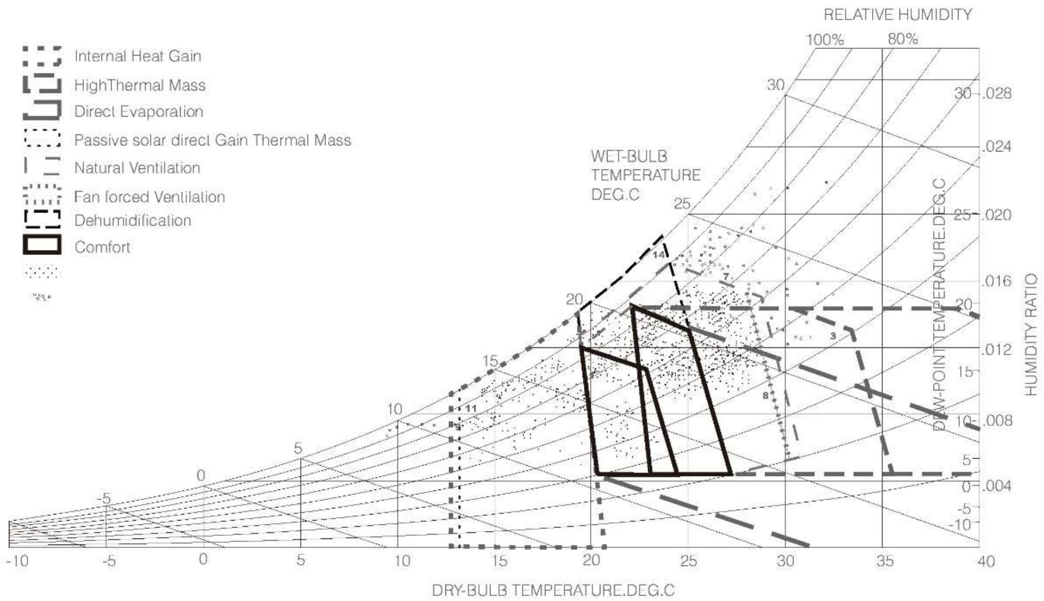


Figure 63, Psychrometric chart summer night Jun-Aug.

Design Strategies

31.9% 1 Comfort (382 hrs)

2.3% 3 High Thermal Mass (28hrs)

4.2% 4 High Thermal Mass Night Flushed (50 hrs)

3.7% 5 Direct Evaporative Cooling (44 hrs)

5.1% 6 Two- Stage Evaporative Cooling (61 hrs)

22.2% 7 Natural Ventilation Cooling (265 hrs)

31.4% 8 Fan- Forced Ventilation Cooling (375 hrs)

25.4% 14 Dehumidification Only (304 hrs)

Total:

69.9% Comfortable hrs using selected strategies (836 out of 1196 hrs)

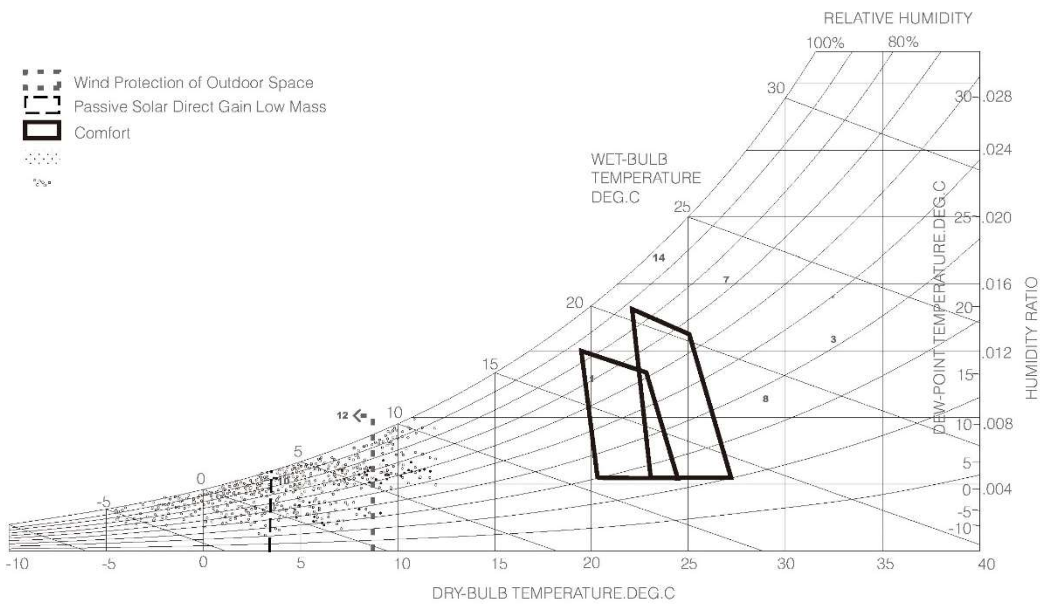


Figure 64, Psychrometric chart winter day Dec-Feb.

Design Strategies

0.0% 1 Comfort (0 hrs)

0.8% 9 Internal Heat Gain (13 hrs)

3.3% 10 Passive Solar Direct Gain Low Mass (39 hrs)

2.1% 12 Wind Protection of Outdoor Spaces (24 hrs)

Total:

4.1% Comfortable hrs using selected strategies (48 out of 1170 hrs)

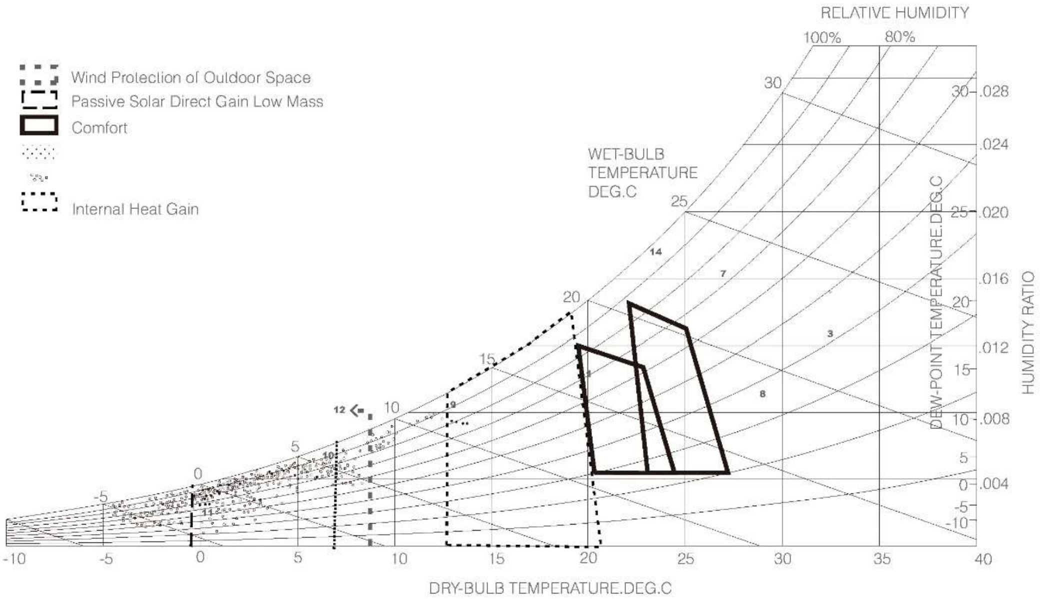


Figure 65, Psychrometric chart winter night Dec-Feb.

Design Strategies

0.0% 1 Comfort (0 hrs)

0.4% 9 Internal Heat Gain (0 hrs)

0.3% 10 Passive Solar Direct Gain Low Mass (0 hrs)

1.7% 11 Passive Solar Direct Gain High Mass (0 hrs)

1.5% 12 Wind Protection of Outdoor Spaces (0 hrs)

Total:

2.4% Comfortable hrs using selected strategies (28 out of 1170 hrs)

In the coldest season, winter day, almost all the season the environment is below comfort level without equipment or heating supply, but wind protection, solar gain, and high thermal mass are still helpful. The situation will not change much when we talk about the winter night.

Generally, in summer day, we should consider sun shading, fan, natural ventilation, thermal mass, and dehumidification; in summer night, we should consider fan, natural ventilation, thermal mass, evaporation, and dehumidification; In winter day, we should consider wind protection, thermal mass, and maximizing solar gain; In winter night, we should consider wind protection and thermal mass. These strategies are the guideline for the proposal.

3.4 Proposal

3.4.1 General information

The inspiration comes from the activities done by ASC, who have made their efforts to create a neighborhood to executed people from the historical center. They turned abandoned house to homes and build small, simple facilities for the neighborhood. The proposal is trying to expand the spontaneous trend into a completer and more systematic project that can be a win-win result for the citizens and the government.

Figure 66, ASC activities in Giudecca Island.

3.4.2 Sustainable aims

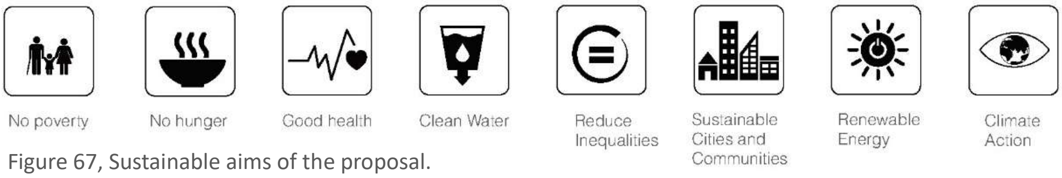


Figure 67, Sustainable aims of the proposal.

According to the UN's sustainable aims, we hope the proposal can finally meet about eight aspects. Through provide relatively cheaper rent house, it can reduce poverty of Venice and increase equalities and create a sustainable community. By using design strategies, the proposal can cover the energy cost by solar panels which are renewable energy. Through the collection and reuse the rainfall, it can supplement part of the clean water supply. The rooftop urban farm and landscape space can supply part of the food and helpful to good health. It will be a meaningful attempt in a built city area to increase density for living and technically build energy plus complex react to climate change.

3.4.3 Vision

The proposal is converting the rooftop to a sustainable community. The sample neighborhood called Calle Ramo Gran, has fourteen buildings, which are built around 70s or 80s around three floors. In the proposal, we try to modify the rooftop and add a new functional part which can increase the living density that Venice needs and be helpful to turn the existing neighborhood to a sustainable one. The relationship between the new part and the existing neighborhood is symbiosis. The former supply food, energy, water, and offer new public space to the existing neighborhood. The latter provides opportunity and place and as a support to create a local community and identity. If the proposal completed, it will create 45 residential units per 33 sqm each, 1950sqm rooftop urban farm. 310sqm public space, 600 new green space. The new residential units can offer low rent house to people who cannot live in the historical center. It is a meaningful way to lighten the conflict between the government and low-income citizens. The new urban farm can both supply vegetables to the new residents and the former neighborhood. Venice is an island city. All the resources are transferred through the boats, which increases the expense of the daily food. Rooftop urban farm can shorten the distance from farmland to the table, while saves the living expense of the citizens. The new rooftop public space including children's playground, small Platz, offer place for children, party, exercises, the outdoor meeting. It can improve people's health and create a good local atmosphere.

3.4.4 Process

The selected experimental building is three-floors residential building. It holds about 18 units for 18 families. The building is built around 80s with imple RC structure and sloped roofs.

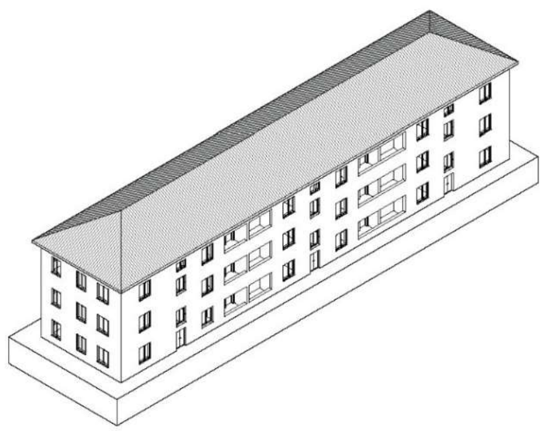


Figure 68, The selected experimental building.

