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Faculty of Technology
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جامعة عبد الرحمان ميرة – بجاية
كلية التكنولوجيا
قسم الهندسة المعمارية

Theme :

Towards the Creation of a Bioclimatic Habitat Model Specific to the Coastal Region: the case of Tourist Living Spaces in Bejaia.

Thesis submitted for the Master II degree in Architecture.

« Speciality: Architecture» **« Theme: Habitat»**

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Abstract :

In coastal regions, buildings are inevitably confronted with singular climatic conditions, as illustrated by the example of Béjaïa, where high atmospheric humidity, strong maritime winds and intense sunshine prevail. Faced with these environmental challenges, bioclimatic architecture is emerging as an innovative approach, based on architectural design in symbiosis with the local environment. This methodology aims to optimize the use of natural resources such as sea breezes and solar radiation, helping to reduce energy consumption while ensuring optimum thermal and visual comfort for occupants.

The main objective of this research is to identify a housing typology suited to the coastal context of Bejaia, which will be implemented in the final-year project by the design of a group of collective, semi-collective and individual houses in Tichy, in perfect harmony with the specific features of the site.

To achieve this, a purely theoretical study was carried out, providing an in-depth understanding of the habitat, the coastline, as well as the bioclimatic approach, its principles and strategies, and comfort. This theoretical analysis was combined with a field study analyzing five typical residences of different typologies on the shore of Béjaïa. The goal was to find the optimum typology for the location and identify its good qualities. To accomplish this goal, three important aspects of bioclimatic design were investigated: building materials, natural light, and natural ventilation. This analysis was based on in situ measurements that were supplemented by numerical simulations using DialuxEvo software for daylight analysis, RWIND for wind analysis, and the Ubakus web interface for building material evaluation, with the results interpreted for each parameter.

After undertaking these extensive theoretical and empirical investigations, the findings were carefully applied to the final-year project. Later computer simulations of daylighting and building material properties validated the veracity of the decisions made. Indeed, the obtained results eloquently demonstrate the optimal match between the architectural proposal and the site's environmental constraints, demonstrating the validity of this bioclimatic conceptual approach, which ensures a habitat that provides ideal thermal and visual comfort to its occupants.

Keywords : Coastline, Bioclimatic architecture, Bejaia, Climatic conditions, Thermal comfort, Visual comfort

list of tables :

List of figures :

Signings :

I humbly dedicate this work:

To all those who have contributed in any way to its development,

To my family,

To my friends.

Acknowledgements:

First, I would like to express my deep gratitude to God, the Almighty and Merciful Creator, for granting me the perseverance and resilience needed to complete this modest work.

I would like to express my sincere thanks to my supervisor, Dr. SARAOUI Selma, and my co-supervisor, Mme. LABRECHE Samia, for their invaluable advice and constructive comments, which greatly enriched this dissertation.

My gratitude also extends to the members of the jury for their interest in this work, as well as for the time and effort invested in its evaluation, and for their enlightened suggestions.

I would also like to express my gratitude to all those who, directly or indirectly, contributed to the production of this thesis.

Thank you.

INTRODUCTORY CHAPTER

General introduction :

Algeria, by virtue of its geographical position and vast territorial expanse, stands out as the largest country in Africa and the tenth largest in the world, covering an area of 2,381,741 square kilometers. This vast expanse gives Algeria a remarkable ecological, cultural, and climatic diversity, shaped by a variety of influences ranging from the arid Sahara to the Mediterranean coastline.

Algeria's geographical distribution greatly influences its population. Nearly four-fifths of its territory is dominated by the Sahara, leaving the coastal strip, stretching for some 1,200 kilometers, as the main place of habitation for a large part of its population. This coastal region, characterized by a Mediterranean climate, attracts people because of its easy access to the sea, its dynamic economy based on maritime activities, and its tourist attractions such as beaches and water sports.

However, the concentration of people in coastal cities has increased the issues of urbanization, particularly the pressure on housing. The increasing demand for homes in these places has resulted in fast urbanization and, in many cases, uncontrolled construction that ignores the coast's environmental and climatic characteristics. As a result, many structures are planned without considering local climatic conditions, possibly harming both residents and the environment.

> One of the crucial aspects in the design of a structure is its context, which can affect the building in ways that are either positive (e.g. offering heat or shade) or extremely negative (erosion, collapse). The essential feature of this context is that it is constantly evolving, often unpredictably. In turn, the building has a responsibility towards this context: at the very least, it has to get on well with it, but sometimes it can even improve it. (Simitch & Warke, 2015, p.46)

This remark emphasizes the critical need of adapting architecture to its ever-changing environment.

Architecture that overlooks these contextual aspects risks lacking quality and thinking, perhaps exacerbating environmental and occupant comfort issues. In this context, bioclimatic architecture is emerging as an essential approach to designing buildings that meet the needs of inhabitants while minimizing their impact on the environment. By integrating design strategies adapted to local climatic conditions, bioclimatic architecture aims to create sustainable, comfortable, and energy-efficient living spaces. In this way, it offers a path to more responsible urbanization and a better quality of life for the populations of Algeria's coastal regions.

Problematic :

Bejaia is one of Algeria's coastal cities, with a coastline over 120 km long. It has witnessed a complex history, marked by political events, economic and social transformations, and the influence of various civilizations through the ages, from prehistory to the present day.

The impact of this varied history is reflected in the region's architectural diversity, with a particular focus on housing. The latter is representative of different historical eras, with distinct typologies corresponding to the pre-colonial, colonial, and post-colonial periods. This architectural diversity is the result of the interaction between the natural territory and the influences of the various civilizations that have left their mark on the region over time.

However, despite this historical and architectural wealth, contemporary urbanization poses major challenges. The high demand for housing along the coast has led to rapid urbanization, characterized by standardized architecture that takes no account of the region's specific climatic and environmental features. This uncontrolled urbanization compromises the sustainability of buildings and the comfort of residents.

Indeed, homes built without taking into account local environmental conditions, such as high humidity, sea winds and soil properties, face serious problems that affect their resilience and the quality of life of their occupants. Faced with these challenges, it is crucial to promote a bioclimatic approach in the design of these constructions.

The aim is to understand the specific environmental features of a particular site, and to propose appropriate architectural and urban solutions in synergy with their natural surroundings. This involves considering local climatic conditions, optimizing available natural resources, and promoting sustainable and ecologically responsible construction techniques. In addition, buildings must functionally meet the needs of their users.

In the case of our end-of-study project, the challenge is to design three types of housing - individual, semi-collective and collective - on the Hammadites beach on the coast of Béjaïa, taking into account the above-mentioned climatic data, the requirements of the inhabitants in terms of spatial quality, while taking advantage of the site and its maritime landscape, and ensuring the durability of these constructions.

- **What is the role of bioclimatic housing in coastal environments? And on what criteria is it based?**
- **How can bioclimatic approaches be integrated into coastal housing?**
- **Are there any housing typologies in the city of Bejaia that are adapted to this environment? And how can they influence and inspire designers in their new designs?**

Hypothesis :

As an anticipated response to the problem, we put forward the following hypotheses:

- Bioclimatic coastal housing aims to maximize the use of natural resources such as sun, wind and water to ensure thermal comfort and reduce energy consumption. Criteria include orientation, insulation, natural ventilation, and the use of local, sustainable materials.

- Integrating the bioclimatic approach into coastal housing means considering local climatic and environmental particularities, using passive techniques such as natural ventilation and green spaces to regulate temperature, and using eco-friendly materials and energy-efficient technologies to reduce carbon footprints.

- In the wilaya of Bejaia, traditional coastal housing typologies such as courtyard houses with their thick stone walls can be optimally adapted to the climate of this environment. Their designs can influence new construction by drawing on all the building processes and materials used and trying to reproduce them in new designs with a contemporary twist.

Work objectives :

The objectives of this research are:

- Analyze the different types of housing on the coast of Bejaia.
- Drawing on the architectural and design elements and strategies that suit this area from each typology to be able to propose a new type of habitat in response to our problem.
- Integrating the bioclimatic dimension in housing with architectural strategies and features
- Develop a housing typology adapted to the coastline of the wilaya of Bejaia, considering the imperatives of sustainability and respect for the local environment, with the aim of promoting sustainable housing in harmony with its ecosystem.

Methodology :

To answer the question posed and verify the hypotheses formulated, two approaches are taken:

The first, purely theoretical, approach consists in grasping the general concepts relating to habitat and coastline and their interrelationship. This is followed by an exploration of bioclimatic architecture, including its principles and strategies. This approach is based on exhaustive bibliographical research, drawing on various sources such as books, scientific articles, thesis, and seminars.

The second approach is experimental, combining techniques designed to assess both the quality and quantity of different types of housing located on the coast of the Bejaia wilaya.

Three evaluation criteria, aligned with the principles of bioclimatic architecture, are defined: the study of natural lighting, the choice of building materials, and the evaluation of natural ventilation within these houses.

For quantitative evaluation, a specific application called "Aftab Alpha" is used. This application specializes in photo processing and generates false color images taken at different times of the day. These images are crucial for validating the use of "DialuxEvo" software in the qualitative study of daylight quality inside homes.

Two other tools are used in this qualitative study: the first is "RWIND" software, dedicated to simulating air flows inside and outside homes; the second is a web interface called "Ubakus", specialized in analyzing the behavior and characteristics of the building materials making up the walls of the homes studied.

These methodologies are used to determine the type of house best suited to the coastal environment of Bejaia.

Thesis structure :

To achieve the desired objectives, this thesis was divided into two parts, divided into four chapters making up the body of the manuscript, in addition to an introductory chapter and a general conclusion.

The first part is purely theoretical, covering the first two chapters devoted to understanding the basic concepts through a literature search.

The second part covers the third and fourth chapters, which deal with the experimental part of the study, the in-situ analysis protocol, the simulation, and the interpretation of the results. The last part covers the final project, from the analysis of the project site to the various related details.

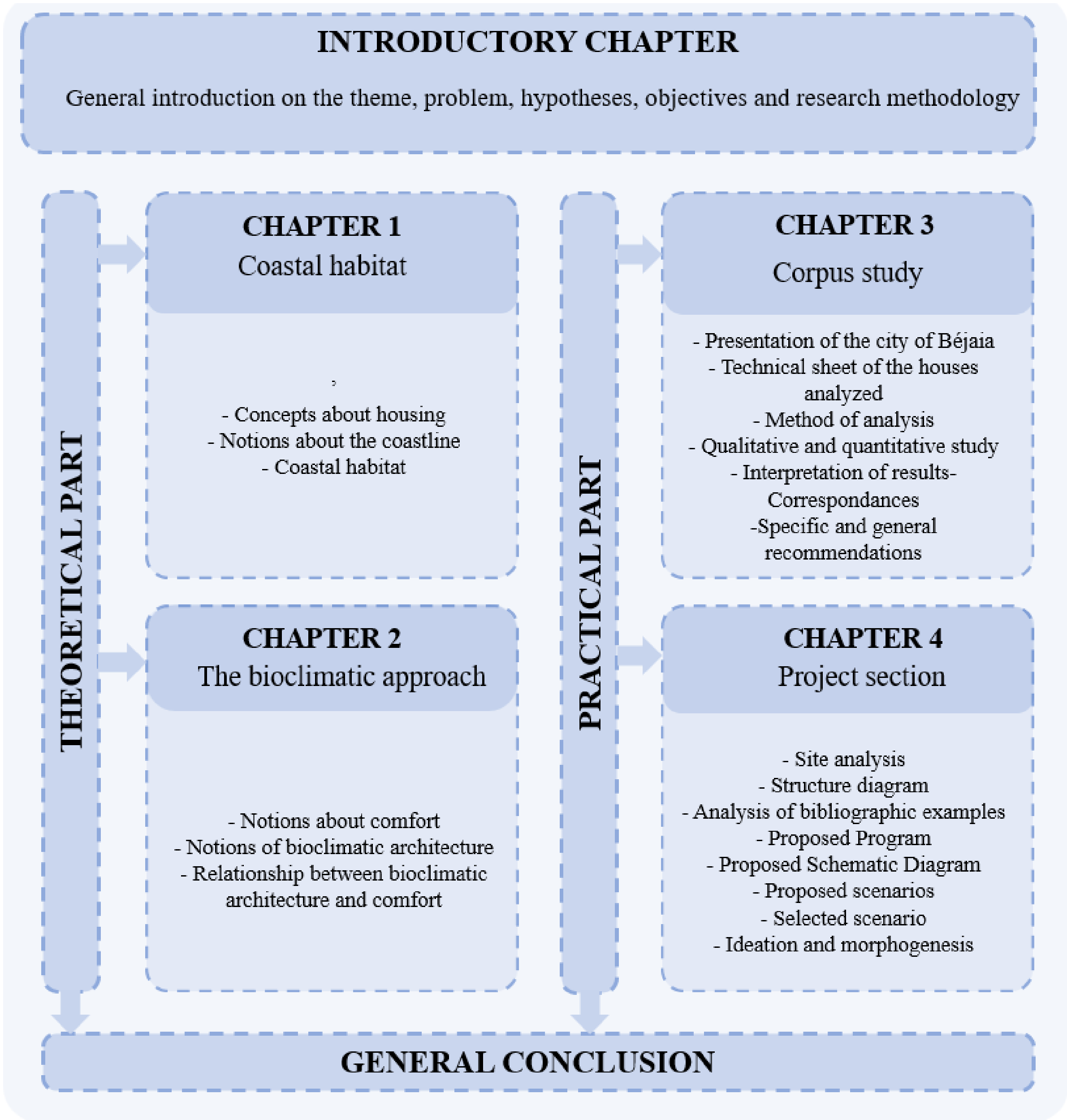


Figure 1 : Thesis structure (Source: Author, 2024)

CHAPTER I

COASTAL HOUSING

Introduction :

Habitat is the physical and social environment where individuals and communities live and interact. It embodies a multitude of complex dimensions encompassing cultural, economic and environmental aspects, making its study a multi-disciplinary approach combining perspectives from urban planning, sociology, economics... and architecture. Architecture and habitat are intimately linked, forming an evolving dialogue between spatial design and human needs, which differ from one individual to another and from one culture to another. A thorough understanding of occupants' habits and needs, while respecting the environment in which they live, is the best way to design built environments that meet the physical, emotional, and social needs of individuals and communities.