Step 1: Demolish the existing slope roof and build a new flat waterproof roof as a basement of the next phase. According to the original structure, new beams are added to the roof level, functioning as the foot base of the next phase and as a waterproof barrier for the green roof or the opening of the stairs. The joints of the adding part to the original part uses reinforce steels inserting into the existing beam. The roof waterproof layer should be cleaned and redo to make sure no water leaking problem.

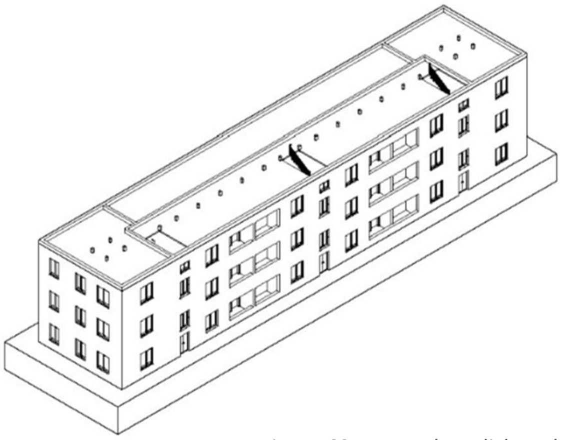


Figure 69, step 1 demolish and enhance.

Step 2: Arrange the residential units according to the existing structure. These parts are the main comfort control part of the proposal. Through the comparison, arranging the units on the north part of the roof is the best choice in this existing building. Because of the affordable aims, 4 units per 35sqm is reasonable, while other area is kept as semi-outdoor space, and outdoor space. Each unit is around 4.5 m in depth, 7.8m in width and 3m in height, including a kitchen, a living room, a bedroom, and a bathroom. Each unit can hold a single, a couple, or a couple with a child. Two units can transform to one unit in order to hold a bigger family.

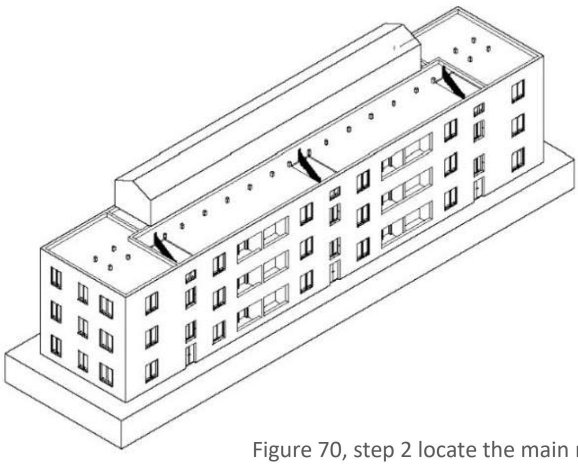


Figure 70, step 2 locate the main residential units.

Step 3: Finally, build a greenhouse as a buffer space as the main strategy to reach adaptive comfort. Similar to the case, the green both offer a semi-outdoor space to control the environment and offer a multifunctional space for urban farming and leisure. The greenhouse is made of wood frames and transparent coverings. It has sufficient openings to support the different strategies in different seasons. Through different behaviors in summer and winter, it can function as an organ that adjusts the climate to be more comfortable. The support wood frame is made by normally standard system, which could be easily bought from the market. The accessibility is a key point to the low budget. With the standard frames, a self-build modification is allowed in the future.

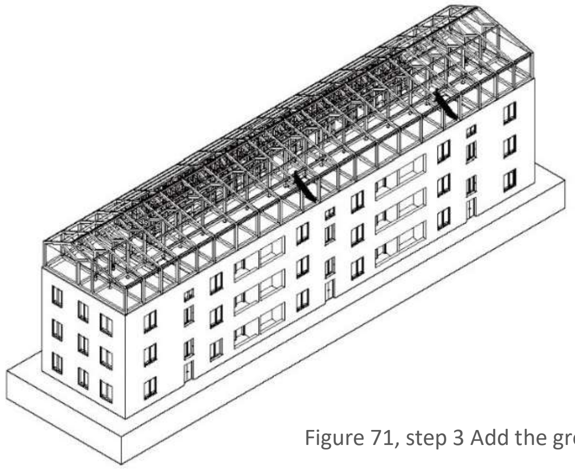


Figure 71, step 3 Add the greenhouse as buffer space,

3.4.5 Symbiotic system

The finished proposal functions as a symbiotic system between the new rooftop part and the existing building. If the whole neighborhood applies this strategy, it can create around 1950 sqm urban farming, 45 units per 33 sqm low rent social houses, 310 sqm new rooftop public space, and 600 sqm landscape area. The new roof occupants on the rooftop plant the vegetables and supply it to the existing neighborhood as a supplement for the low rent. Also, look after the landscape and public space for the neighborhood. The existing neighborhood agrees the modify and offer the place and in return get bio food and more public space. It is a symbiotic relationship between them. The government will solve the issues of protest, and illegal occupy, with affordable invest, get a new sustainable neighborhood in return. The proposal creates a win-win situation for everyone.

The system is like the pic below. The residence units using a pre-fab wood structure with easy joints; the new rooftop farmland with greenhouse supply bio vegetables and deal with the organic waste; the new public space for the neighborhood can offer a place to activities like birthday parties, ceremonies, is helpful to nurture a local atmosphere. New landscape to improve the microclimate of the place. Solar PV panels can produce green energy.

Figure 72, New benefits created

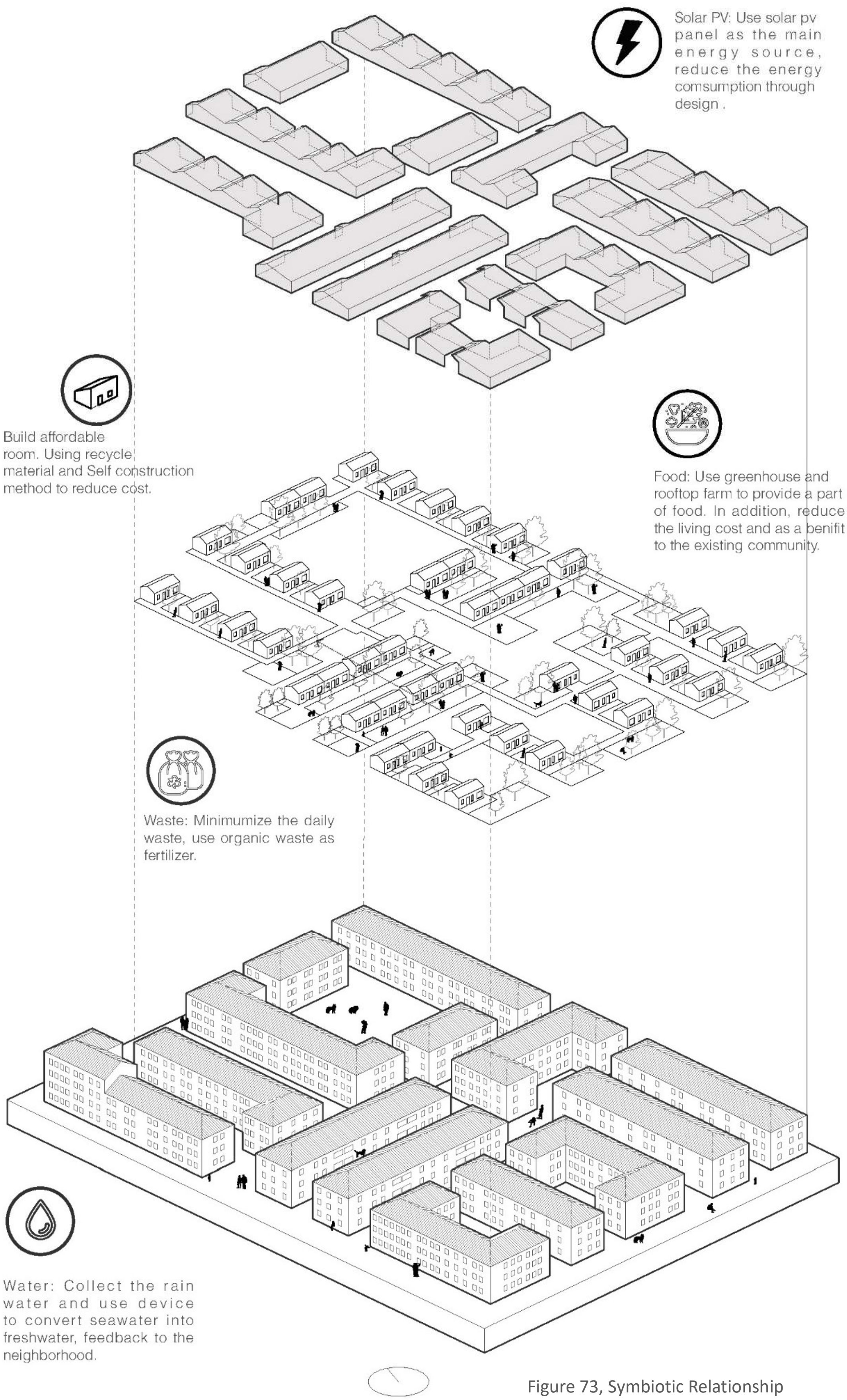


Figure 73, Symbiotic Relationship

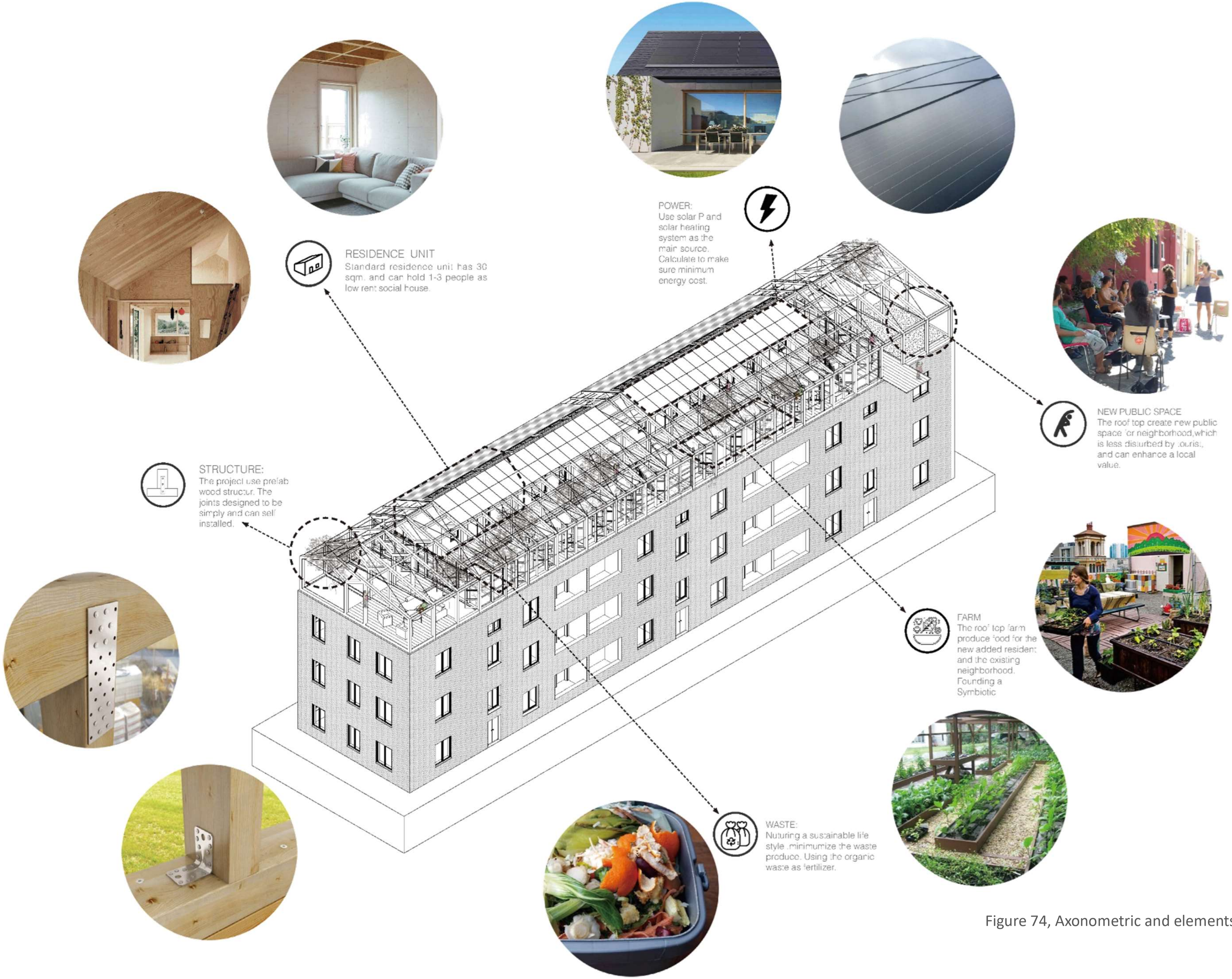


Figure 74, Axonometric and elements

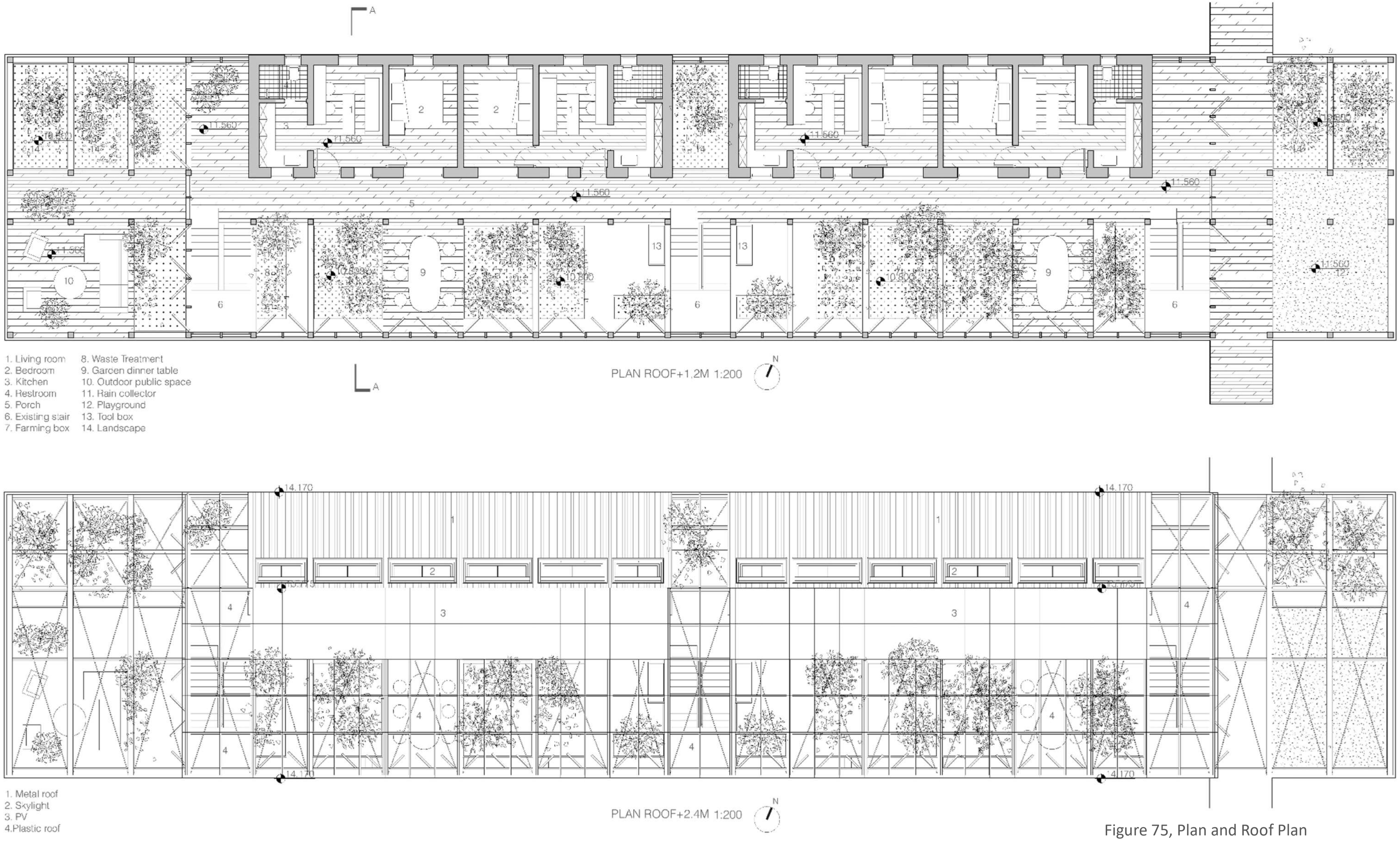
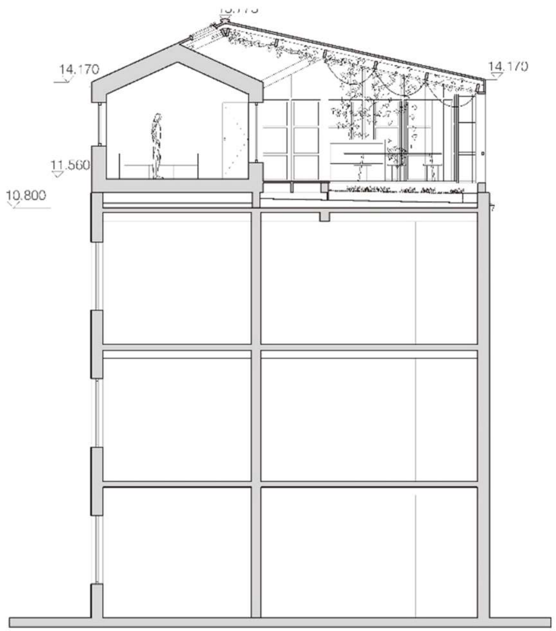
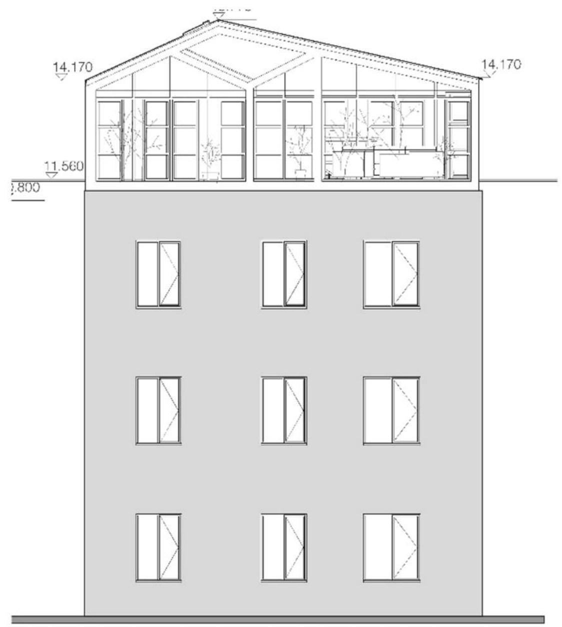


Figure 75, Plan and Roof Plan



SECTION A-A 1:200



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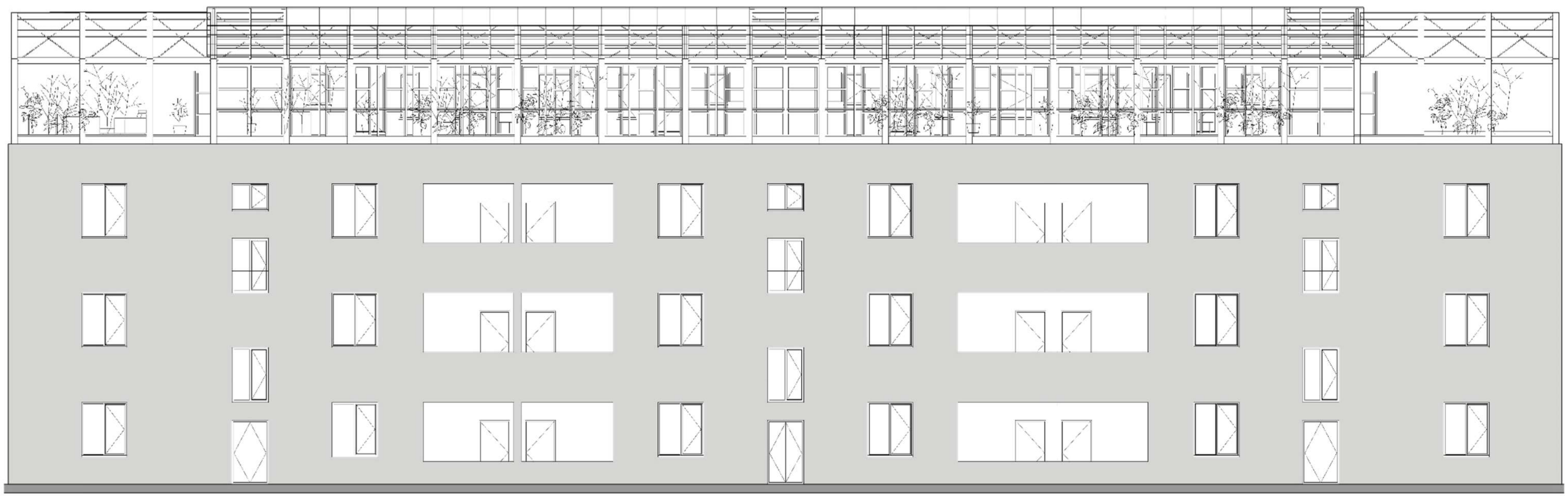


PLAN ROOF+2.4M 1:200

Figure 76, Elevation and Section

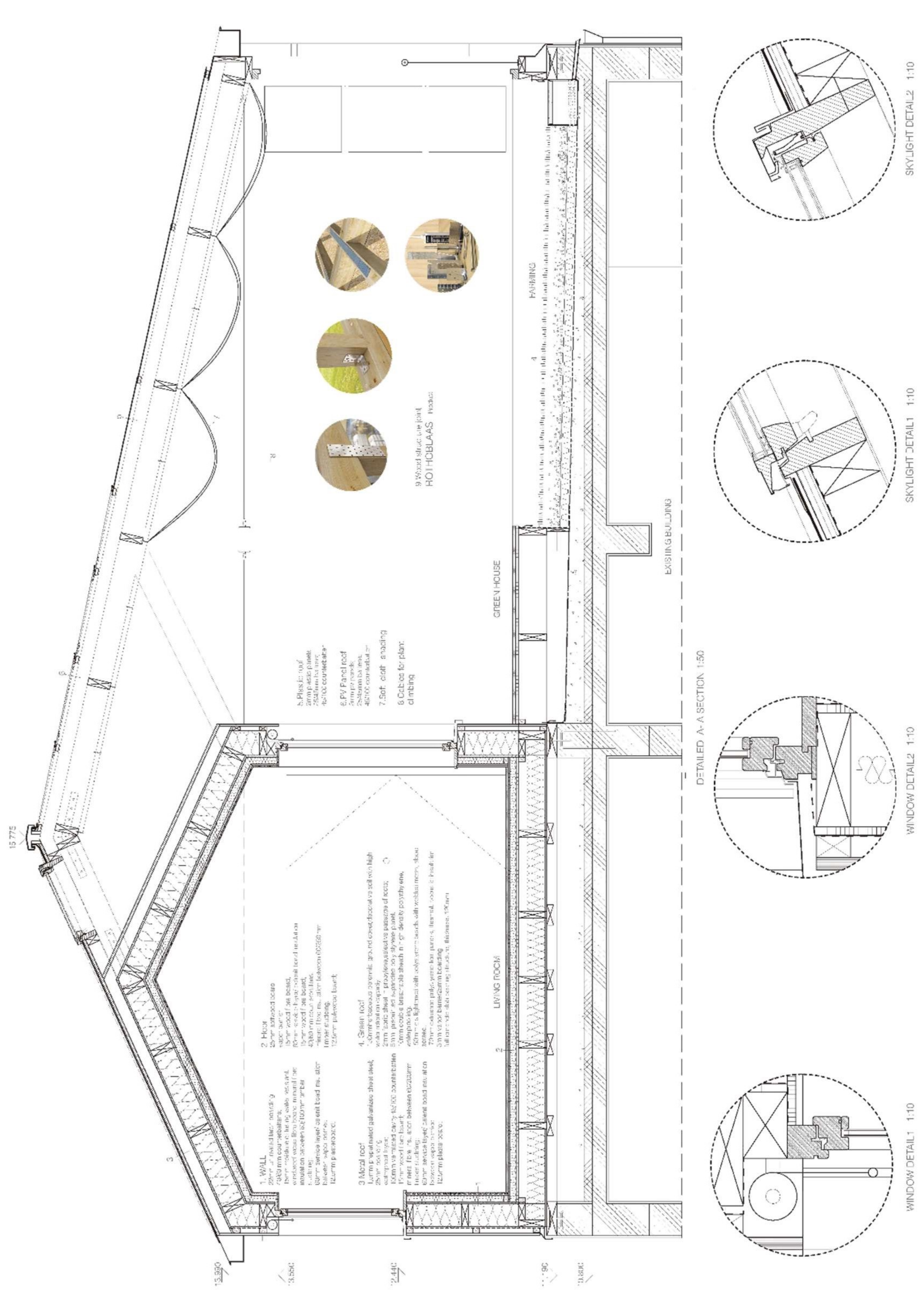


Figure 77, Detail Section and Details

3.4.6 Technical drawings (above)

Plan and Roof plan. (p64)