This holistic approach to habitat is more crucial when it comes to coastal areas, as interfaces where land and sea elements converge. These coastal regions are distinguished by their intrinsic appeal, their unique landscapes, and their socio-economic dynamics. However, they are not immune to the hazards and threats inherent in this environment, which can give rise to major challenges affecting both urban infrastructures and the health of the people who live there.

In the remainder of this study, we will examine a few concepts relating to Habitat, its history in the word and in Algeria in the first part, then coastline, highlighting the various maritime risks and significant challenges, both natural and man-made, that characterize these essential environments in the second part.

I.1. General information on habitat :

I.1.1. Some preliminary definitions of habitat :

I.1.1.1. Habitat :

From a functional point of view: « the habitat is the whole formed by the dwelling, its external extensions, the equipment and their external extensions, the secondary and tertiary workplaces » (Duplay & Duplay, 1985, p.44).

« Living environment and conditions of a population in general, and in particular the way in which human settlements are grouped together. In an urban environment, the part of a built fabric specifically dedicated to housing the inhabitants » (Merlin & Choay, 1988, p.295).

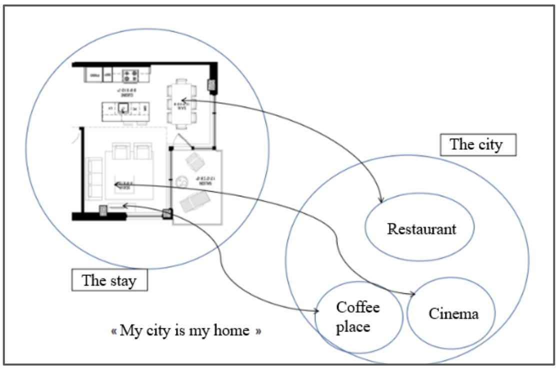


Figure 1.1 : The habitat and its extensions.
(Source: Kezzar, 2020)

I.1.1.2. Inhabiting :

According to Norberg Schulz (1985) « the action of inhabiting consists in knowing one's belonging to a given, concrete place » (p.19).

According to Heidegger (1951) « to dwell means to be at peace in a protected place. It's about the significant relationship that has been established between the corporeal and spatial aspects, and it's more than just housing or residing. » (p.170).

> Inhabiting therefore means being active, acting on the vast space of the world to qualify it and constitute one's dwelling, to enclose it and define its threshold, interior and exterior, to modulate its openness and achieve hospitality. The individual brings out of the surrounding world the elements that will form his dwelling, removing parts of it and bringing others closer. (Saferaty-Garzon, 2003, p.213)

I.1.1.3. The inhabited *:*

According to Kezzar (2020), "inhabited" refers to the space, at its various scales, that is occupied by its inhabitants. It's an adjective meaning: occupied by one or more resident people, e.g. an inhabited house. And it means: that shows a human presence, e.g. an inhabited planet.

I.1.1.4. Housing *:*

According to the Larousse dictionary (n. d.), habitation is "the action of living in, staying in a house or building for a long time, and is therefore the place of habitual residence".

According to Chabane (2023), it is defined according to four strata: domicile, habitation, the living machine, and one’s home.

I.1.1.5. Habitability :

According to the Robert dictionary (n.d.), habitability refers to the quality of what is habitable.

Habitability, according to Adimi (2012), is not simply an analysis of a home's services and amenities in relation to human needs. It is a subjective appreciation of the living environment, judging it to be livable or unlivable, constraining or offering opportunities and freedom of design. This perception is intrinsically linked to our personal expectations, needs and vision of the ideal home.

I.1.1.6. Resident :

According to Ali-khodja (2020), « (the occupant of the living space) refers to a society, a culture, beliefs and a way of representing the world » (p.11).

I.1.1.7. Apartment :

These are the parts of buildings intended for residential occupancy, excluding any profit-making activity (liberal, competitive, or artisanal).

According to Chabane (2023), housing corresponds to the physical unit and spaces that support practices such as cooking, eating, sleeping, washing, etc. It can be individual or collective.

I.1.2 History of housing in the world :

According to Chabane (2023), the history of habitat can be summarized as follows: Habitat has evolved throughout history. In prehistoric times, humans were nomadic, living in natural shelters or huts made of simple materials. In the Neolithic period, agriculture and animal husbandry enabled humans to become sedentary and build larger, more solid house. In Antiquity, Celtic houses were large and had only one room, while Roman houses were more solid and had stories. In the Middle Ages, people lived mainly in the countryside, but towns began to take on greater importance in the 12th century. Houses were larger and sturdier, with carved stone first floors. Castles and fortified houses appeared, built first of wood, then of stone. In modern times, houses were built of stone and roofs were covered with tiles or slate. The houses of the working classes were more solid, but still very rudimentary and uncomfortable. From the 19th century onwards, cities began to expand, and houses were built using new materials such as concrete and steel. In the 21st century, buildings must preserve nature and consume less energy, as in the case of eco-neighborhoods, solar homes...

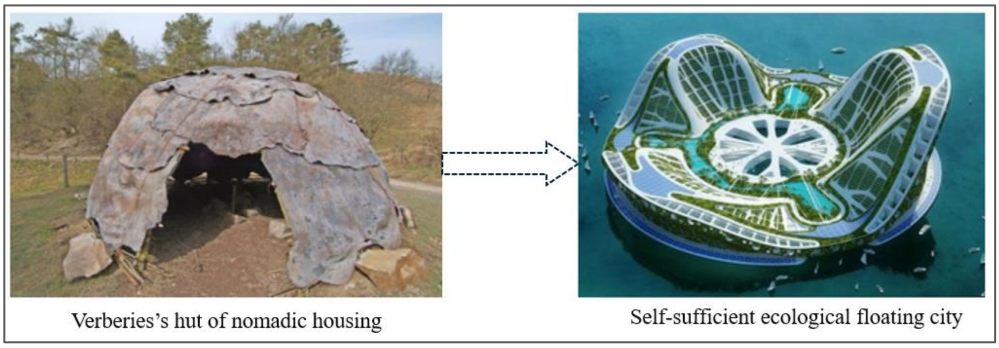


Figure 1.2 : Habitat development over time.
(Source: Chabane, 2023)

I.1.3. Habitat types and typologies

I.1.3.1. Habitat types :

I.1.3.1.1. Single-family housing :

A single-family dwelling where only one family lives; also known as a "single-family home", it can be detached (a single house), or grouped (several single-family houses). (House construction, n.d.)

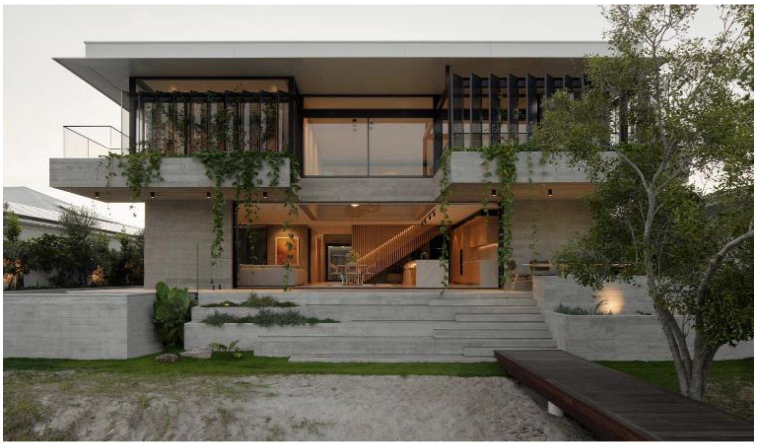


Figure 1.3 : single-family home.
(Source: uni.xyz, 2023)

I.1.3.1.2.Collective housing :

A type of dense, high-rise urban housing in which common spaces such as parking areas, green spaces, stairwells, and elevators are shared by all residents. This type of housing can take a variety of forms, from apartment blocks to residential complexes and housing cooperatives. The aim of collective housing is to encourage community living, reduce costs by sharing certain resources, and maximize the use of available space, particularly in densely populated urban areas.

Figure 1.4 : Group housing (Source: Archdaily, 2023)

I.1.3.1.3. Intermediate housing :

An intermediate form between the single-family home and the apartment building. It's a solution that combines the advantages of individual and collective housing. It consists of a limited number of vertically arranged houses, each with independent access and characterized by the existence of a terrace or private garden. ADEUS (2004) states that "intermediate housing can be grouped into three main types: single-family homes: attached, semi-detached or row houses (this type of intermediate housing is the most common). Small collectives: resulting from the requalification or restructuring of certain buildings, such as renovated farms or barns. Small collectives: low-volume collective housing, townhouses, or urban villas.

Figure 1.5 : Semi-collective housing. (Source: www.caue-observatoire.fr, 2023)

I.1.3.2. Housing typologies :

I.1.3.2.1. Urban housing :

This is the type of housing found in the city, generally multi-story, with the building agglomerated with other buildings.

"It is characterized by high density, and what the city lacks in surface area, it gains in height. (Cavaillès, 1936)

Figure 1.6 : Urban habitat.
(Source: https://www.projetsurbains.com, 2023)

I.1.3.2.2. Suburban and peri-urban housing :

Suburban:

According to Cnrtl (n.d.) suburban is located on the outskirts of, or in the immediate vicinity of, a large city.

Peri-urban:

According to Cavailhès et al. (2003), peri-urban space refers to an area on the outskirts of cities that combines both housing for urban workers and agricultural activities.

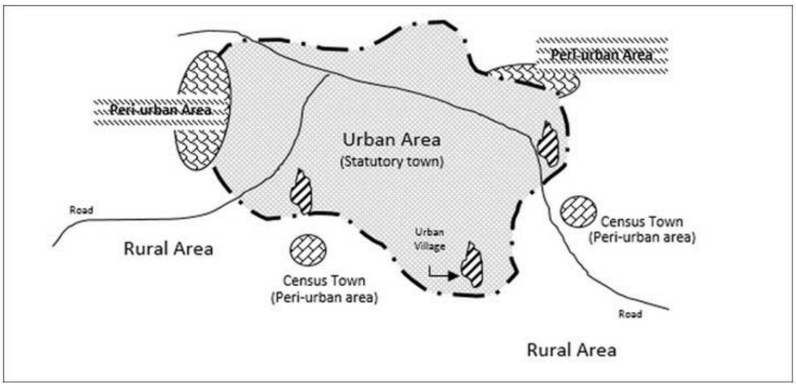


Figure 1.7 : Peri-urban space (Source: Rumi, 2019)

Suburban habitat refers to habitat in relatively densely built-up suburbs (apartment blocks, etc.), especially in the first ring of suburbs around the urban center, while peri-urban habitat refers to habitat in less densely built-up areas (villas, residential areas, semi-rural communes).

Figure 1.8 : Suburban housing.
(Source: https://www.mansionglobal.com, 2023)

I.1.3.2.3. Rural housing

« The countryside is the habitat of those who, grouped or dispersed, occupy only part of the territory allocated to them and live there in small numbers, the rest of this territory being occupied by woods, fields or crops » (Cavaillès, 1936, p.562).

According to the same author, the shape of the dwelling should not be considered as a discriminating factor between rural and urban housing. In fact, many rural houses are tall, attached to other buildings and integrated into a built-up area along a narrow street.

Figure 1.9 : Rural housing.
(Source: https://www.algeriainvest.com, 2023)

I.1.4. Housing in Algeria :

According to Attar (2022), the earliest forms of civilization in Algeria date back a very long time, and traces still exist in the Seffar region, where engravings of primitive man tell of an earlier life. Settlement in Algeria can be divided into three main periods: pre-colonial, colonial, and post-colonial. The first period is characterized by a vernacular habitat of diverse typologies, reflecting the contextual disparities existing in the Algerian territory and the varieties of regional cultures. There were three distinct geographical contexts corresponding to three typologies: vernacular houses in the north, in the highlands and in arid and semi-arid zones. The second period is marked by the arrival of the French, socio-spatial deconstruction, and the creation of colonial villages. Towns in Algeria during the French colonial period were essentially built up in two ways: the creation of colonial centers and perimeters, and the extension of existing towns through the partial or total destruction of medinas. The third period was characterized by planning in Algeria through various three-, four- and five-year plans, as well as the adoption of an urban social housing policy through the creation of the Ministry of Housing and Construction in 1977. Despite all these established programs, Algeria still suffers from an endless housing deficit.

I.2. General information on the coast:

I.2.1. Definitions :

I.2.1.1. The coast :

According to the Larousse dictionary (n.d.), the coastline means a sinuous zone where the sea or a lake comes into contact with the land.

Veyret and Laganier (2017) argue that the coastline is not simply a line, but rather a space that varies in width, representing the contact between land and sea, and whose width depends on the characteristics of the continental relief.

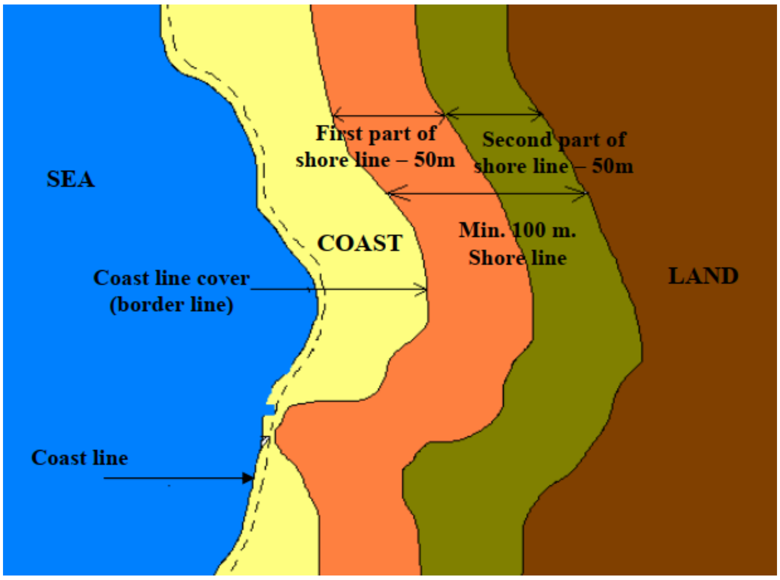


Figure 1.10 : Coastal space.
(Source: Sesli et al, 2002)

I.2.1.2. A coastal town *:*

Coastal cities are located at the interface or in transition zones between land and sea. These are cities that develop along the coast, generally characterized by industrial and tourist activity and a high concentration of population.

Figure 1.11 : Bejaia coastline.
(Source: https://www.wallpaperflare.com, 2023)

I.2.2. Hazards and risks :

- Hazard: According to ENS Lyon (n.d.), hazard is a phenomenon resulting from factors or processes that are at least partly beyond human control: flood, cyclone, landslide, volcanic eruption, earthquake, tsunami…

- Risk: according to Larousse (n. d.), risk is the possibility, probability of a fact, of an event considered as an evil or a damage.

When human, economic and environmental issues are vulnerable, the hazard becomes a risk (ENS de Lyon, n. d.).

I.2.2.1. Marine hazards :

I.2.2.1.1. Prevailing winds :

A prevailing wind is a surface wind that blows mainly from the same direction. (Let's Talk Science, n.d.)

« The speed of the air depends mainly on the site of implantation, in an urban environment the air is slowed down by the density of the built environment, Unlike in a suburb the air reaches maximum speeds at reduced heights » (Yahiaoui, 2019, p.11).

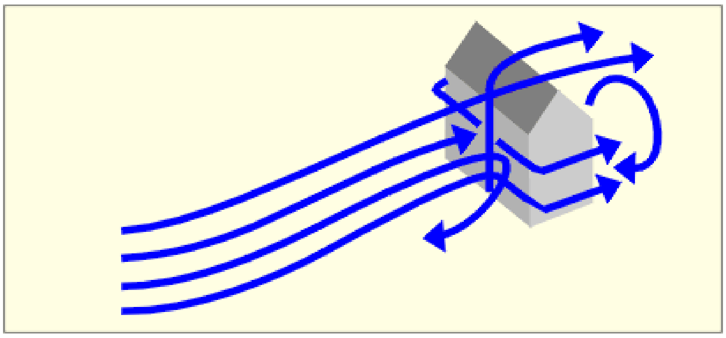


Figure 1.12 : Wind effects on the house.
(Source: https://energieplus-lesite.be, 2023)

I.2.2.1.2. Humidity :

Humidity measures the quantity of water vapor present in the air. Relative humidity, on the other hand, represents the percentage of water in the air in relation to the maximum amount of water vapor the air can contain at a given temperature. The higher the temperature, the more water vapor the air can hold.

According to the WHO (2009), humidity affects both the condition of buildings and human health, and the most significant health effects observed are an increase in the occurrence of respiratory symptoms, allergies and asthma, as well as disturbances to the immune system.

Figure 1.13 : Effect of humidity on walls.
(Source: https://dampproofingbournemouth.com, 2023)

I.2.2.1.3. Coastal erosion :

Coastal erosion is the process by which coasts retreat due to the action of the sea.

According to Rios Rodriguez (2019), this is the retreat of the coastline, coastline, and land, which was originally caused by natural factors, has gradually become a consequence of human activities.

Figure 1.14 : effect of coastal erosion.
(Source: https://medium.com, 2023)

I.2.2.1.4. Sea spray :

According to the Robert dictionary (n.d.), it is a dust of droplets formed by breaking waves and carried by the wind.

Also known as salt fog, it causes the corrosion of metal objects near the coast, due to the acceleration of the corrosion process by salts in the presence of abundant oxygen and humidity in the atmosphere (Aquaportail, n.d.).

Figure 1.15 : effect of salt spray
(Source: https://corksoluk.com, 2023)

I.2.2.1.4. The tide :

According to Geo (n. d.), it refers to the upward and downward movement of oceans and seas. It is the result of the attraction of the moon and sun on the sea, but also of the earth's rotation, which generates a centrifugal force that can cause sea water to penetrate land.

Figure 1.16 : Tidal effect.
(Source: imgur.com, 2023)

I.2.2.1.5. Tsunamis :

According to the Larousse dictionary (n.d.), tsunamis are tidal waves of telluric origin, caused by a sudden instability of the ocean floor resulting from an earthquake, volcanic eruption, or landslide. The resulting waves are extremely deadly.

Figure 1.17 : tsunami.
(Source: i.pinimg.com, 2023)

I.2.2.2. Human threats :

In addition to natural factors, human activities have a significant impact on coastal evolution. Global warming is causing oceans to expand and glaciers to melt, exacerbating coastal erosion. In addition, urbanization, tourism, industrial pollution, and plastic waste all contribute to damaging coastal ecosystems.

I.2.3. The Algerian coast :

Algeria's 1,200-kilometer coastline includes the country's largest cities. This region is one of the country's most popular tourist destinations, stretching from Algiers la blanche to Oran via Annaba and the wild creeks of Kabylia. It attracts hikers, swimmers, fishermen and water sports enthusiasts. Despite the tourist activity, preserving the marine flora and fauna is a priority. MTA (n. d.)

According to Kacemi (2023), Algeria's coastline, rich in tourism assets, is threatened by population concentration, economic activities, and urbanization. Unlike other Mediterranean countries, Algeria has not accorded tourism a major role in its development policies, and there is no sustainable tourism management policy, even though Zones d'Expansion Touristiques (ZET) were created in 1966. Unfortunately, most of these zones have been diverted from their original purpose for real estate projects.

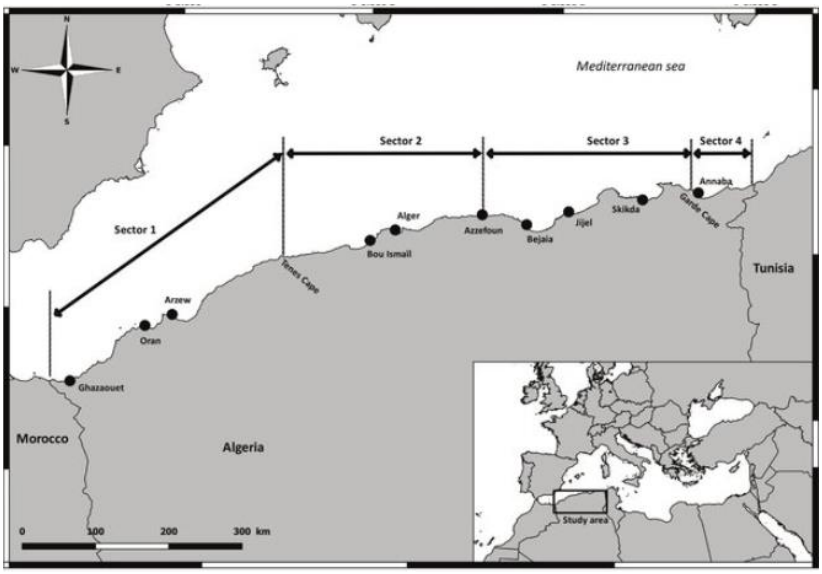


Figure 1.18 : Algerian coastline (Source: Bakalem et al, 2020)

I.2.3.1 Laws and regulations governing construction on the coast :

- Law 02-02 of 05-02-2002 on the protection and enhancement of the coastline:

Meghfour and Tabet (2007), announce that the law in question represents a significant step forward in recognizing the naturalistic dimension of coastal spaces and rejecting the traditional conception of development as a simple expansion of infrastructure. Rather than strictly defining coastal development, it emphasizes the importance of protection and enhancement for sustainable development. The legislation delineates three coastal strips with specific restrictions on urban development.

The first strip, which is unbuildable up to 100 meters from the shore, can be extended up to 300 meters to take account of the sensitivity of the coastal environment.

The second strip, 800 meters wide, prohibits new carriageways running parallel to the shoreline, with certain exceptions.

The third strip, 3 km wide, prohibits any extension of urban development parallel to the shoreline, as well as the extension of two adjacent built-up areas at a distance of less than 5 km. In addition, construction and land use in this strip are regulated according to the economic activities authorized by the urban planning instruments.

The authors add that it is important to note that many provisions of this law still require further development and clarification.

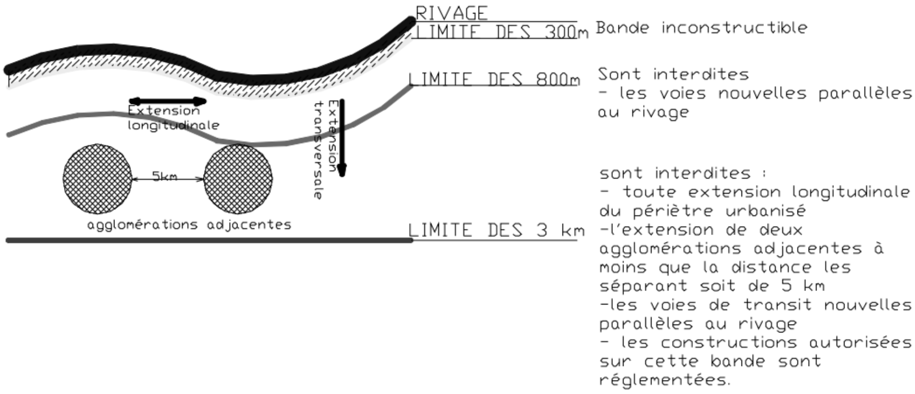


Figure 1.19 : Bands defined by law (Source: Meghfour, 2007)

I.3. Integration of housing into the coastal environment :

Far from the urban aspect of the coastal environment, construction in this environment must take account of its characteristics in order to ensure sustainability as well as the health and comfort of occupants. This is achieved by identifying the characteristics of this environment through :

- The harmonious integration of buildings into the coastal landscape, by choosing materials and colors that blend naturally into the environment.
- Proper orientation of buildings to promote natural ventilation thanks to sea breezes, and to maximize the use of natural light, thus reducing dependence on electricity and ensuring occupant comfort.
- Use corrosion- and weather-resistant materials, or apply protective coatings to prevent damage from salt, wind, and moisture.
- Raising buildings to reduce tidal and flood risks.
- The adoption of water recovery technologies, solar panels, wind turbines and other renewable energy solutions.
- The use of vegetation as a means of solar protection and wind modulation.

By respecting these architectural principles, it is possible to design sustainable structures that respect their local environment, while meeting the needs and comfort of their occupants.

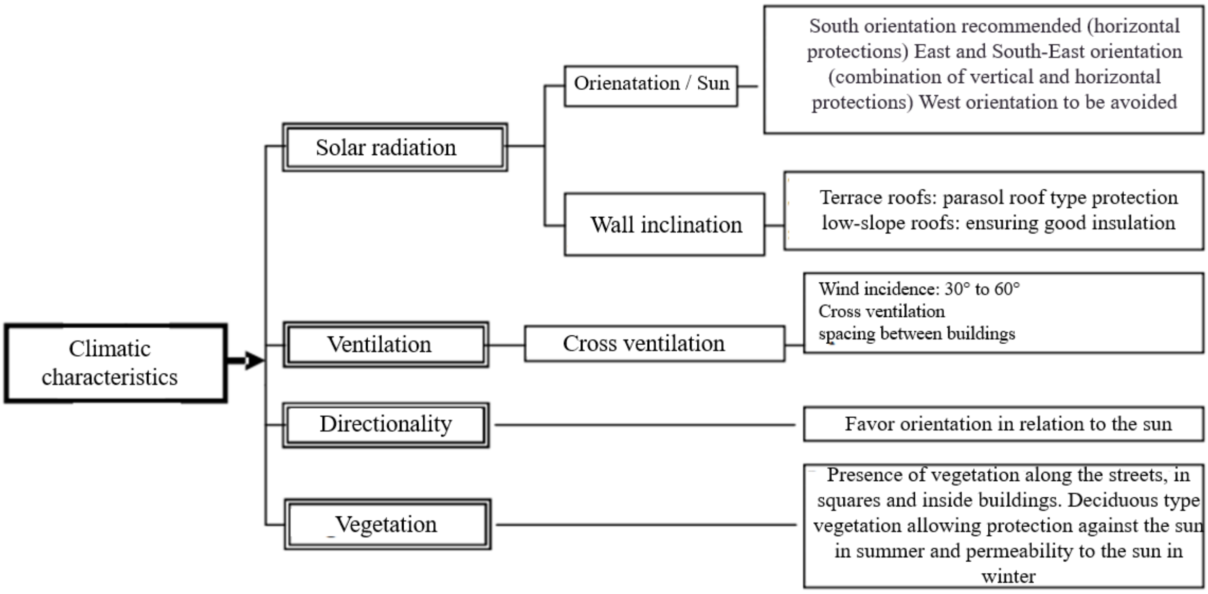


Figure 1.20 : Actions to be taken for coastal construction (Source: Meghfour, 2007)

Conclusion :

The concept of habitat transcends the simple notion of housing to encompass all the spaces and trajectories that shape our daily urban lives. As Barou (2005) eloquently put it:

> I do live in this three-room apartment block, but my real habitat embraces more than that, it includes the stairwell and elevator, the entrance hall, the bicycle room, the immediate surroundings of the building, the pathway leading to the street, the neighboring streets that serve the RER station, the school, the bakery, the public garden.... (Barou, 2005, p.53)

In a similar way, the coastline is a territory with a dual nature, where prospects for prosperity and imminent peril exist side by side. On the one hand, it represents a veritable nursery of wealth, home to a diversity of flourishing ecosystems, offering enchanting panoramas to coastal residents and constituting a breeding ground for economic opportunities through trade and tourism. However, these benefits are perpetually under siege from threats of considerable gravity, whether of natural origin, such as maritime hazards affecting the health of coastal populations and the stability of their houses, or of anthropogenic origin, characterized by human selfishness and anarchic urbanization, which jeopardize both the sustainability of the coastline and the integrity of its ecosystems, as well as the safety and durability of coastal constructions.