Elevation and Section(p65)

Detail section and details(p66)

Residential unit detailed plan:

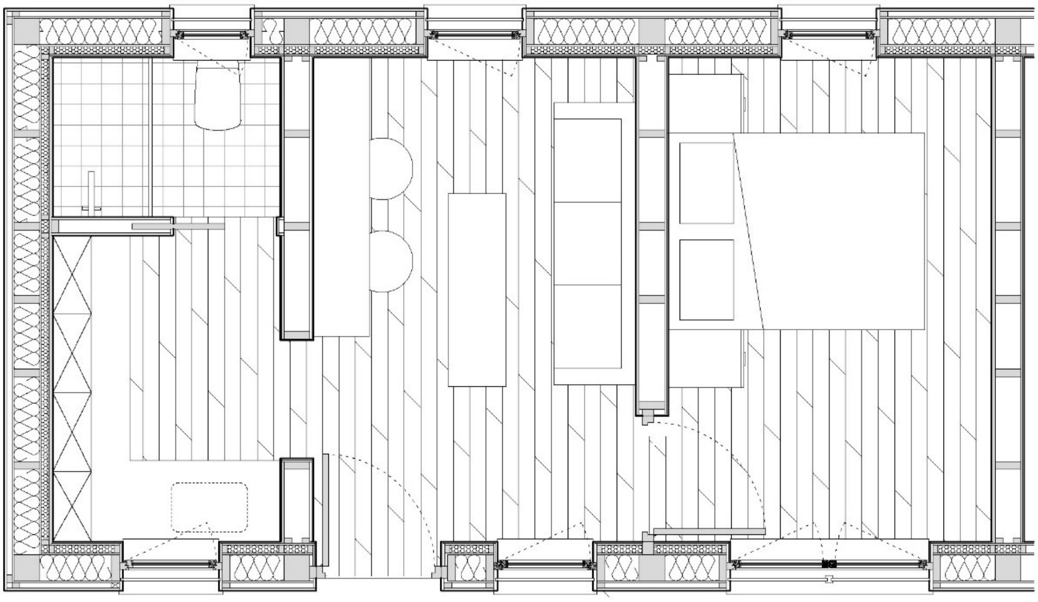


Figure 78, Resident Unit Plan 1:50

3.4.7 Construction Detail

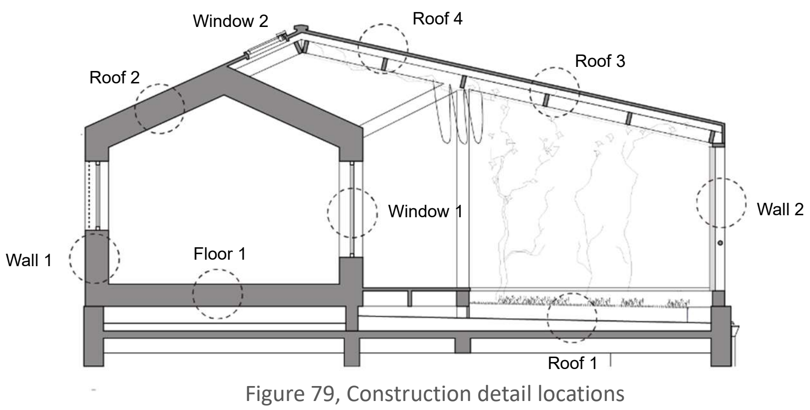


Figure 79, Construction detail locations

Roof 1 (Vegetation)

150mm Herbaceous perennial ground cover, decorative Soil with high water retention capacity

2mm Fabric sheet in propylene, selective passage of roots

8mm Preprinted expanded polystyrene panel

10mm double breathable sheath in high density polyethylene, waterproofing

50mm cls lightened with polystyrene beads with welded mesh, slope screed

70mm extruded polystyrene foam panels, thermal, acoustic insulation

3mm vapor barrier

Full concrete slab, bearing structure, thickness 120mm

Roof 2 (Metal with wood frame)

1.5mm preprinted galvanized sheet steel

25mm boarding

100mm ventilated cavity, 45/100counterbatten;

Waterproof layer

15mm wood fiber board

Mineral fiber insulation between 60/200mm timber studding;

60mm service layer/ celenit board insulation

Between vapor barrier

12.5mm plywoodboard

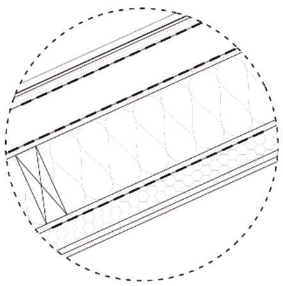


Figure 80, Roof 2, 1:10

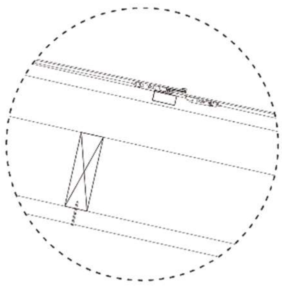


Figure 81, Roof 4, 1:10

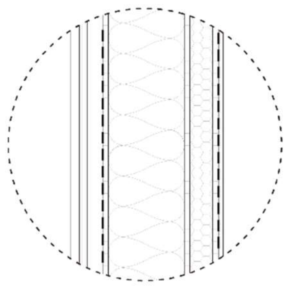


Figure 82, wall 1:10

Roof 3 (buffer space transparent part)

Use the PALRAM THERMAGLAS 8mm twin wall polycarbonate sheet

25/45 wood battens

45/100 counter battens

Roof 4 (PV solar panels)

ALLMAX PLUS PV panels from the manufacture Trina solar.

Figure 83, PV panel.

Wall 1 (residential units external wall)

22mm untreated larch boarding

40/60mm counter battens

15mm moisture diffusing water resistant, windproof wood fiberboard

mineral fiber insulation between 60/200mm timber studding

60mm services layer/mineral fiber insulation between 15mm layers of oriented strand board

Vapor barrier

12.5mm plasterboard

Wall 2 (buffer space external wall)

Use the PALRAM THERMAGLAS 8mm twin wall polycarbonate sheet

25/45 wood battens

45/100 counter battens

Floor1

22mm softwood board

Vapor barrier

15mm wood fiber board

60mm service layer/Celenit board insulation

15mm wood fiber board

40/60mm counter battens

mineral fiber insulation between 60/250mm timber studding

12.5mm plasterboard

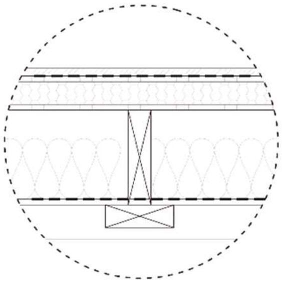


Figure 84, Floor 1 detail.

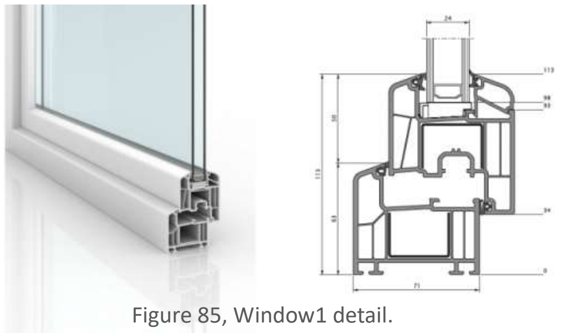


Figure 85, Window1 detail.

Window 1 (Residential unit)

Double glazed Glass in PVC frames

Accommodates glazing with a thickness of up to 47mm thermal or acoustic insulation

3.8 Energy strategy

Window 2 (buffer space opening)

Use the PALRAM THERMAGLAS 8mm twin wall polycarbonate sheet

Wood frames

3.5 Energy strategy and performance

3.5.1 Buffer space strategy

In this proposal, the buffer space strategy is used as the main measurement to reduce the building energy load. The hypothesis is that the buffer space as an intermediate climate area to help the indoor environment to reach comfort.

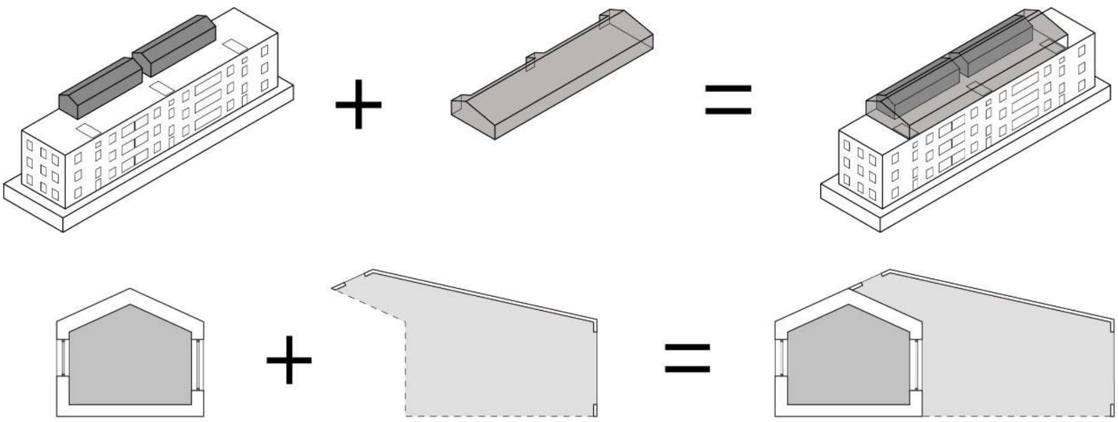


Figure 86, Buffer space concept.

3.5.2 U Value

According to the 3.4.7 construction, we can calculate the U value of different components of the project. U-value is the overall heat transfer coefficient that describes how well a building element conducts heat or the rate of transfer of heat through one square meter of a structure divided by the difference in temperature across the structure. The calculating formula is:

Thermal Resistance (R) = 1/Hi + ∑(Thickness/ Thermal Conductivity) + 1/He

U value = 1/R

Thermal conductivity: the property of a material to conduct heat.

R；a measure of thermal resistance, or the ability of heat to transfer from hot to cold, through materials (such as insulation) and assemblies of materials (such as walls and floors)

He and Hi; Laminar coefficient

The regulation in Italy set a maximum U value limit for different areas. Venice locates in zone E. From the table, the minimum required U-values for building elements are listed. For walls, the U-value is 0.34; for roof, the U-value is 0.30; for floors, the U-value is 0.33; for windows, the U-value is 2.2; Specific demand for windows glass only is 1.7. This regulation can be a reference to the proposal.

Then, according to the construction layer 3.4.7, the U-value can be calculated per elements for the next stage.

Roof 2, U=0.149

Layer	Material	Air layer	Thickness	Conductivity	Density	Specific heat (c)	Thermal resistance	Thermal resi
			[m]	[W/mK]	[kg/m³]	[J/kgK]	[m²K/W]	[m²K/W]
R_{si}	**Internal surface resistance**							
1	12.5mm Polywood		0.01	0.13	700	1660	0.10	
2	60 celenit board		0.06	0.09	460	1660	0.66	
3	200mm mineral wool		0.20	0.04	100	837	5.71	
4	15mm wood fiber board		0.02	0.37	640	1660	0.04	
5	100mm ventilated cavity	normal	0.10	5.56	1	1000		0.017985612
6	25mm wood board		0.025	0.130	700	1660	0.19	
R_{se}	**External surface resistance**							
			0.413					

Steady-state analysis	Symbol	Unit	Value
Superficial mass	M_s	[kg/m²]	83.550
Thermal resistance	R_t	[m²K/W]	6.721
Transmittance	U	[W/m²K]	0.149
Conductance of component	C	[W/m²K]	0.149
Areal heat capacity	C_{ta}	[kJ/m²K]	122.167
Time constant	τ	[h]	228.066

Figure 87, U value of Roof 2.