CHAPTER II

BIOCLIMATIC APPROACH

Introduction :

Architecture is profoundly influenced by local climatic conditions, an inherent parameter that shapes building design. The diversity of weather conditions, such as humidity, precipitation and sunshine, represents a challenge for architects, who must integrate them into their design process to ensure the success of their architectural creations and the comfort and well-being of their occupants.

In this context, bioclimatic architecture is emerging as a fundamental approach that recognizes and cultivates a close symbiosis between the building, its occupants and the natural environment. This method aims to optimize energy performance while enhancing thermal, visual, and sensory comfort.

This chapter discusses the different facets of comfort and bioclimatic architecture, as well as its key strategies for designing a climate-integrated building.

II.1 The bioclimatic approach :

According to Potvin and Demers (2003), Bioclimatology is defined as the science that studies the influence of climatic factors on living beings.

Victor Olgyay (1963), defines the bioclimatic approach as the interrelation between climatology, biology, technology and architecture; where climatology refers to the energetic exploitation of sun and wind, biology to the satisfaction of human physiological needs, technology to the control of the environment and finally architecture as the point of convergence of different fields to create a unique object that uses the art of construction by adapting to local environmental, social and economic constraints.

II.1.2. Definition of bioclimatic architecture :

Referred to as climatic or natural architecture, this approach involves erecting buildings in harmony with their environment. The aim is to create buildings that take advantage of advantageous climatic conditions (such as sunshine in winter and coolness in summer) while protecting themselves from harmful influences.

According to Chesné (2012), architecture that takes the environment into account, focusing on the use of materials, greenhouse gas emissions and waste and water management, is called ecological, sustainable, or green architecture. If it is based on the use of energy resources, particularly the sun, it is called solar or passive architecture.

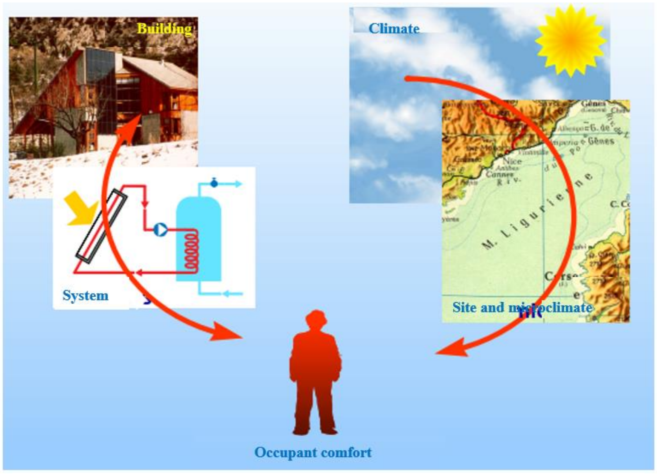


Figure 2.1 : The occupant at the heart of bioclimatic architecture.
(Source: Liébard and De Herde, 2005)

II.1.3.Historical background :

According to Gaillard (2022), bioclimatic architecture developed in the second half of the last century, with the aim of integrating the climatic qualities of an environment, but the "bioclimatic" concept did not originate in architecture, nor was it created by Olgyay, But the concept of "bioclimatic" did not originate in architecture, nor was it created by Olgyay, who took up the bioclimatic study of comfort developed by physiologists, stemming from research into microclimalogy and agriculture initiated by Andrew Hopkins, and that bioclimatic design over the course of its development was reduced to a simple application of principles aimed at achieving energy savings, neglecting its multidisciplinary roots.

II.1.4. Classification :

II.1.4.1. Passive architecture : this is based on a design that favors solar capture, and that the distribution of interior spaces considers the heat requirements of each space according to the activity taking place.

II.1.4.2. Active architecture : based on the use of technological means, the cost is higher, i.e. sophisticated heating is used, regardless of the sun. These technologies require the use of non-renewable energies,

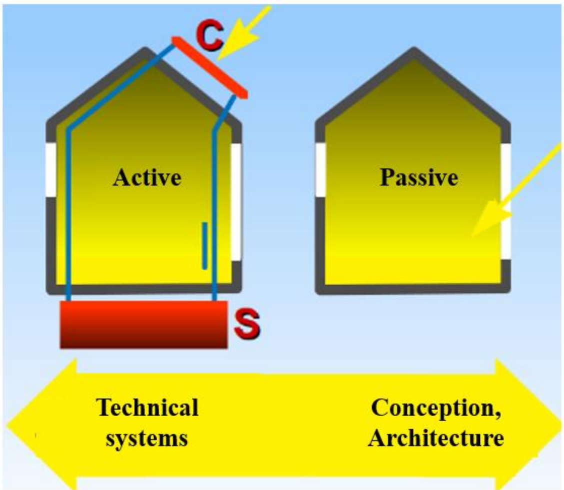


Figure 2.2 : Passive and active systems
(Source: Liébard and De Herde, 2005)

II.1.5. The objectives of bioclimatic architecture :

Chesné (2012) observes that the essence of this approach lies in designing buildings in a "natural" way, which means integrating them fully into their environment. Bioclimatic buildings must therefore take into account the topography of the land, the surrounding vegetation, and the path of the sun throughout the day. As a result, their primary objective is to ensure occupant comfort by making them contextually efficient, while minimizing energy consumption and negative environmental impact.

II.1.6. The principles of bioclimatic architecture :

II.1.6.1. The layout *:*

The way in which the building is placed on the site is called layout.

Herde and Liébard (2005) state that judicious building layout is the architect's most important task, given its importance in determining light levels, ventilation possibilities, solar gain...

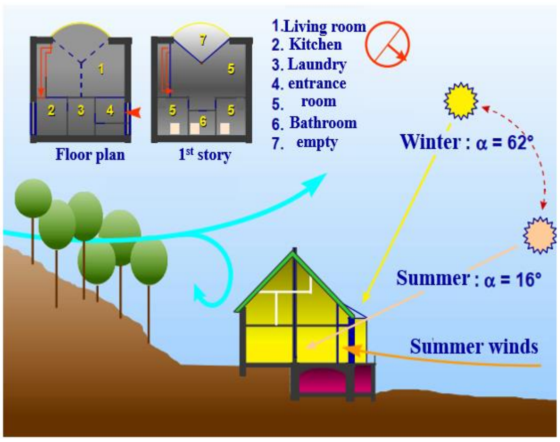


Figure 2.3 : effect of house layout
(Source: Liébard and De Herde, 2005)

Khadraoui (2019) says that "in-depth analysis of the siting area, whether exposed or protected, natural or urban, is necessary to determine the potential and problems (advantages and disadvantages) in order to arrive at a design that is in harmony with its environment and meets the needs of the occupant".

The relief and characteristics of the terrain (direction of slope, type of soil, etc.), the path of the sun, prevailing winds, the presence and type of vegetation and the context (natural, urban) are all factors to be considered when siting the building.

II.6.2. Orientation :

The orientation of a building in architecture implies its arrangement in relation to the four cardinal points.

Herde and Liébard (2005) see that the need for natural light, solar heating and protection against overheating are key considerations, and each orientation has its own specific characteristics: for example, the north offers even light all year round, while the east captures the morning sun with low rays...

II.6.3. Openings :

According to Herde and Liébard (2005), contact between the interior of the building and the environment is established through openings, heat exchange, heat loss (they have a higher heat loss coefficient K than insulated walls), solar gain and heat gain from openings. And during the design phase, the inclination, orientation, and distribution of openings must be considered, as well as any fixed protective elements (awnings, sunshades, roof overhangs, etc.) that provide protection from intense sunlight in summer.

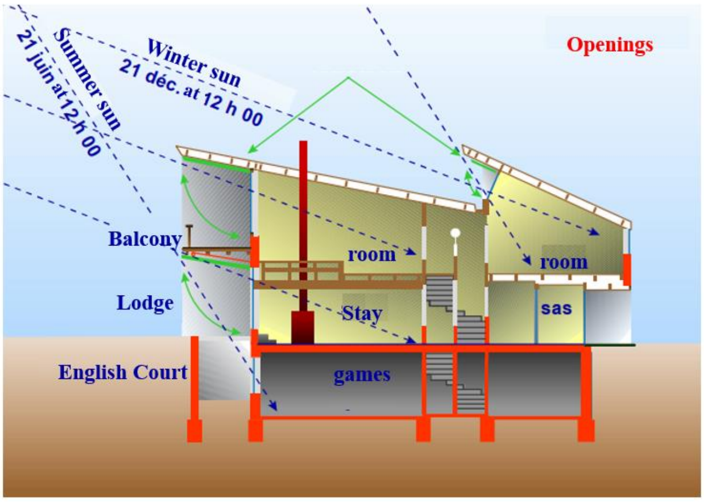


Figure 2.4 : layout of openings in the house
(Source: Liébard and De Herde, 2005)

II.6.4. The shape of the building :

The shape of buildings influences their energy performance. A low shape coefficient indicates high compactness, reducing heat exchange with the exterior. Spherical shapes are often considered optimal. Size and mode of contact, as in terraced houses, can also affect compactness. By reducing wasted surfaces, compact buildings can improve energy efficiency.

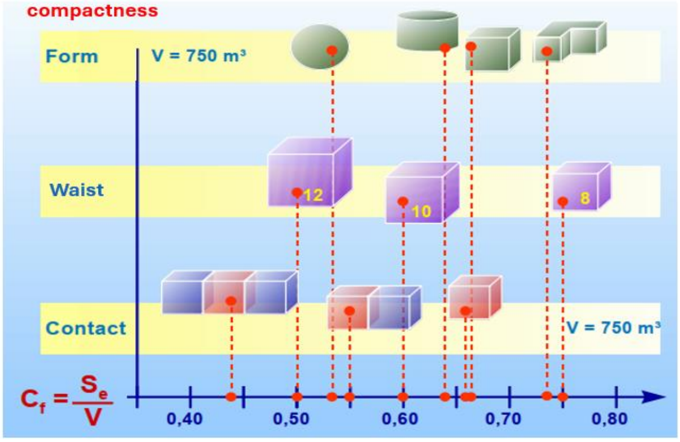


Figure 2.5 : Coefficient of the form.
(Source: Liébard and De Herde, 2005)

II.6.5. Interior distribution of spaces :

Space zoning consists of dividing a space into different zones, each with its own thermal ambience. Zones are prioritized according to their orientation in relation to the points of the compass, to make the most of solar gain and protect against excessive heat or cold. Buffer zones such as the garage to the north protect from the cold, while verandas to the south capture the sun's heat to warm the interior. The aim is to create a comfortable microclimate in each zone according to its use, thanks to intelligent bioclimatic design.

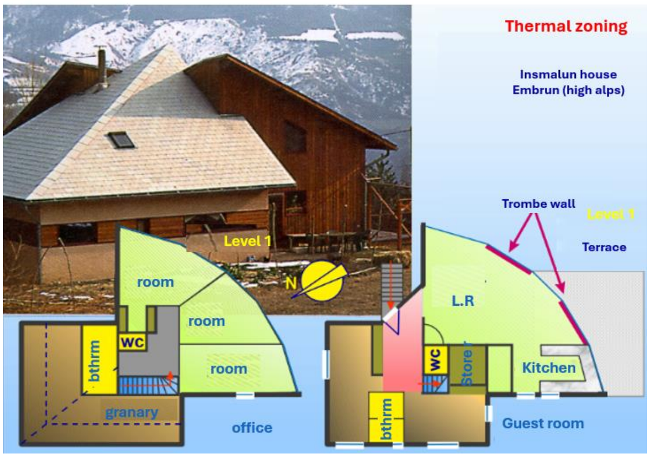


Figure 2.6 : Thermal zoning
(Source: Liébard and De Herde, 2005)

II.6.6. Sun protection :

According to Herde & Liébard (2005), solar shading has several roles: limiting glare, reducing overheating, increasing window insulation, and providing privacy and decoration. There are two main types: those positioned inside, outside or in the glazing, and those that are mobile or fixed. The mobile ones adapt to the sun and occupants, while the fixed ones offer a constant degree of protection. Solar shading devices include vegetation, roof overhangs, sunshades, louvers, Venetian blinds, awnings, and protective glazing. The choice of type depends on orientation, desired contact with the outside world and cost.

Figure 2.7 : Solar protection elements
(Source: Liébard and De Herde, 2005)

II.6.7. suitable materials (thermal inertia) :

The use of building materials depends on several parameters, such as thermal properties (conductivity and resistance), requirements, building type, construction systems and climatic properties.

"Bioclimatic construction implies the use of locally available materials for a variety of reasons, such as low extraction costs and avoidance of transport (cost and gas emissions). The search for materials with lower environmental impact will undoubtedly guide the development of local materials such as wood, stone, earth and clay." (Khadraoui, 2019)

II.6.8. Thermal insulation :

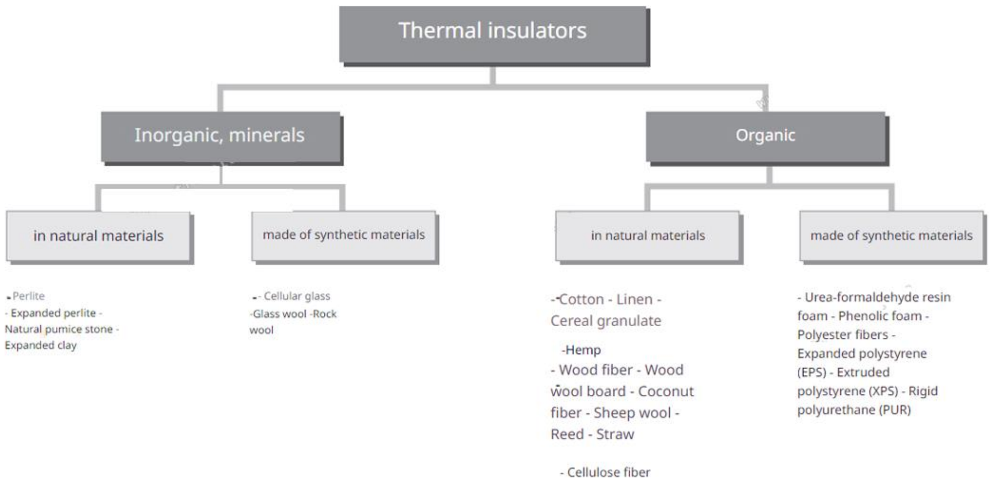


Figure 2.8 : Thermal insulation (Source: Sy, 2023)

Thermal insulation ensures comfort by limiting heat transfer with the outside world. It retains heat in cold weather and keeps you cool in hot weather. According to Herde & Liébard (2005), thermal insulation can be installed in the wall in various ways (external insulation, sandwich insulation, internal insulation) without affecting the wall's insulation quality. However, the inertia of the wall changes according to its position. Thermal conductivity expresses a material's insulating capacity.

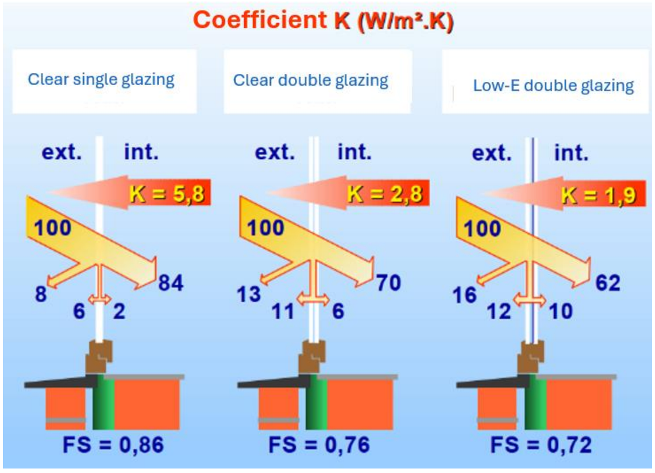


Figure 2.9 : Thermal performance and glazing types (Source: Liébard and De Herde, 2005)

Insulators come in different types, which can be grouped according to insulating material and shape:

- **insulating materials:**
  - Mineral wool: e.g. glass wool, rock wool, cellular wool.
  - Ecological insulation: wood wool, cellulose wadding, sheep's wool.
  - Synthetic insulation: polyurethane (PUR), expanded polystyrene (EPS)...
- **the shape :**
  - Insulating rolls: flexible and easy to work and cut.
  - Rigid insulating boards: offer better thermal insulation than insulating rolls.
  - Sprayed insulation: applied directly to the surface to be insulated, in liquid form that dries quickly.
  - Loose-fill insulation: granules, balls or flakes in bags. It can be machine-blown to cover flat surfaces or applied directly with adhesive to bond to inclined surfaces. (Isolation Expert, n. d.).

II.7. Bioclimatic architecture strategies :

Bioclimatic architecture involves a wide range of strategies, techniques and simple building systems for heating, cooling, ventilating, etc. the interior of a building. These techniques generally use standard know-how and materials, and low-tech systems, although increasingly, the development of certain systems uses electronics to be controlled and managed automatically.

II.7.1. The warm (winter) strategy *:*

Liébard and De Herde (2005), said that during cold spells, this strategy involves capturing heat from solar radiation, storing it in the mass of building materials, conserving it through insulation and finally distributing it throughout the building.

II.7.1.1. Capture solar energy: capturing the heat of solar radiation, which is received by a building, requires careful study of its orientation, materials and surfaces, inclinations, topography, shading, etc.

II.7.1.2. Storing : According to Khadraoui (2019), storing solar energy until it is needed. To do this, we need to master the thermal inertia of absorbing materials.

II.7.1.3. Preserve : all heat (from sunlight, internal contributions, heating) is preserved by considering the use of thermal insulation, the compactness of the volume and the use of buffer spaces.

II.7.1.4. Distribute : According to Liébard and De Herde (2005), heat distribution in the building, either naturally, when the heat accumulated in a material during the period of sunshine is returned to the ambient air by radiation and convection, by thermocirculation (migration of warm air masses naturally upwards) or by forced ventilation. It is therefore essential to ensure a perfect distribution of different spaces and levels.

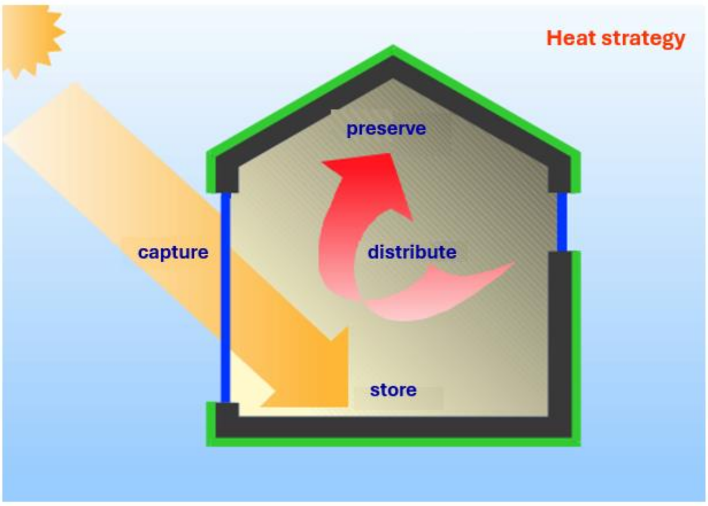


Figure 2.10 : Hot strategy.
(Source: Liébard and De Herde, 2005)

II.7.2. The cold strategy (summer) *:*

Liébard and De Herde (2005), said that during the warm season, this strategy consists of protecting the home from solar radiation and heat inputs, minimizing internal inputs, dissipating excess heat and then cooling naturally.

II.7.2.1. Protect : the building and its openings in particular must be protected from direct sunlight, in order to limit direct gains and this through the study of the orientation, inclination and protection of openings and the use of shading devices through screens that can be permanent, removable, or seasonal (vegetation).

II.7.2.2. Minimize internal gains : minimize internal gains due to occupants and equipment (artificial lighting, electrical equipment, density of occupants, etc.) and favor natural light, for example.

II.7.2.3. Dissipate overheating (ventilation) : through ventilation, vertical evacuation through chimneys and special cooling devices. 2

II.7.2.4. Cooling the premises : cooling is achieved either by ventilation (especially at night, to remove the heat stored in the materials during the day), or by increasing the air volume, or through natural devices such as the use of water basins, vegetation, Canadian wells, etc.

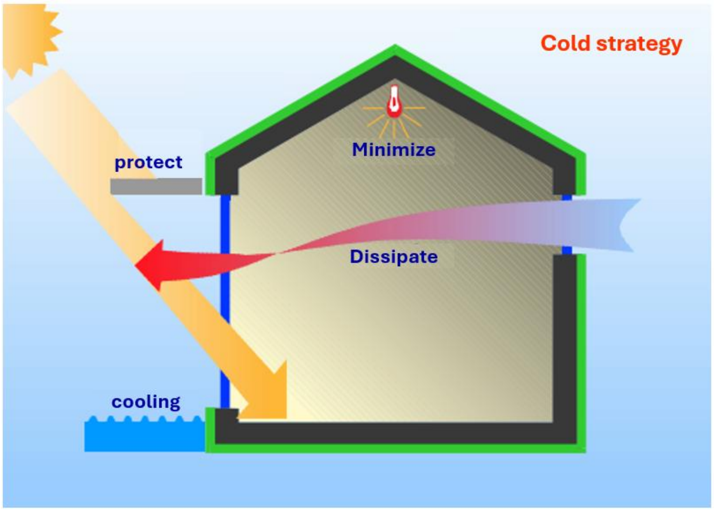


Figure 2.11 : Cold strategy.
(Source: Liébard and De Herde, 2005)

II.7.3. Daylighting strategies *:*

According to Liébard and De Herde (2005), this strategy involves capturing solar radiation, letting in natural light, distributing it evenly throughout interior spaces and controlling it to avoid visual discomfort.

II.7.3.1. Capture : Capture through the glazed surface, where parameters such as surface roughness, type of glazed wall, thickness and state of cleanliness, the nature of surfaces in the external environment influence the quantity of light captured.

II.7.3.2. Penetration : light penetration into buildings depends on external conditions (type of sky, season, time of day, site clearance, etc.) and location, orientation, inclination, size, type of glazing, etc.

II.7.3.3. Distribution : consider the presence or absence of obstacles due to room geometry or furniture, the properties of surfaces and coatings, the type of glazing and diffusion devices such as reflectors.

II.7.3.4. Protecting and controlling : the aim of protection and control is to avoid visual disturbance by means of fixed (e.g. roof overhangs, awnings, light shelves, moucharabiehs) or movable (e.g. shutters, louvers, or blinds) sun protection from herde 2005.

[2]**II.7.3.5. Focusing** : through zenithal or lateral lighting to highlight a particular object or place (creating a luminous contrast with ambient lighting, which is less powerful). Example of an atrium in the center of a building, allowing daylight to penetrate while creating an attractive space for circulation and rest

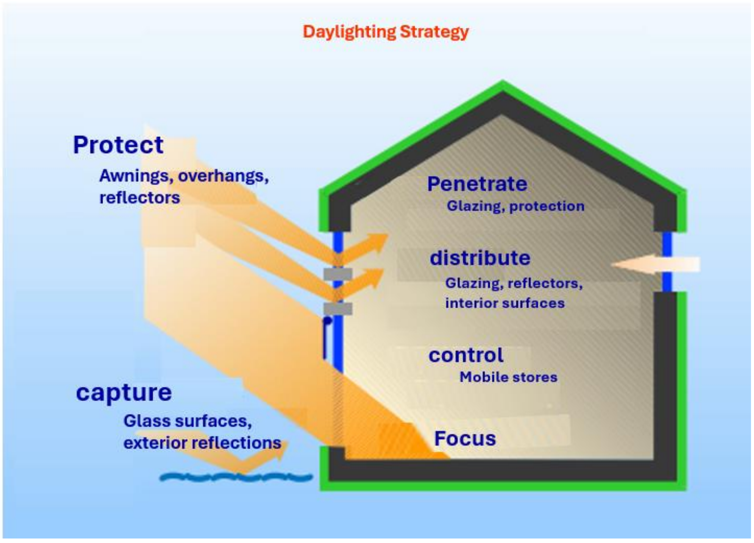


Figure 2.12 : Daylighting strategy.
(Source: Liébard and De Herde, 2005)

II.7.4. Natural ventilation strategies *:*

Ventilation conditions inside a building are among the main factors determining human health, comfort and well-being. They have a direct effect on the human body through the physical effects of air purity and movement, and an indirect effect through their influence on the temperature and humidity of air and interior surfaces. (Givoni, 1969, p.230)

As announced by Energieplus (n.d.), all-natural ventilation uses wind pressure and temperature differences between indoors and outdoors to move air, without the need for electricity, offering an economical, environmentally friendly, and low-maintenance solution, free from noisy fans.

According to Ferradji (2018), ventilation renews indoor air by evacuating stale air and replacing it with fresh air. It contributes to the durability of buildings by eliminating humidity, a source of deterioration, and promoting coolness in summer for greater comfort. However, to optimize its operation, flow rates must be modulated: minimize daytime ventilation in summer when temperatures are high and favor night-time ventilation. Similarly, in winter, it's advisable to reduce flow rates to limit heat loss.

II.7.4.1. Single facade ventilation :

Air enters from one opening and exits from the same or another in the same façade.

According to Dutreix (2010), to ensure the effectiveness of this ventilation strategy, the surface area of openings should represent around 5% of the room's floor area. In addition, vents must be at least 1.5 m high, and the room depth must be 2.5 times the ceiling height.

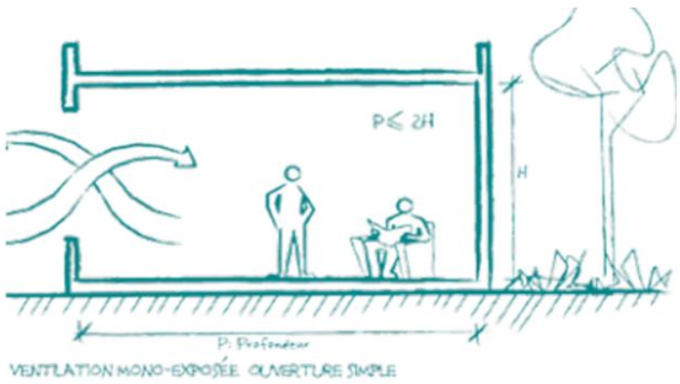


Figure 2.13 : Ventilation from a single facade
(Source: conseils.xpair.com, 2023)

II.7.4.2. Cross ventilation :

According to Givoni (1969), cross ventilation is considered the most effective strategy for natural ventilation. It involves creating a flow of air through the building, by placing openings on two opposite façades. One opening is located on the side where the air exerts a positive pressure (overpressure zone), while the other opening is on the side where the air exerts a negative pressure (under pressure zone). The pressure differential between these two zones generates a flow of air through the building.

According to Ferradji (2018), this type of ventilation is conditioned by wind speed, which varies according to local climate and the presence of obstacles inside the space to be ventilated. Despite its advantages, it's important to consider disadvantages such as annoying draughts and heat loss in winter. Cross ventilation is optimal when the air flow changes direction within the space, moving between the inlet and outlet.