Roof 3, U= 0.58

Use the PALRAM THERMAGLAS 8mm twin wall polycarbonate sheet

Roof 4, U=1.2

ALLMAX PLUS PV panels from the manufacture Trina solar.

Wall 1, U=0.150

Layer	Material	Air layer	Thickness	Conductivity	Density	Specific heat (c)	Thermal resistance	Thermal res
			[m]	[W/mK]	[kg/m³]	[J/kgK]	[m²K/W]	[m²K/W]
R_{si}	Internal surface resistance							
1	12.5mm Polywood		0.01	0.13	700	1660	0.10	
2	60 celenit board		0.06	0.09	460	1660	0.66	
3	200mm mineral wool		0.20	0.04	100	837	5.71	
4	15mm wood fiber board		0.02	0.37	640	1660	0.04	
6	22mm wood board		0.022	0.130	700	1660	0.17	
R_{se}	External surface resistance							
			0.310					

Steady-state analysis	Symbol	Unit	Value
Superficial mass	M_s	[kg/m²]	81.350
Thermal resistance	R_t	[m²K/W]	6.680
Transmittance	U	[W/m²K]	0.150
Conductance of component	C	[W/m²K]	0.150
Areal heat capacity	C_{ta}	[kJ/m²K]	118.581
Time constant	τ	[h]	220.019

Figure 88, U value of Wall 1.

Wall 2, U= 0.58

Use the PALRAM THERMAGLAS 8mm twin wall polycarbonate sheet

Floor 1, U=0.123

Layer	Material	Air layer	Thickness	Conductivity	Density	Specific heat (c)	Thermal resistance
			[m]	[W/mK]	[kg/m³]	[J/kgK]	[m²K/W]
R_{si}	Internal surface resistance						
1	22mm Polywood		0.02	0.13	700	1660	0.17
2	15mm wood fiber board		0.02	0.37	640	1660	0.04
3	60 celenit board		0.06	0.09	460	1660	0.66
4	15mm wood fiber board		0.02	0.37	640	1660	0.04
4	250mm mineral wool		0.25	0.04	100	837	7.14
6	12.5mm wood board		0.013	0.130	700	1660	0.10
R_{se}	External surface resistance						
			0.375				

Steady-state analysis	Symbol	Unit	Value
Superficial mass	M_s	[kg/m²]	95.950
Thermal resistance	R_t	[m²K/W]	8.149
Transmittance	U	[W/m²K]	0.123
Conductance of component	C	[W/m²K]	0.123
Areal heat capacity	C_{ta}	[kJ/m²K]	138.702
Time constant	τ	[h]	313.954

Figure 89, U value of Floor 1.

Window 1 (Residential unit), U= 0.74

INOUTIC Arcade classic double-glazed Glass in PVC frames windows.

Window 2, U= 0.58

Use the PALRAM THERMAGLAS 8mm twin wall polycarbonate sheet

3.5.3 Strategies and Performance

According to the climate we analyze above, the characteristic of this area is the hot summer and cold winter. In the summer, the weather is hot and humid; while in the winter, almost the whole period is under the comfort level and heating supply is needed. There are two main aspects we can reach adaptive comfort: behavior level and architecture techniques level. In the proposal, the residential unit is compact and small with good thermal insulation and well-placed openings to form ventilations in summer. The buffer space is like a greenhouse with a wood frame and polycarbonate coverings. It is important to adaptive comfort that the occupants can adjust the microclimate through reasonable behaviors. The buffer space affords this responsibility. As we all know, the greenhouse is always effective in the winter seasons, this is why this strategy is popular in the northern part like Denmark or German. In summer, the greenhouse will be too hot. So, it is very important to change the greenhouse to an open and shading area where the ventilation will take the heat away. A shading curtain below the roof is designed to work in summer. Enough opening is designed and placed in the low part of the envelope facing the main wind direction and in the upper part on the roof in the other side to blow the heat away. In this way, the buffer space can work properly through different strategies in summer and winter.

Firstly, the model could be simplified because the plan is symmetrical, the residential units are standard, so that it could be simplified as one unit with a part of buffer space. In this way, the analysis could be clearer, and the simulation can be easier, but the result is equal to the original model.

Model info:

1.Residence Unit:
Volume: 121 m^3
Surface: 114m^2
Roof: 38m2
South: 23m2
Window 4m^2
Door 2$m^{2,}$
East: 15m^2
West: 15m^2
North: 23m^2
Window 3m^2

2.Greenhouse
Volume: 381 m^3
Surface: 249.7 m^2
Roof: 120m^2
PV: 21m^2
Opening: 7.2m^2
South: 37.5m2
Opening:29m^2
East:39m^2
West: 39m^2
Opening:25m^2
North: 14.2m^2

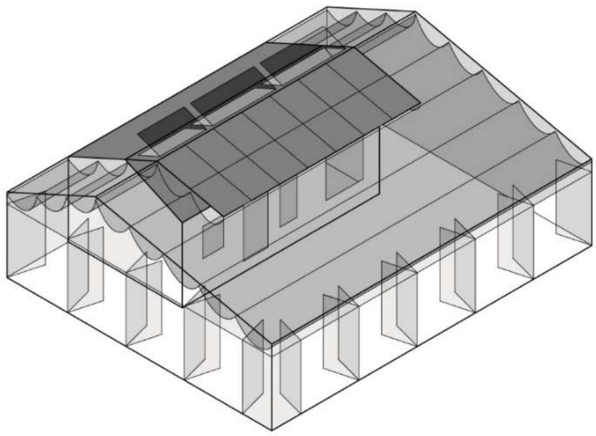


Figure 90, Model in summer.

Summer

In the summer day(June to August), form the climate analysis part, we can know that the average low temperature for June, July, August is 16.1C, 18.3C, 17.7C, meanwhile, the average high temperature for this three months is 24.9C, 27.7C, 27.5C. The precipitation of these three months is around 78mm, 63.9mm, 64.8mm. Rainfall days for the June is around 8.6days, but July and August decrease sharply to 6 days. The solar radiation in these months are the highest in a year. Besides, the humidity of these months is the lowest of the year around 72%. Main wind comes from the southeast in the whole summer. From the climate consultant software, we can get the advice for this season. If we study the summer day and night separately, in the summer day. 414hrs of 1196hrs is comfortable if we have not used any strategies. If we apply sun shading of the windows, 602 hours more could be comfortable. The fan ventilation cooling could make 457hrs more while the natural ventilation cooling could make 248hrs more. Others like thermal mass, evaporation, and dehumidification can be helpful. Through all this, 76.2% of this period could be comfortable.

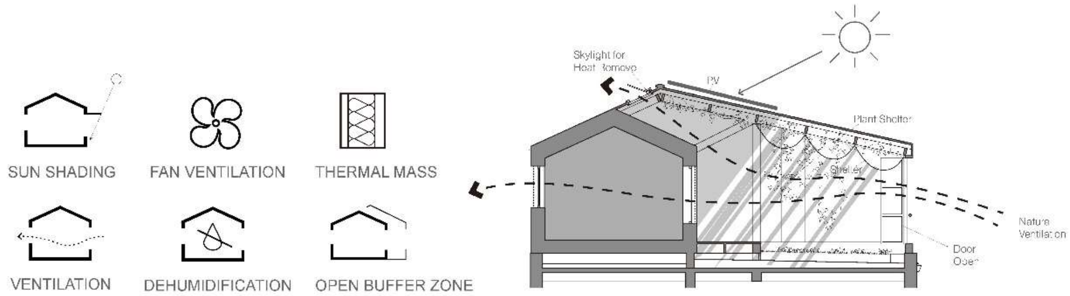


Figure 91, Strategies in summer day.

In the summer day, several behaviors for the buffer space should be done. First, in order to provide shading, the curtain on the roof should be unfolded, which can prevent solar heating. Secondly, all the opening should open, including the window of the residential unit, to create ventilation, which can take the heat away. The opening is at the lower part of the south and higher part in the roof because the heated air always moves upwards and stimulate in the upper part. Moreover, in summer, the roof farming and the plants are flourish, they can provide evaporation to take some heat away. In the summer, the buffer space should be totally open and worked as a shading element.

In the summer night, 382 hrs out of 1196 hours is regarded as comfort if we have not used any strategies. Then the Fan and natural ventilation help to add 640 hours more to be comfortable, making it the most important strategies. The dehumidification is the second important, which could add 304 hours more to be comfortable. In this situation, the buffer space should still be totally open and let the ventilation go through. It almost has no help to the comfort just make sure do no harm.

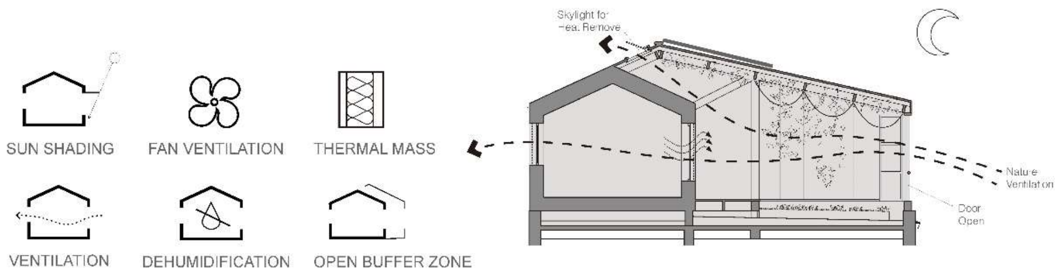


Figure 92, Strategies in summer night.

Model info:

1.Residence Unit:	2.Greenhouse
Volume: 121 m^3	Volume: 381 m^3
Surface: 114m^2	Surface: 249.7 m^2
Roof: 38m2	Roof: 120m^2
South: 23m2	PV: 21m^2
Window 4m^2	South: 37.5m2
Door 2$m^{2,}$	East:39m^2
East: 15m^2	West: 39m^2
West: 15m^2	North: 14.2m^2
North: 23m^2	
Window 3m^2	

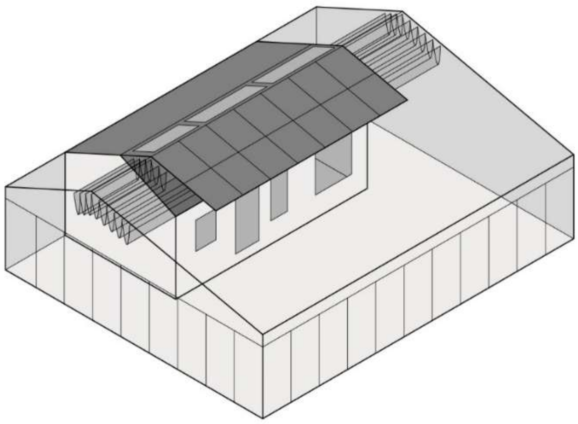


Figure 93, Model in winter.

Winter

In the winter season(December to February), form the climate analysis part, we can know that the average low temperature for December, January, February is 0.6C, -0.1C, 0.8C, meanwhile the average high temperature for these three months is 7.4C, 6.6C, 8.6C. The precipitation of these three months is around 50.6mm, 47mm, 48.3mm. Rainfall days for December is around 5.9 days, for January is 6 days and for February is 5.2 days. The solar radiation in these months is the least in a year. Besides, the humidity of these months is the highest of the year around 80%. Main wind comes from the northeast in the whole winter. From the climate consultant software, we can get the advice for this season. The main character in the winter in Venice is that it is impossible to reach indoor comfort without any equipment or outside heating supply. If we study the winter day and night separately, In the winter day, 0 hours of 1170 hours is comfortable if we have not used any strategies. Passive solar gain low mass, and wind protection is helpful to a little extent.