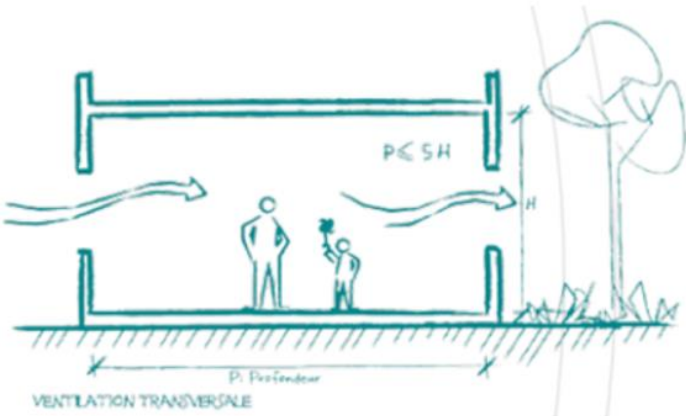


Figure 2.14 : Through-ventilation.
(Source: conseils.xpair.com, 2023)

II.7.4.3. Thermal draft (chimney effect) :

Natural ventilation is based on the phenomenon of thermal convection, where warm air tends to rise while cold air descends. In practice, this means that warm air is evacuated through a high outlet in damp rooms such as bathrooms and kitchens, creating a low-pressure zone. To compensate for this evacuation, fresh air enters through an inlet at the bottom of the main rooms, allowing outside air to circulate through the dwelling and ensuring constant air renewal. This natural ventilation mechanism is particularly effective in summer, especially at night, as buildings often maintain a temperature difference of at least 10°C between inside and outside due to their thermal inertia. This disparity creates a sufficient draught effect to promote air circulation and thus contribute to natural indoor cooling. Natural ventilation is based on the phenomenon of thermal convection, where warm air tends to rise while cold air descends. In practice, this means that warm air is evacuated through a high outlet in damp rooms such as bathrooms and kitchens, creating a low-pressure zone. To compensate for this evacuation, fresh air enters through an inlet at the bottom of the main rooms, allowing outside air to circulate through the dwelling and ensuring constant air renewal. This natural ventilation mechanism is particularly effective in summer, especially at night, as buildings often maintain a temperature difference of at least 10°C between inside and outside due to their thermal inertia. This disparity creates a sufficient draught effect to promote air circulation and thus contribute to natural indoor cooling.

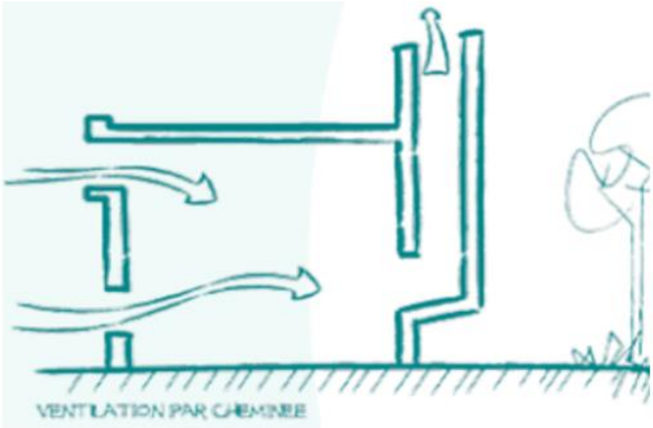


Figure 2.15 : Chimney effect ventilation (Source: conseils.xpair.com, 2023)

II.2.2. Resident comfort :

II.2.2.1. Definition of comfort :

According to Larousse (n. d.), comfort is defined as a set of conveniences producing psychological, intellectual, and moral well-being and tranquility, achieved by the rejection of all preoccupations.

According to Salmi (2019), comfort in the home will be perceived through the senses such as the sensation of cold or heat, the olfactory sense, hearing, the eye, or vision (colors, equipment visually aggressive or not, ...).

In architecture, we distinguish between visual comfort, hygrothermal comfort, acoustic comfort, olfactory comfort, and functional comfort.

II.2.2.2. Types of comfort :

II.2.2.2.1. Thermal comfort *:*

Thermal comfort is a feeling of physical well-being resulting from a combination of multiple parameters and factors related to the building, climate and users.

Thermal comfort is the balance between heat exchange between the human body and the surrounding givoni environment.

« It is determined by the equilibrium established by heat exchange between the body and its environment » (Herde & Liébard, 2005, p.32).

In humans, this comfort depends on six parameters: linked to the individual: metabolism; linked to the environment: ambient air and wall temperature, relative air humidity and air velocity.

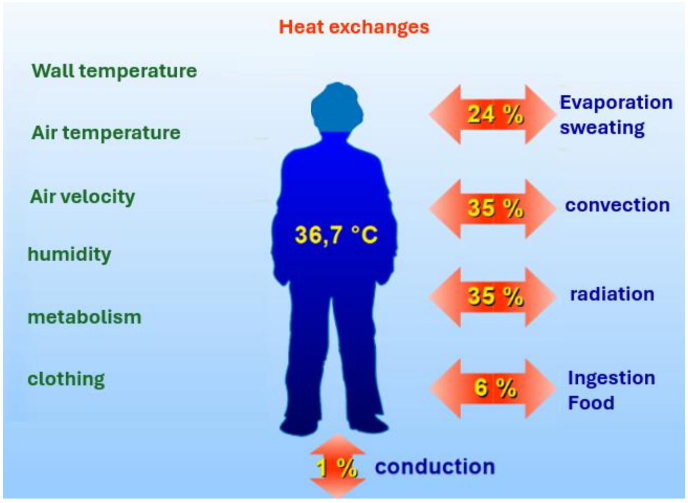


Figure 2.16 : Heat exchange between individuals and their environment.
(Source: Liébard and De Herde, 2005)

II.2.2.2.2. Visual comfort *:*

Visual comfort is a subjective impression linked to the quantity, distribution, and quality of light. The visual environment enables us to see objects clearly in a pleasantly colored atmosphere without feeling tired, thus creating a feeling of comfort, as discussed by Catholic University of Louvain, (n. d.).

II.3. The relationship between bioclimatic architecture and comfort :

Bioclimatic architecture establishes a harmonious relationship between the building and its natural environment, optimizing thermal and visual comfort for occupants. It makes clever use of local renewable resources such as sun, wind, and water. One of the main objectives is to maintain satisfactory indoor thermal comfort without using energy-hungry air conditioning. This is achieved through high-performance insulation, orientation to allow solar gain in winter and protection in summer, and efficient natural cross-ventilation. Maximizing natural lighting while properly managing cast shadows is also a priority for visual comfort. Using local, healthy, and sustainable materials also contributes to user well-being.

It creates stimulating, aesthetically pleasing interior spaces adapted to the climate and human physiological needs, while preserving natural resources. The design of the building envelope aims to capture, store, and redistribute locally available renewable energies to reduce energy requirements for heating and cooling.

II.4. Algeria's climate :

The World Meteorological Organization (WMO, 2020) defines climate as average weather conditions over an extended period, usually 30 years or more, encompassing parameters such as temperature, precipitation, humidity, winds, and extreme weather events.

Cubasch et al. (2013) say that various factors, such as latitude, altitude, proximity of water masses, ocean currents and major atmospheric systems, influence climate. In addition, human activities, notably greenhouse gas emissions, have a significant impact on climate, as evidenced by the phenomenon of global warming.

Located in the subtropical zone of North Africa, Algeria's climate varies from region to region (North-South, East-West). The coastline and the Tellian Atlas enjoy a Mediterranean climate characterized by hot, dry summers and cool, wet winters, while the high plateaus in the center of the country have a semi-arid climate, and the desert region spreads out to the south of the Saharan Atlas chain. The spatio-temporal distribution of precipitation in Algeria is highly variable, decreasing from north to south and from east to west. The Office national de la météorologie (n.d.) reports that annual rainfall drops below 100 mm south of the Saharan Atlas, signaling the beginning of the desert.

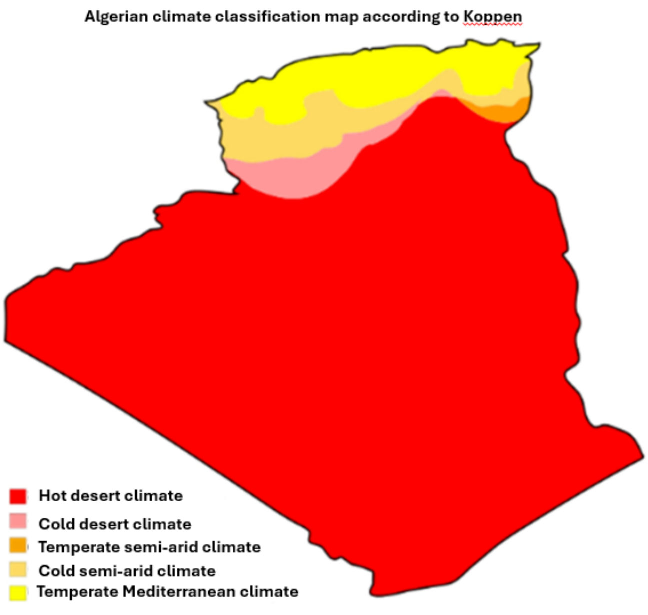


Figure 2.17 : Algerian climate classification maps according to Koppen (Source: Bersi, 2018).

One of the key aspects of Algeria's climate is its coastal region, characterized by a Mediterranean climate. This type of climate is characterized by mild, humid conditions, with relatively moderate temperatures throughout the year. Algeria's coastal areas, particularly in the north, enjoy a temperate climate with hot, dry summers and mild, rainy winters as stated by Aoudia et al. (2020). The average annual temperature in the coastal regions ranges from around

15°C to 20°C, with the hottest months being July and August and the coolest January and February. Precipitation patterns in the Algerian coastal region are also influenced by the Mediterranean climate. The region receives an annual average of around 400 to 800 millimeters of precipitation, with the highest levels occurring in the winter months.

The analysis of the Algerian coastline carried out by Nouaceur, Lagnelol and Turki (2017) highlighted substantial variations in climatic parameters, particularly temperatures and precipitation, since the 1980s. An increase in minimum temperatures was observed from 1984, followed by a rise in maximum temperatures from 1987, with the latter showing a more marked trend. At the same time, after a prolonged period of drought between 1987 and 2002, an upsurge in precipitation was observed from 2003 onwards, characterized by extreme rainfall events. Nevertheless, these changes have created increasing challenges for urban areas, marked by recurrent floods causing material and human damage, underlining the urgent need for appropriate management of water resources and a reassessment of urbanization.

Conclusion :

Bioclimatic architecture refutes the idea of contemporary design and does not depend on modern technologies and techniques such as heating and air-conditioning systems. Rather, it represents a return to traditional practices, characterized using natural materials and adapted construction techniques, aimed at exploiting local climatic conditions to maximize thermal comfort inside houses. Nevertheless, recent technological advances and innovations in building equipment and materials offer greater scope for further optimizing the environmental performance of buildings.

CHAPTER III

Study Corpus (Bejaia’s Coast)

Introduction :

The Algerian coastal town of Béjaïa boasts a coastline stretching for 120 kilometers, where a remarkable architectural diversity flourishes. The houses that dot this landscape reflect a multiplicity of styles, inherited from different eras in the city's history.

This chapter aims to empirically merge two themes explored in previous chapters, namely coastal housing, and bioclimatic architecture, through the study of a few housing typologies found on the coast of the wilaya of Béjaïa.

This study is based on the evaluation of three fundamental parameters of bioclimatic architecture: building materials, natural light, and ventilation.

The first section of this chapter begins with a presentation of the wilaya of Béjaïa, including its climate and coastline. The second section consists of a detailed presentation of the homes analyzed. The third section deals with the analysis methodology, which combines two approaches: an empirical method based on in-situ measurements, enabling the validation of daylight simulation software, and a second method involving numerical simulations using two software packages and a web interface.

Finally, the last section is devoted to interpreting the analysis results, and to specific recommendations for each home and in general.

III.1 Presentation of the city of Bejaia :

Béjaïa, located in Algeria's northeastern Kabylia region, is one of Algeria's oldest cities, founded in 26-27 BC by Emperor Augustus under the name of Saldae. The town prospered in the Middle Ages and became a major intellectual center. The citadel, the city's most important historic monument, is the result of the interaction of different cultures: Roman, Hammadite, Spanish, Turkish, French and Arab-Muslim, according to Unesco, (n. d.). It covers an area of 3,261 km² with an estimated total population of 972,050 (2017). The city is divided administratively into 52 communes and 19 daïras and is bounded to the north by the Mediterranean Sea, to the south by the wilayas of Bouira and Bord Bou-Arreridj, to the west by the wilaya of Tizi-Ouzou and to the east by the wilayas of Sétif and Jijel, as stated by Meradi (2008). The territory of the Béjaïa wilaya is a compact, hummocky mountain mass, crossed by the Soummam valley corridor. It is characterized by a predominance of mountainous terrain, with few plains. The town is also crossed by several wadis (rivers) due to heavy rainfall, the most important of which are Oued Soummam, Oued Agrioun, Oued Djemaa and Oued Zitouni.

Figure 3.1 : Geographical map of the wilaya of Bejaia (Source: https://d-maps.com, 2023)

III.1.1. Accessibility to the city of Bejaia :

According to ANIRF (2019) the city of Bejaia has several transport networks linking it with the country's other wilayas and with foreign countries. The road network is the most widely used means of transport in the wilaya, with a total length of 4,448 km. The city also boasts a category B international airport (ABBANE RAMDHANE) with a runway 2400 m long and 45 m wide, inaugurated in 1982 for national flights and in 1993 for international flights. The city also boasts a maritime network with a terminal designed to develop passenger traffic, with an annual capacity of 1,000,000 passengers and 100,000 vehicles. Finally, the city has a rail network linking the city of Bejaia and the country's capital via Bouira, with thirteen stations operated by the 'Société nationale des transports ferroviaires' (SNTF).

III.1.2. Climate of the wilaya of Bejaia :

According to Climate-Data.org. (n. d.), has a Mediterranean climate, with variations depending on the area. The coastal zone and the Soummam valley enjoy a mild, rainy climate in winter, and dry, hot weather in summer, ideal for seaside tourism. Mountain areas enjoy dry, hot summers and rainy, cold winters, with occasional snowfalls, ideal for mountain tourism and winter sports. On average, the driest month is July, with just 5 mm of precipitation, while the greatest amount of precipitation occurs in January, with an average value of 93 mm. The highest average temperature is in August, at 25.0°C, and the lowest is in February, at around 10.1°C. Relative humidity is highest in May (72.40%) and lowest in July (72.40%). Bejaia's climate is therefore ideal for seaside tourism in summer and for mountain tourism and winter sports in winter.