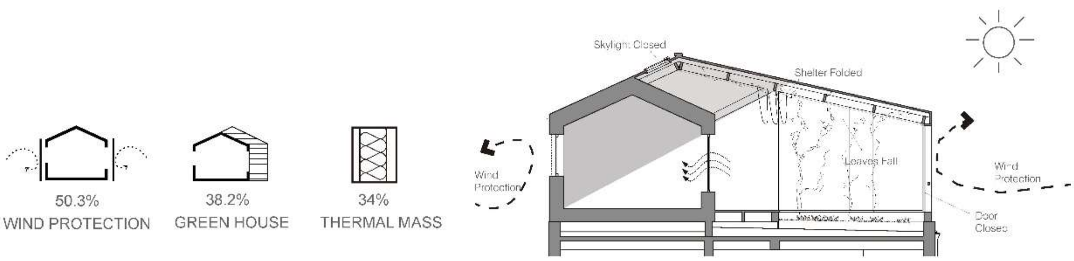


Figure 94, Strategies in winter day.

The aim of the buffer space in these seasons is to use better the solar heat, which is the main function of the greenhouse. So, in the winter day, several behaviors for the buffer space should be done. First, in order to sufficiently absorb the solar heating, the curtain on the roof should be folded. Secondly, all the opening should close, including the window of the residential unit, to prevent heat loss. The windows on the north direction should be closed to prevent the window. In the winter the buffer space should be totally closed and worked as a heat container, which absorbs solar heat in the day and releases it at the cold night. Through this way, it could be helpful to reduce the energy load of the residential units. We can see the energy consumption result from the Archisun. With or without the buffer one. Through the table energy consumption, obviously, the buffer space could reduce the energy consumption a lot.

In the cold winter night, the temperature in buffer space is higher than the outside. So, it can slow the heat loss of the indoor.

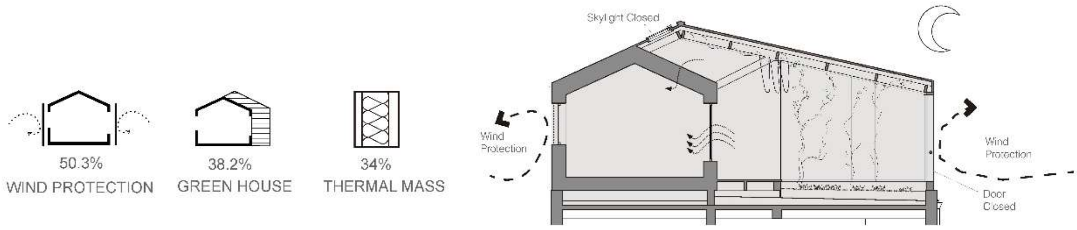


Figure 95, Strategies in winter night.

We use the Archisun to simulate energy performance. Because the Archisun has its limitation. The model should be separated into the residential unit and the greenhouse. We simulate the two parts and get the results. Then with a reasonable conversion. I can estimate the benefits that the greenhouse brings. The summer and winter are the analyzed seasons in this discussion.

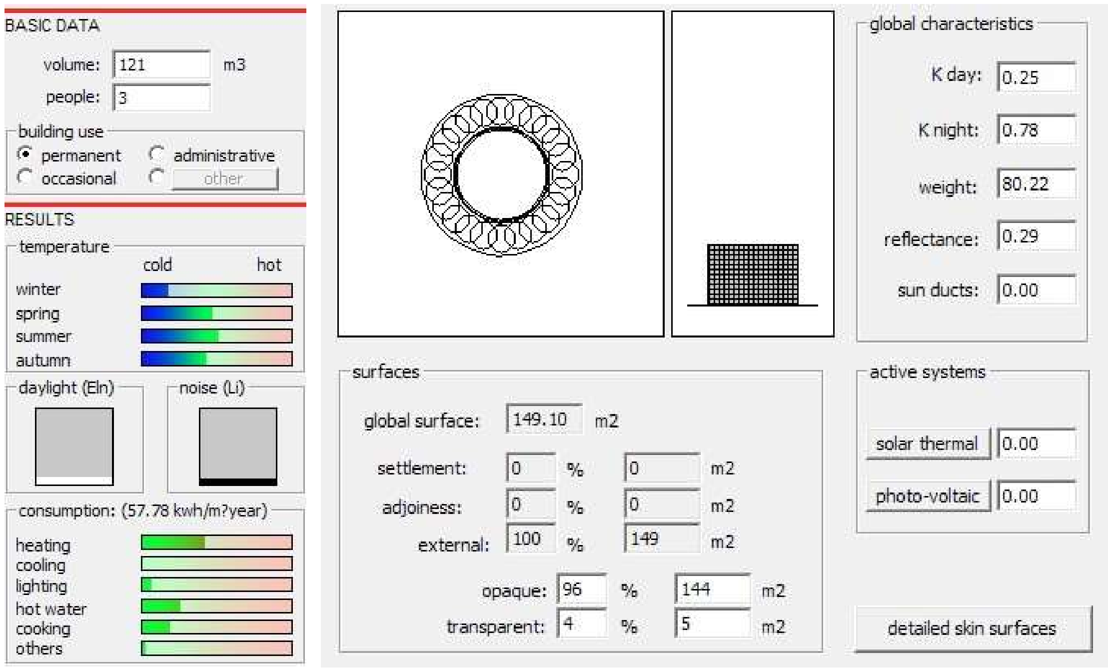


Figure 96, Simulation setting for residence unit.

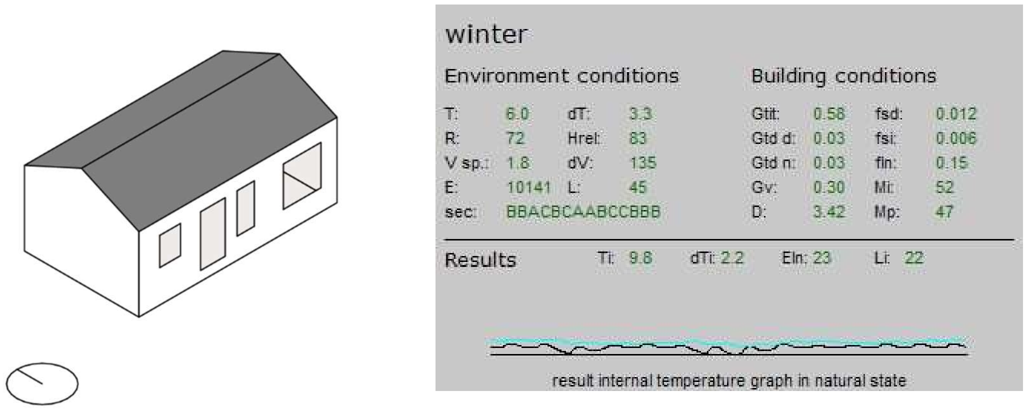


Figure 97, Simulation output 1 for residence unit.

According to the U-value calculation and the volume and surface area of the four directions, the simulation setting environment is showed in the figure above. Then we can get the simulation result. The summer and winter results are showing below.

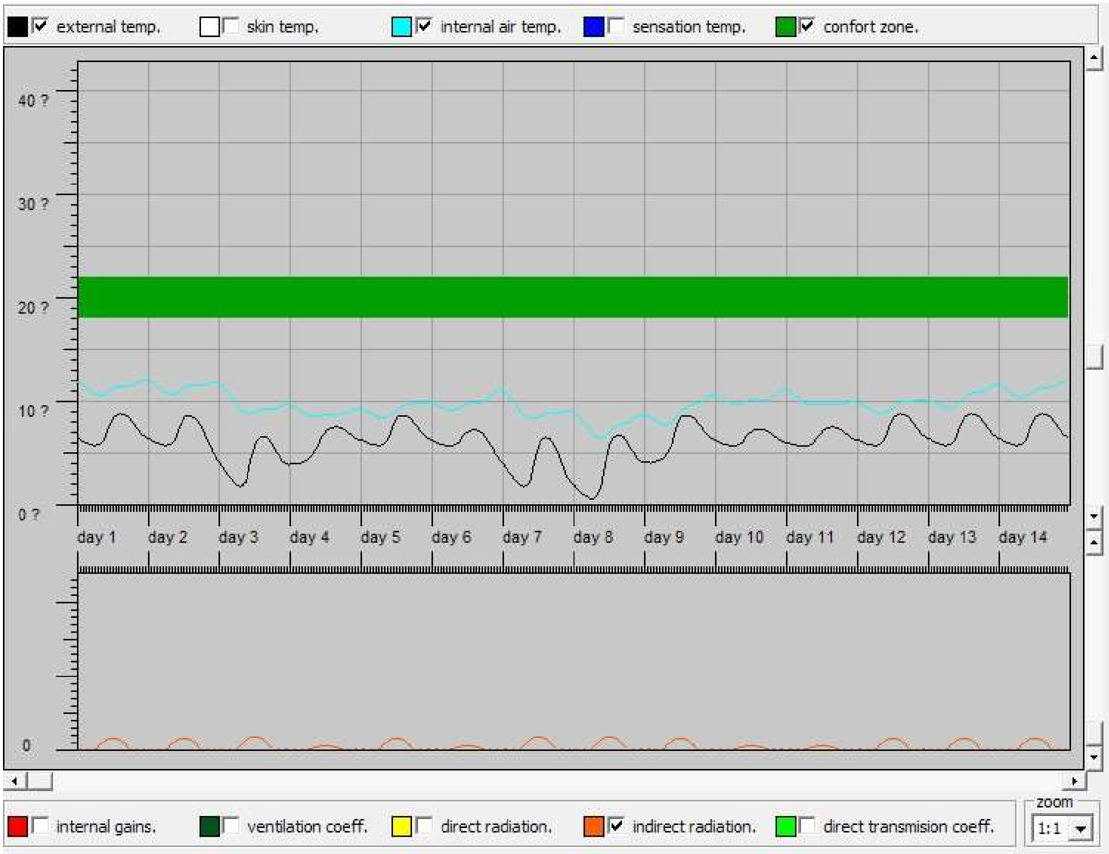


Figure 98, Simulation output 2 winter for residence

It indicates the internal temperature and outdoor temperature. The 15 days is considering different weather situations, such as clear, cloudy, rainy and so on. The green area is the adaptive comfort area in winter in Venice. We can see if we do not use any heating equipment, the whole period is under comfort. Due to the good U-value of the envelope, the indoor temperature is more stable than the outdoor.

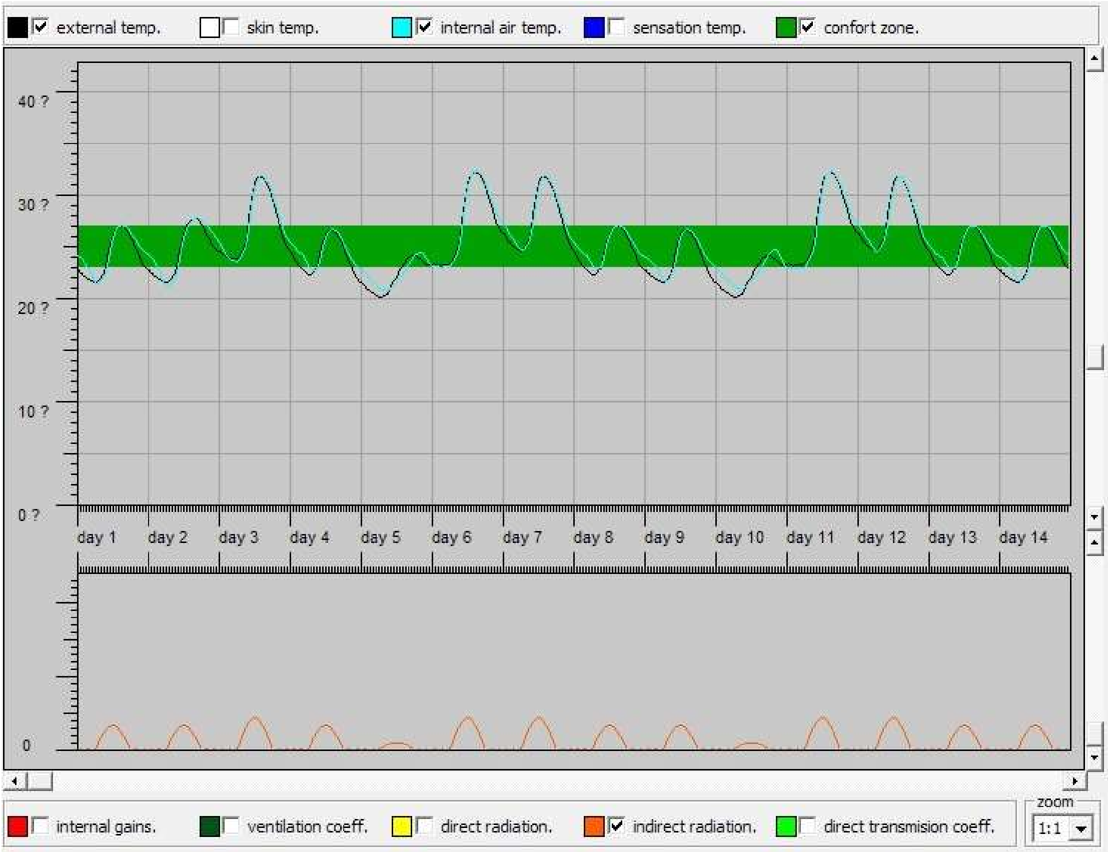


Figure 99, Simulation output 3 summer for residence

In summer, the shading and ventilation can keep the temperature mostly in the comfort zone.

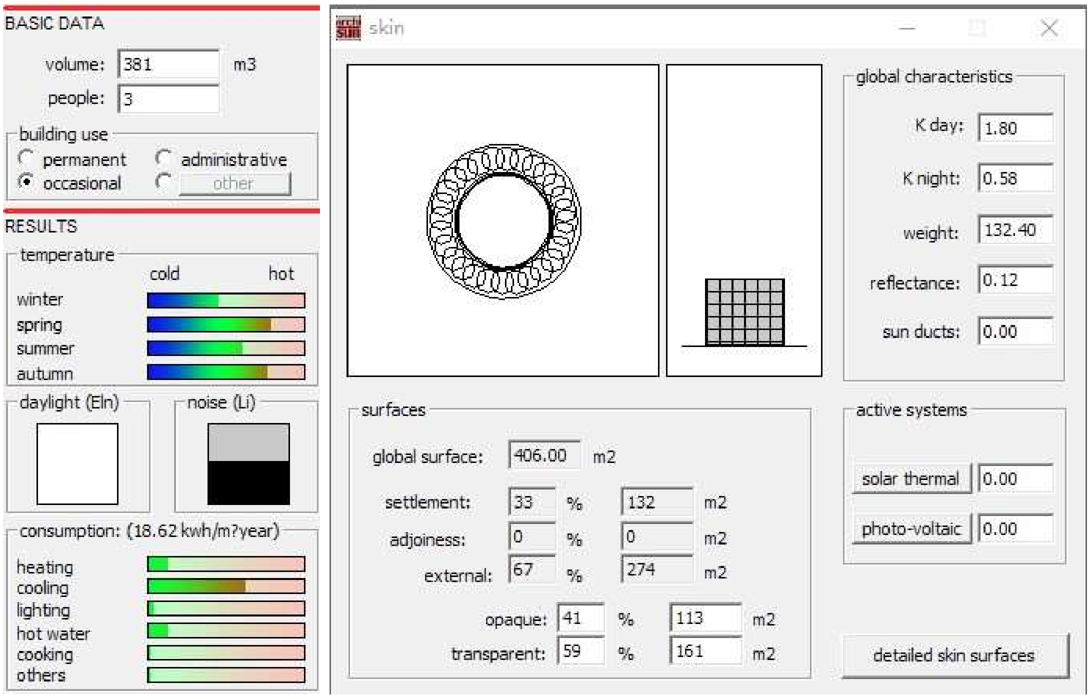


Figure 100, Simulation setting for greenhouse.

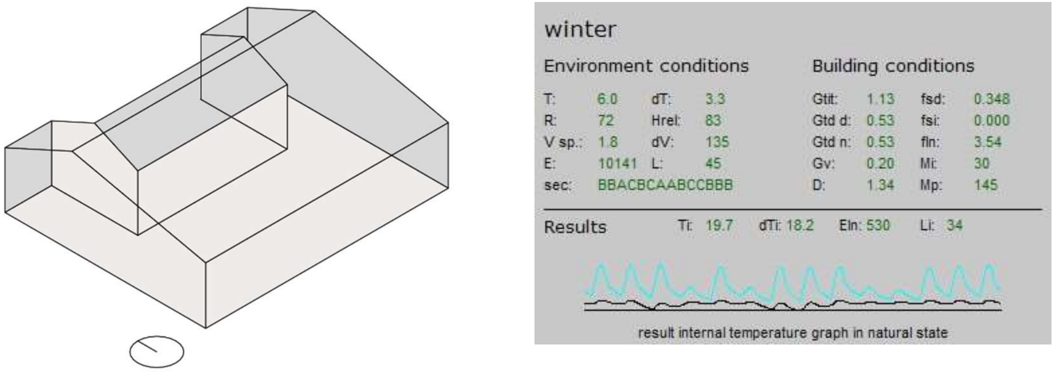


Figure 101, Simulation output for greenhouse.

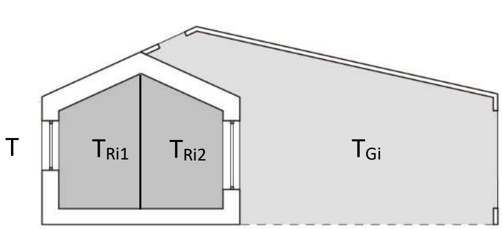
Then simulate the greenhouse separately. The figure shows the setting environment. In winter, the opening is closed. And the green effect will reach its peak in this season. The indoor and outdoor temperature curve shows below.

Figure 102, Simulation output winter for greenhouse.

The result shows that the greenhouse indoor temperature is far higher than the outdoor temperature due to the greenhouse effect. When the weather is cloudy, the greenhouse effect is weak, where the curve does not show the peak. On the other hand, the day and night show a sharp difference because the light thermal mass, and high u value of the glass. The heat produced by the greenhouse effect cannot kept long after sunset. It is why the curve is combined by peak and valley sharply.

Figure 103, Simulation output summer for greenhouse.

In the summer, according to the strategies discussed in the previous part, the shading curtains will be unfolded, and the windows will be open. In this way, the greenhouse effect will be reduced to zero in this way. The curves show the strategies are successful. In addition, the evaporation has not been calculated in yet.



T_{Gi}, Indoor temperature of greenhouse;

T, outdoor air temperature;

T_{Ri1}, indoor temperature under T;

T_{Ri2}, indoor temperature under T_{Gi};

$T_{Ri2} = (T_{Ri1} - T) + T_{Gi}$

$T_{Ri} = T_{Ri1} + T_{Ri2}/2$

Figure 104, Formula for calculation the greenhouse effect.

After the separate simulation, it is time to consider how much will the greenhouse affect the residence unit. There is no need to discuss the summer situation. In winter, the simulation 1 shows the outdoor average temperature is 6.0℃, while the indoor average temperature of the greenhouse in simulation2 is 19.7℃. Around 50% area of the residential unit is surrounded by the greenhouse. So, the situation can be simplify that 50% of the residential unit is facing a environment with 6.0℃, while the other 50% is facing a environment with 19.7℃. In the simulation 1, the indoor temperature of the residential unit is 9.8℃. To simplify the process reasonably, we set the outdoor temperature to T, and the indoor residence unit temperature under T is T_{Ri1}. The indoor temperature of the greenhouse is T_{Gi}, and the indoor residence temperature under T_{Gi} is T_{Ri2}. Due to the same U-value of the envelope and the same surface, we can accept that: $T_{Ri2} = T_{Gi} + \triangle T$; $\triangle T = T_{Ri1} - T$; Then the final indoor temperature of the residential unit should be $T_{Ri} = (T_{Ri2} + T_{Ri1})/2$. And finally the Through this formula, we can estimate the effect of the greenhouse to the residence indoor temperature. After calculation, the curves in winter should be like the figure below.

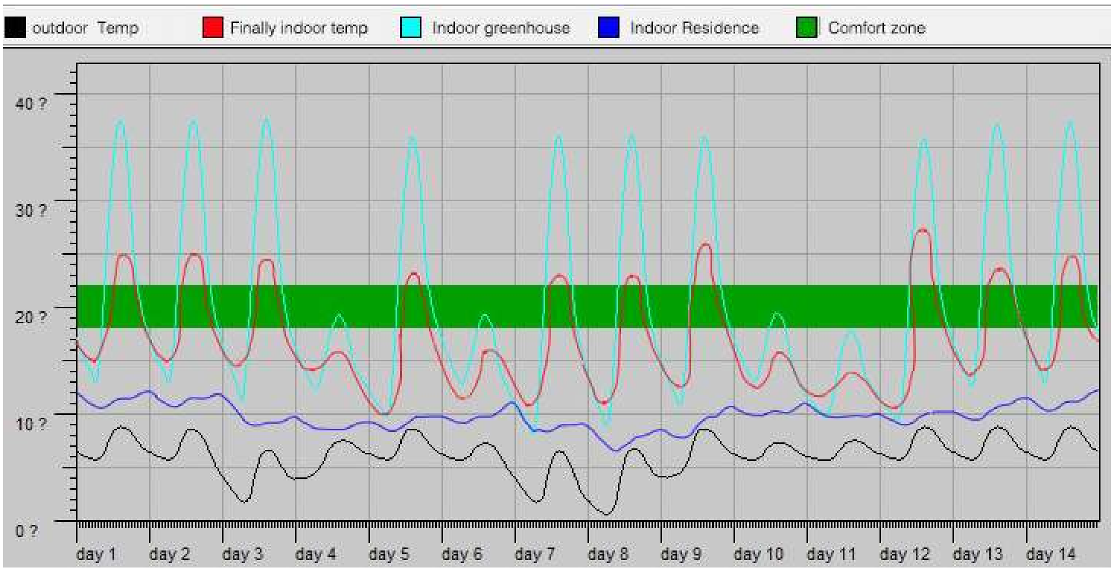


Figure 105, tables of the greenhouse effect.

Form the result, it is obvious that the greenhouse is helpful to the indoor temperature of the residential unit to reach adaptive comfort.

3.5.1 The covering materials

We have known the different situation we faced in different seasons, and the buffer space functioned differently according to this. In the summer, we need the greenhouse to prevent solar heating as more as it could. Meanwhile, in winter day, we need the greenhouse to absorb the solar heat as much as it could and keep it at night as long as it could. So, what kind of covering material could meet the specific demands. Glass, plastic, polycarbonic sheet and membrane are the typical materials on the market we use to build skylight window or greenhouse. According to the demand, we studied the different materials, and simulated in the Archisun to see which one is the most suitable one for the buffer space. On other hands, because the project is an affordable social house, so the duration and cost should be considered.

Glass

Glass is a well-known material for greenhouse covering. It is also a long-used material through greenhouse history. In fact, the glass lacks energy efficiency and can be costly, also, it does not diffuse light, and it demands a better structure to sustain the weight. Single pane and double-pane are the two common types of glass. The thermal insulation value, or R-value, of a single-pane glass greenhouse, is about 0.9. While the double-pane greenhouses have an R-value of 1.5 to 2.0, making them better than the single pane glass for insulation. Double pane glass greenhouses can also have a coating applied to the inside to reflect heat and add more insulation to the greenhouse. But the double pane glass is the most expensive material among the greenhouse coverings.

Polycarbonate

Polycarbonate is a relatively new material for greenhouse. It is made from thick plastic, making it cheaper and more versatile than glass greenhouses. This material is better than glass in many aspects. Single-wall or twin-wall polycarbonate sheet are common types of Polycarbonate sheets on the market.

Single wall

Like the single-pane glass, the single-wall polycarbonate sheets do not diffuse light or insulate heat well. The R-value of single-wall polycarbonate material is 0.83. Single-wall polycarbonate is also worse in light transmission than glass. About 94-96% of light passes through single-wall polycarbonate, while 97-98% that of glass. The single-wall polycarbonate is more durable than glass, but more flammable, which bring safety issues.

Twin-wall

Like the double-pane class, with the air gap between two layers, twin-wall polycarbonate panel is superior to single ones in almost every way. The R-value of twin-wall polycarbonate sheet is 1.42, better than single-pane glass or single-wall polycarbonate sheet. It also could diffuse light, but only 80-84% of light passes through the panels. In addition, polycarbonate panels are known to cloud over time. This clouding is called the yellowing effect. This effect will reduce the light going through the panel. The flammable issue is the same as single wall polycarbonate sheet.