According to ANIRF (2019), the Bejaia region receives a significant amount of rain during winter, with an average of 600 mm/year. However, rainfall is highly variable from month to month, with wet and dry seasons. The rainiest months are December, January, and February, while the driest are June, July and August. Snowfall is rare and only occurs on the highest mountain peaks. The amount of rainfall decreases from the coast inland, except for a few mountain peaks that receive snow.

III.2 Presentation of the Bejaia coastline :

According to ANIRF (2019), Bejaia's coastline stretches over 120 kilometers, alternating rocky bays and fine sandy beaches from east to west. It covers an area of 785 km2, or 24.35% of the wilaya's total surface area. It is bounded to the north by the Mediterranean Sea, to the east by the wilaya of Jijel, to the west by the wilaya of Tizi-Ouzou, and to the south by several communes. The coastal fringe enjoys a mild climate, receiving an average of 800 to 1100 mm of rain per year.

The east coast is characterized by many fine golden sandy beaches, while the west coast has a populated relief dotted with rocky coves and fine sandy beaches. The wilaya of Bejaia is predominantly mountainous, with a coastline of over 100 km, alternating rocky coves and fine sandy beaches from east to west.

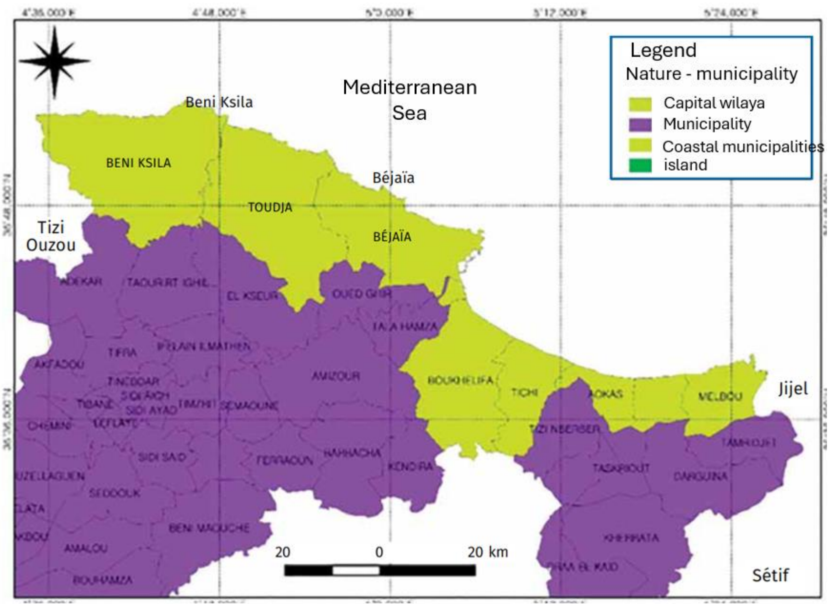


Figure 3.2 : geographical map of the coastline of the wilaya of Bejaia.
(Source: Mennad et al., 2021)

III.3. Presentation of study corpus :

Béjaïa, one of Algeria's coastal towns, boasts a 120-kilometre coastline of striking architectural diversity. The houses that dot this landscape feature a variety of typologies, inherited from different periods in the city's history, offering a singular picture combining tradition and modernity. The region is characterized by a profusion of building styles, forms, techniques, and materials. This architectural juxtaposition creates a landscape rich in contrasts, where urban planning blends harmoniously into the narrative of local history and culture. This particularity will significantly enrich the empirical component of our research on bioclimatic housing in coastal areas.

III.3.1. Selection criteria :

To choose the various houses to be analyzed, we must go through some selection criteria to limit our field of research with more significant cases, we selected them according to the following criteria:

- **Geographical context:** All the homes studied are located on the coast, sharing their locations between the eastern and western regions.
- **Historical context:** The homes examined come from a variety of historical eras, which can be classified under three distinct periods: pre-colonial, colonial and post-colonial.
- **Architectural typology: The** variety of houses ranges from individual ones to collective structures, including both courtyard homes and those with no courtyard.
- **Accessibility of information** : To ensure a comprehensive analysis, it is essential that all relevant information is available, including plans, materials used, and representative images of the buildings' internal and external environment.

After making a selection, we chose five houses: a vernacular detached house in Keramane city, two houses from the colonial period (one detached in Beni-ksila and one collective in Plateau Amimoune), and two other houses from the post-colonial period (one detached in Gouraya and one collective in Sidi-Ali-Lebher).

III.3.2. Houses to be analyzed:

III.3.2.1. Individual housing in Keramane city :

This pre-colonial house is located in the Keramane district of the old town of Bejaia, surrounded by the Vieillard district to the east, the Bab-Ellouz district to the north-west and the Aissat district to the south and south-west. The house is located at the western end of the district. It consists of two volumes on two different levels separated by a patio, which serves as an articulation and vertical circulation area.

III.3.2.2. Individual colonial housing in Beni-Ksila :

It's a individual house dating from colonial times, located in the commune of Beni-ksila, and currently in the possession of the public works department of the wilaya of Bejaia. It's 100 m from the sea, has a single level and comprises three bedrooms, a living room, kitchen, bathroom, WC, and a gallery. It features small rectangular windows, usually arranged in pairs.

III.3.2.3. Colonial collective housing in Plateau Amimoune :

This housing estate is located in the Plateau Amimoune district, built in the 1950s by French architect Jean Royer, in the hills above the town of Bejaia. The Amimoune city is made up of several R+8 blocks organized in two ways: a linear organization following the traces of the demolished western ramparts, and an organization around a central courtyard. All the blocks have two types of floor plan, F2 and F3, accessible via passageways.

III.3.2.4. Post-colonial single-family housing in Gouraya :

This post-colonial dwelling is located in the Gouraya protected zone, 600 m from the sea and facing towards it. It has three levels: a basement, a first floor and an upper floor, and is covered in red tiles. In our case, the first floor was analyzed, comprising a kitchen, living room, two bedrooms, bathroom, and toilet.

III.3.2.5. Post-colonial collective housing in Sidi- Ali-Lebher :

The 140 LSP housing units were built as part of the Sidi-Ali-Lebher project to extend the town of Bejaia in 2006 by the private engineering firm Art Land. The building is 1 km from the sea and has an R+6 floor plan. The buildings comprise two types of housing: a F3 and a F2. The apartment analyzed is a F3 facing the sea and comprises a living room, two bedrooms and a kitchen, bathroom, toilet and terrace.

Detailed information on the homes analyzed can be found in the table below.

III.3.3. Typo-morpho presentation of corpus study :

Table 3-1 : Study corpus analysis (Source: Author, 2023)

<table>
<tr><th></th><th></th><th>Situation</th><th>Boundaries and immediate surroundings</th><th>Plans</th><th>Volumetry</th><th>Building materials</th><th>Indoor and outdoor environments</th></tr>
<tr><td>Pre-colonial period</td><td>House in Keramane city</td><td>

Figure 3.3 : House location.
(Source: Google Earth processed by author, 2023)

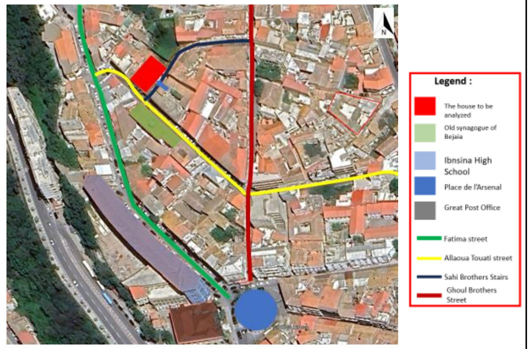
The Keramane district is in the old town on the eastern edge of the Bejaia commune.</td><td>

Figure 3.4 : house boundary and immediate surroundings.
(Source: Google Earth processed by author, 2023)

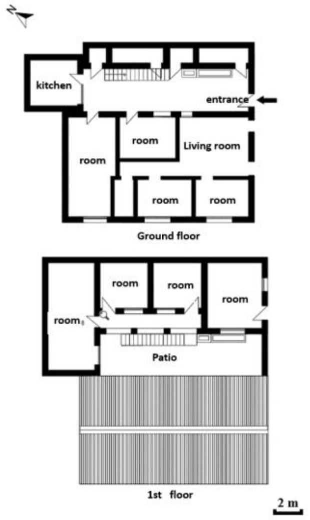
The home is located 500 m from Place de l'Arsenal, accessible from Rue Fatima, which is flanked on the south by Rue Allaoua Touati and on the left by the Frères</td><td>

Figure 3.5 House plans (Source: Author, 2023)</td><td>
Figure 3.6 : 3D view of the house.
(Source: Author, 2023)

The home comprises two volumes on two different levels, separated by a patio.</td><td>
Figure 3.7 : Building materials.
(Source: Author, 2023)

- Red tile
- Clay brick wall</td><td>
Figure 3.8 Outdoor and indoor environments.
(Source: Author, 2023)</td></tr>
<tr><td>Colonial period</td><td>House in Beni-Ksila</td><td>

Figure 3.9 : Location of the house
(Source: Google Earth processed by author, 2023

The house is located northeast of the commune of Beni-Ksila, about 32 km from the town of Bejaia.</td><td>

Figure 3.10 : House boundary and immediate surroundings
(Source: Google Earth processed by author, 2023)

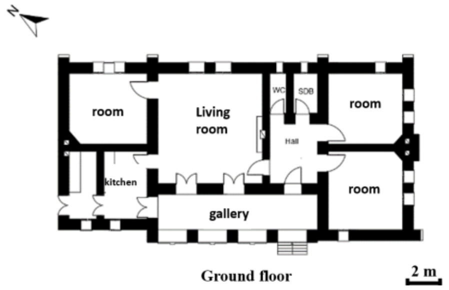
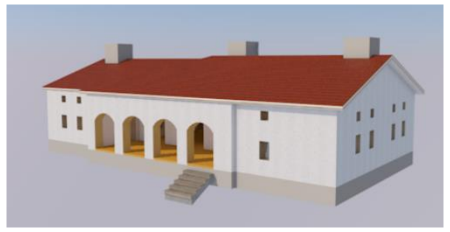
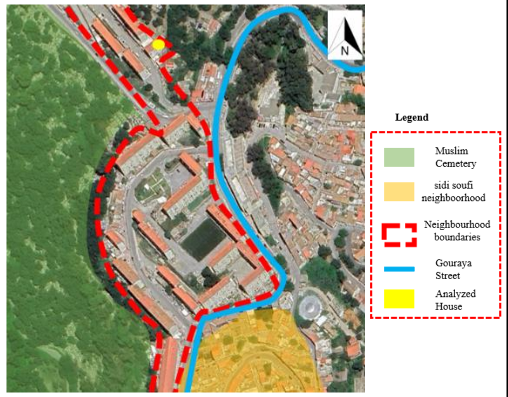
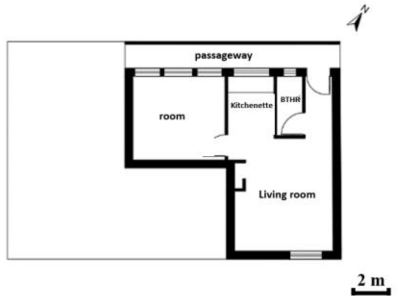
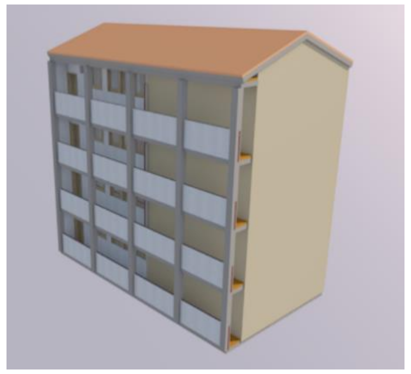
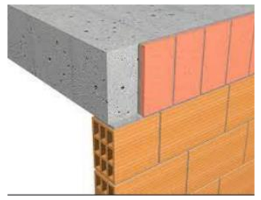
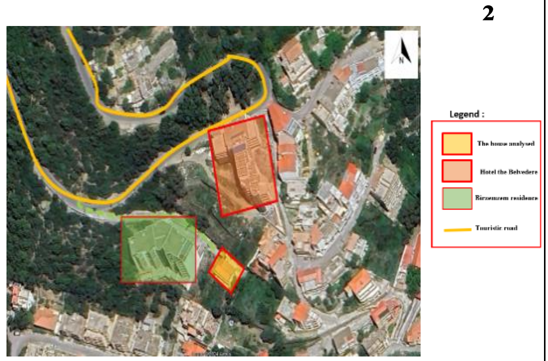
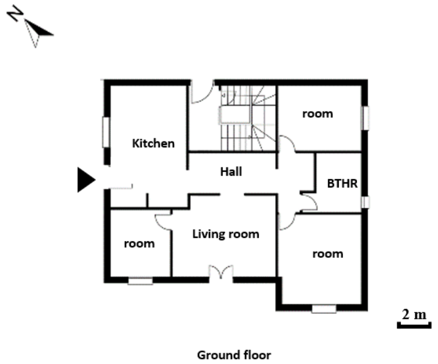
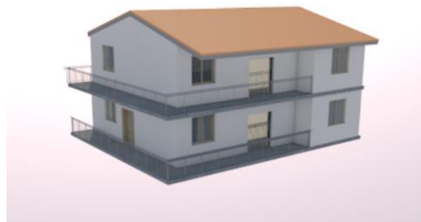
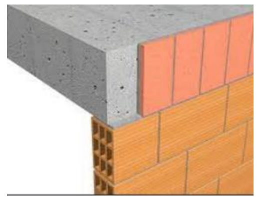
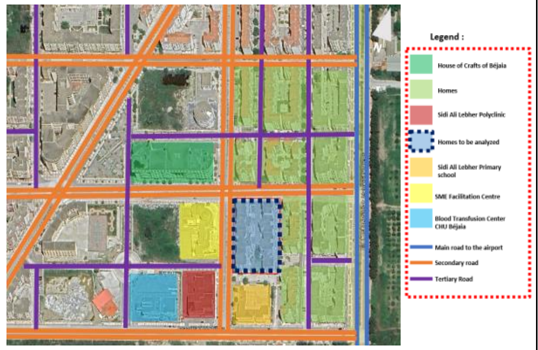
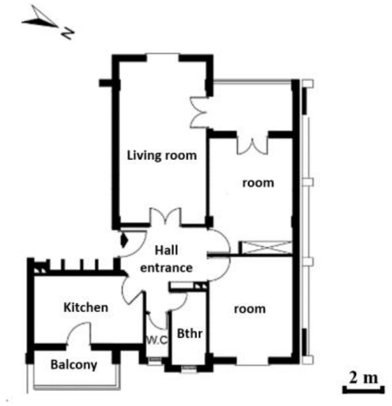
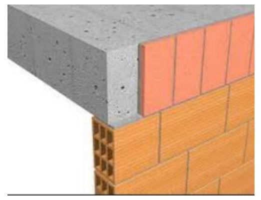
The house is accessible from national road n°24,
It is about 200 m from the Cap-Sigli lighthouse and about 100 m from the sea.</td><td>