Polyethylene

Polyethylene is widely used in the agricultural field for inexpensive and lightweight. The polyethylene film is made of multiple layers of polyethylene and special coating. Oxygen and carbon dioxide can pass through the poly film because it is porous, making the greenhouse breathable. Different coatings could improve performance in different aspects. For example, a UV stabilizer can reduce sun degradation and yellowing, an anti-drip coat can prevent excessive condensation, and the poly glazing can diffuse more light, which ensure the heat go more equally in the space. In comparison to glass, the poly film reduces heat loss by 30-40%. The R-value is in the range of 0.87 to 1.7. The single-layered poly film has an R-value of 0.87, whereas double-layered poly film varies from 1.5 to 1.7. Unfortunately, the poly film is also flammable than glass, but safe than polycarbonate.

Fiberglass

Another good option is fiberglass reinforced plastic, called FRP. It can provide good diffusion and light transmission and can last up to 10 years. It has an R-value of 0.89, which is slightly better than glass. However, UV rays break down the fiberglass over time, making the cover brittle. To maintain the strength of the fiberglass panels, we need to apply a new UV coating every few years.

Glass, Polycarbonate, Polyethylene, and Fiberglass are listed materials. For the case, the chosen material should be well enough for energy efficiency, relatively a good durability, an acceptable price and not difficult to install. In comparison, all the properties of these materials, we can get a table measuring the differences.

Material Name	U-value(W/m2·C)	Thickness(mm)	Density(g/cm3)	Price(€/m2)	Transparence (%)	Duration(year)
Double Pane Glass	0.7	16mm	2.57	30	82	25
Twin wall Polycarbonate Sheet	0.58	8mm	1.5	20	80	15
Polyethylene Film(double)	0.7	0.025mm	0.93	18	80	2
Fiberglass	1.2	0.6mm-4mm	1.5	10	85	15

Figure 106, Material comparison.

After comparison, the twin wall polycarbonate sheet is selected for this project. It is light weight, easy to install, acceptable price, long duration, and good energy performance.

3.5.2 About opening

The opening is important in this proposal, in order to apply the greenhouse strategies, which is common in the cold zones to Venice. In summer, the greenhouse effect should be harmful for adaptive comfort. The heat caused by greenhouse must be removed with the proper percentage and located openings. If there is two less opening or the location is not suitable to take the heat away, the summer will be a disaster. However, if there is too many openings with a large amount of thermal bridges, the buffer space could not keep the heat in winter. A reasonable hypothesis could be drawn that in the main summer wind direction, the opening should be in the lower part and the other side should locate in the upper part or roof because the heated air always moves upwards. And the lower part/ upper part should be a proper ratio.

4. Conclusion

Through the design case and the energy performance discussion, it is approved that the greenhouse as a buffer zone, which is commonly used in cold climate zones, can be applied in the Mediterranean climate and turn out helpful to reach the adaptive comfort in winter. And through the whole concept of the rooftop sustainable social house project, it is helpful for the cities like Venice where suffers a serve affordable housing problem. It can successfully realize some sustainable aims to build a more green, equal, less poverty society.

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Appendix

1. ASHRAE setting in Climate Consultant 6

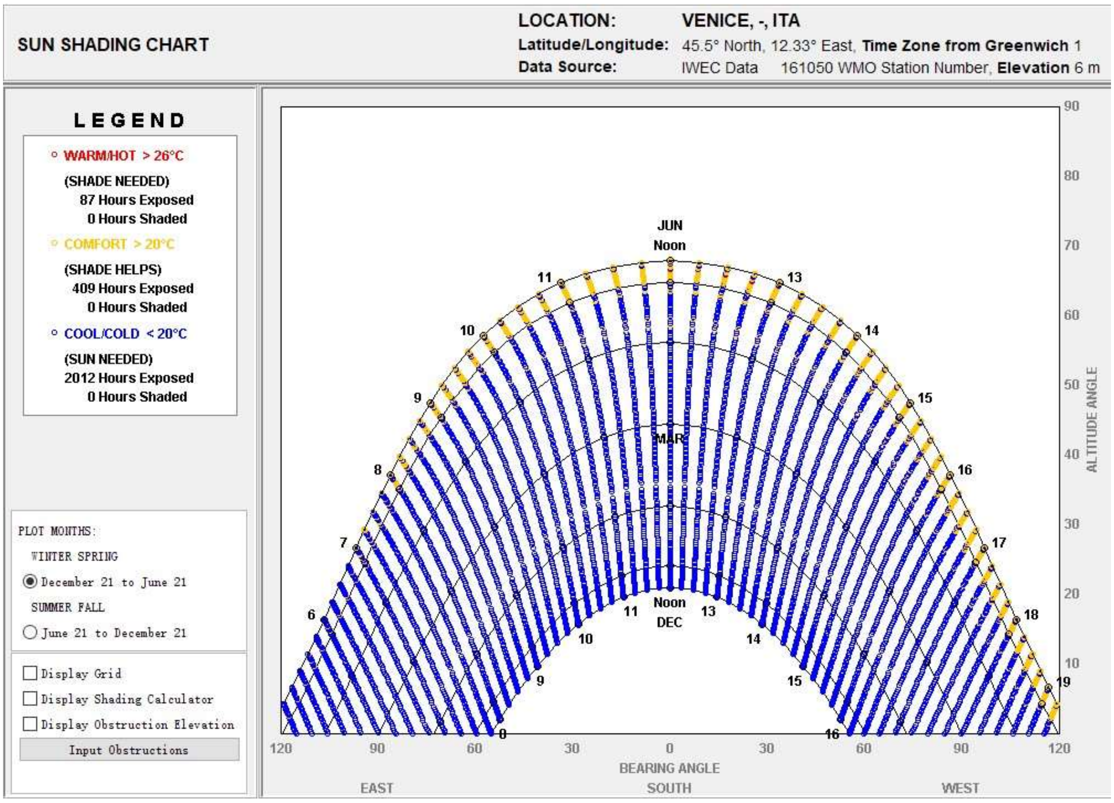
CRITERIA: (Metric Units)

LOCATION: VENICE, -, ITA
Latitude/Longitude: 45.5° North, 12.33° East, **Time Zone from Greenwich** 1
Data Source: IWEC Data 161050 WMO Station Number, **Elevation** 6 m

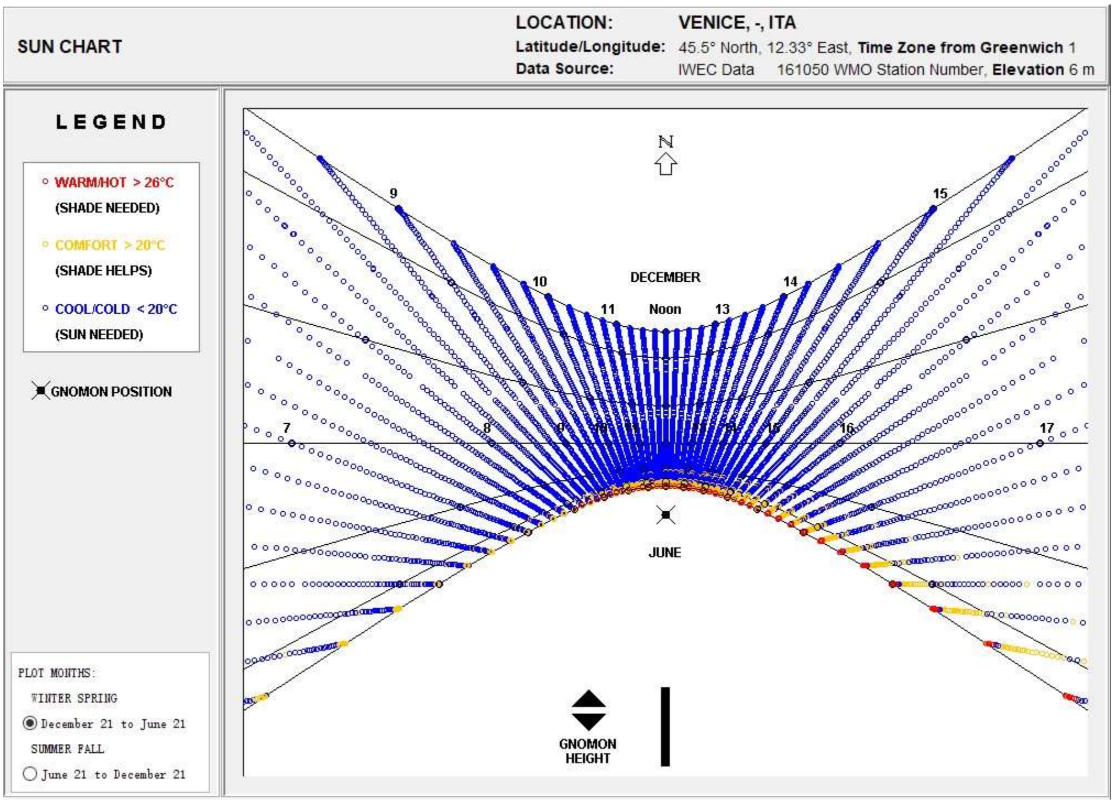
ASHRAE Handbook of Fundamentals Comfort Model, through 2005 (select Help for definitions)

1. COMFORT: (using ASHRAE Handbook through 2005 Model)	
20.0	Comfort Low - Min. Comfort Effective Temp @ 50% RH (ET* C)
23.3	Comfort High - Max. Comfort Effective Temp @ 50% RH (ET* C)
17.8	Max. Wet Bulb Temperature (° C)
2.2	Min. Dew Point Temperature (° C)
2.8	Summer Comfort Zone shifted by this Temperature (ET* C)
1.0	Winter Clothing Indoors (1.0 Clo=long pants, sweater)
0.5	Summer Clothing Indoors (.5 Clo=shorts, light top)
1.1	Activity Level Daytime (1.1 Met=sitting, reading)
2. SUN SHADING ZONE: (Defaults to Comfort Low)	
22.8	Min. Dry Bulb Temperature when Need for Shading Begins (° C)
315.5	Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)
3. HIGH THERMAL MASS ZONE:	
8.3	Max. Outdoor Temperature Difference above Comfort High (° C)
1.7	Min. Nighttime Temperature Difference below Comfort High (° C)
4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:	
16.7	Max. Outdoor Temperature Difference above Comfort High (° C)
1.7	Min. Nighttime Temperature Difference below Comfort High (° C)
5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)	
20.0	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (° C)
11.1	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (° C)
6. TWO-STAGE EVAPORATIVE COOLING ZONE:	
50.0	% Efficiency of Indirect Stage
7. NATURAL VENTILATION COOLING ZONE:	
2.0	Terrain Category to modify Wind Speed (2=suburban)
0.2	Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5	Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)
3.6	Max. Perceived Temperature Reduction (° C)
90.0	Max. Relative Humidity (%)
22.8	Max. Wet Bulb Temperature (° C)
8. FAN-FORCED VENTILATION COOLING ZONE:	
0.8	Max. Mechanical Ventilation Velocity (m/s)
3.0	Max. Perceived Temperature Reduction (° C)
	(Min Vel, Max RH, Max WB match Natural Ventilation)
9. INTERNAL HEAT GAIN ZONE (lights, people, equipment):	
12.8	Balance Point Temperature below which Heating is Needed (° C)
10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:	
157.7	Min. South Window Radiation for 5.56° C Temperature Rise (Wh/sq.m)
3.0	Thermal Time Lag for Low Mass Buildings (hours)
11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:	
157.7	Min. South Window Radiation for 5.56° C Temperature Rise (Wh/sq.m)
12.0	Thermal Time Lag for High Mass Buildings (hours)
12. WIND PROTECTION OF OUTDOOR SPACES:	
8.5	Velocity above which Wind Protection is Desirable (m/s)
11.1	Dry Bulb Temperature Above or Below Comfort Zone (° C)
13. HUMIDIFICATION ZONE: (defined by and below Comfort Zone)	
14. DEHUMIDIFICATION ZONE: (defined by and above Comfort Zone)	

2. Sun shading chart. (Climate Consultant 6)



3. Shadow chart. (Climate Consultant 6)



4. 3D temp chart. (Climate Consultant 6)