Figure 3.11 : House plan.
(Source: Author, 2023)</td><td>
Figure 3.12 : 3D view of the house.
(Source: Author, 2023)

The house is shaped like an elongated rectangle.</td><td>
Figure 3.13 : Building materials
(Source: Author, 2023)

- Red tile
- Stone wall (sandstone)</td><td>
Figure 3.14 : Outdoor environments
(Source: Author, 2023)</td></tr>
</table>

	House in Plateau Amimoune	 **Figure 3.15** : Location of the house. (Source: Google Earth processed by author, 2023 The Amimoune city is located to the east of the commune of Bejaia, on the heights of the old town of Bejaia.	 **Figure 3.16** : House boundary and immediate surroundings (Source: Google Earth processed by author, 2023) The city is bounded by : rue Gouraya to the east, the Muslim cemetery to the west and the Sidi Soufi district to the south. It is accessible from Rue de Gouraya.	 **Figure 3.17 :** House plan. (Source: Author)	 **Figure 3.18 :** 3D view of the house. (Source: Author, 2023) The block is bar-shaped (rectangular), with horizontal circulation via a passageway.	 **Figure 3.19 :** Building materials. (Source: cote-d-ivoire.prix-construction.info,2023) - Tiled roof - Hollow clay	 **Figure 3.20** : Outdoor environments (Source: Author, 2023)
Post-colonial period	**House in Gouraya**	 **Figure 3.21** : House location. (Source: Google Earth processed by author, 2023 The house is located to the north-east of the town of Bejaia, 600 m from the sea.	 **Figure 3.22 :** Boundary and immediate surroundings (Source: Google Earth processed by author, 2023) The home is accessible from the tourist road and is close to the Birzemzem residence and Hotel Le Belvedere.	 **Figure 3.23** : House plan. (Source: Author, 2023)	 **Figure 3.24** : 3D view of the house. (Source: Author, 2023) The dwelling is rectangular in shape with two levels.	 **Figure 3.25** : Building materials. (Source: http://www.cote-d-ivoire.prix-construction.info,2023) -Tiled roof - Hollow clay brick wall.	 **Figure 3.26** Outdoor and indoor environments. (Source: Author, 2023)

	House in Sidi-Ali-Lebher	 **Figure 3.27 :** Location of the house. (Source: Google Earth processed by author, 2023 Sidi Ali Lebher is located to the south-east of the commune of Bejaia. The case study is located about 1 km	 **Figure 3.28 :** House boundary and immediate surroundings (Source: Google Earth processed by author, 2023) The house is bordered to the north by apartment buildings, to the southeast by a polyclinic, and to the southwest by an SME facilitation center.	 **Figure 3.29** : House plan. (Source: Author, 2023)	 **Figure 3.30 :** 3D view of the house (Source: Author, 2023) The bar-shaped building has seven levels.	 **Figure 3.31 :** Building materials. (Source : http://www.cote-d-ivoire.prix-construction.info,2023) - Hollow slab flat roof - Hollow clay brick wall.	 **Figure 3.32** : Outdoor environment (Source: Author, 2023)

III.4 Research methodology :

In our analysis of the houses selected and quoted below, we have identified two key parameters that constitute the fundamental elements of our theme. The first parameter is very high humidity, which is a major factor in frequent problems in the coastal region. The second parameter is sunlight, which can be absent in the homes or, conversely, excessive, causing a glare effect.

For the first parameter, humidity, we have observed that this problem is generally linked to ventilation, temperature variations inside and outside the home, and the construction materials used in homes.

For the second parameter, sunlight, we have found that it is linked to the orientation of the building and the devices used at openings to protect against direct sunlight or to allow natural light to enter.

III.4.1. Empirical study (in-situ) :

The first step is to visit the houses to be analyzed, collect the various plans and sections for some and take readings for others, observe the various building materials, in order to draw up a technical data sheet of the homes analyzed.

For the assessment of the first parameter, humidity, given the challenges associated with taking temperature measurements inside and outside house (the presence of air-conditioning systems can distort results, as can repeated restrictions on access to the interior of homes by some homeowners), Both during the day and at night, we chose to adopt an approach based on the analysis of natural ventilation and the characteristics of the materials making up the walls of these homes, using a simulation carried out with two specialized software programs (see section on simulation).

To analyze the second parameter, sunlight, we took photos of the interiors of houses where there was an opening allowing light to penetrate, as well as the presence of a sunspot.

The photos are then processed using an application called 'Aftabalpha', which creates the false color of a photo.

"'Aftabalpha': consists in creating and analyzing HDR images based on luminance. It's a Python-based program with some commands scripted in C++. It uses some Radiance.

commands. DCRAW is used whenever it processes RAW image files". (Aftabalpha, 2023).

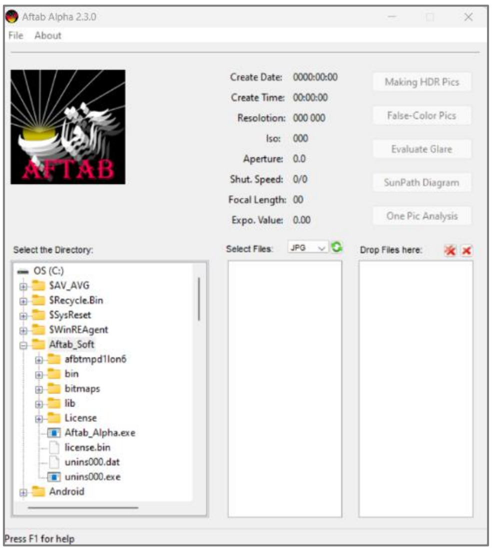


Figure 3.33 : Aftabalpha tool interface.
(Source: Aftabalpha, 2023)

We have chosen two photos of two rooms in two different houses:

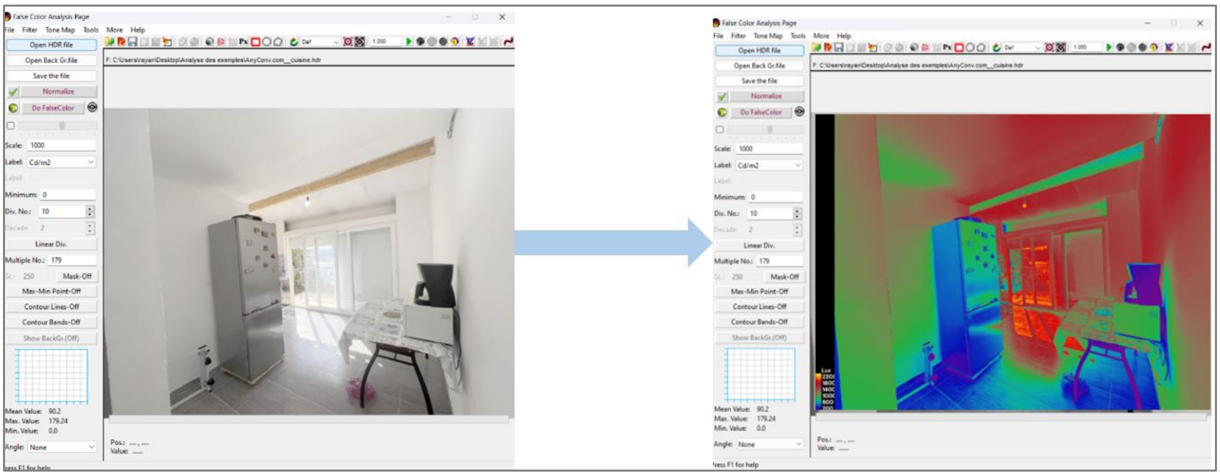


Figure 3.34 : False color of part no. 1 (Source: Author, 2023)

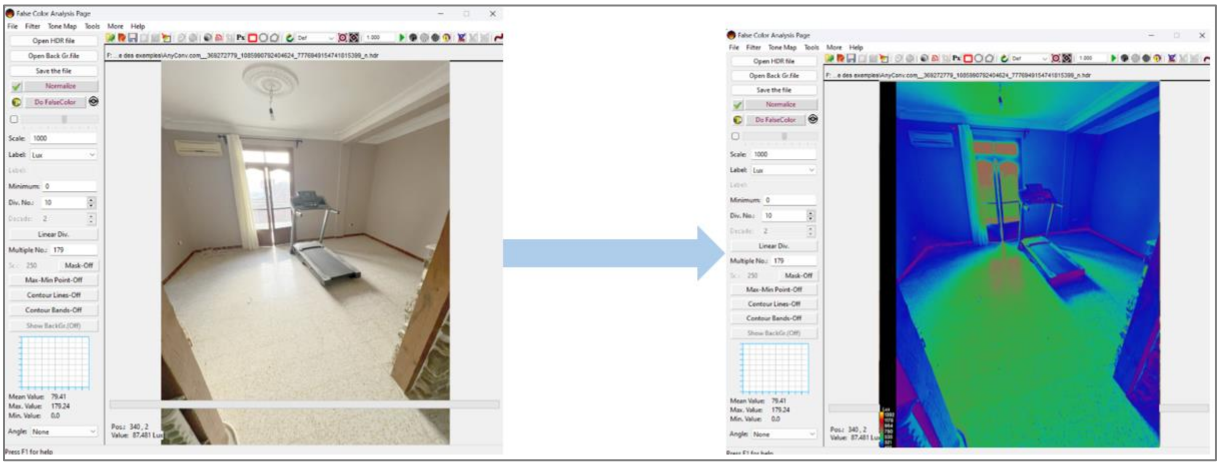


Figure 3.35 : False color of part no. 02 (Source: Author, 2023)

III.4.2. Complementary simulation :

III.4.2.1. Analysis of daylight :

For the analysis of the daylight in the houses, we opted for dedicated simulation software to evaluate daylighting, and for the evaluation we used DIALux Evo software, a powerful lighting design software that enables the design, calculation, and visualization of light for exterior and interior spaces. (DIALux, 2024)

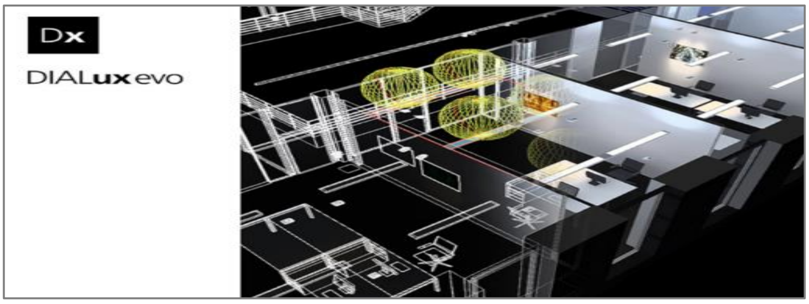


Figure 3.36 : DilauxEvo software logo
(Source: DialuxEvo, 2023)

III.4.2.1.1. Validation of analysis means :

Before integrating this software into our analysis, we need to validate the reliability of its results. This involves comparing simulation results with data measured in situ, collected simultaneously at the same location and under identical climatic conditions.

the results are as follows:

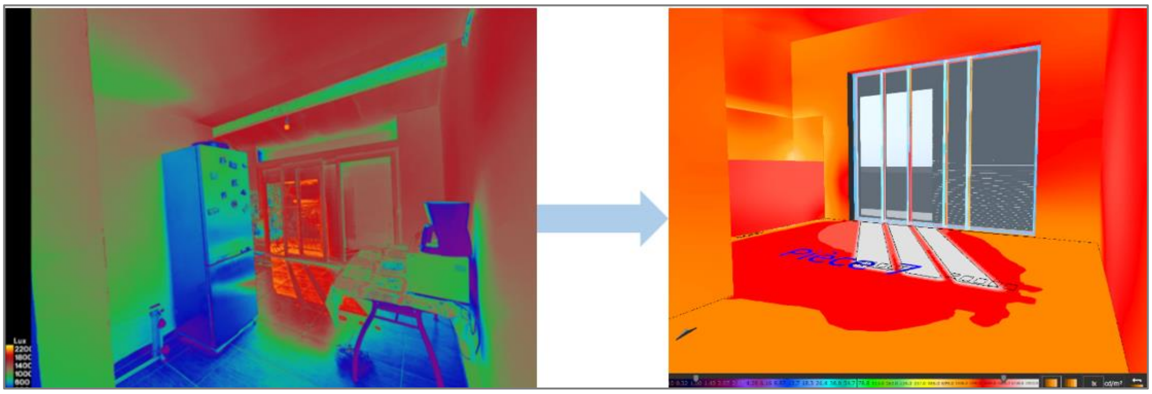


Figure 3.37 : Comparison of false color and DialuxEvo results.
(Source: Author, 2023)

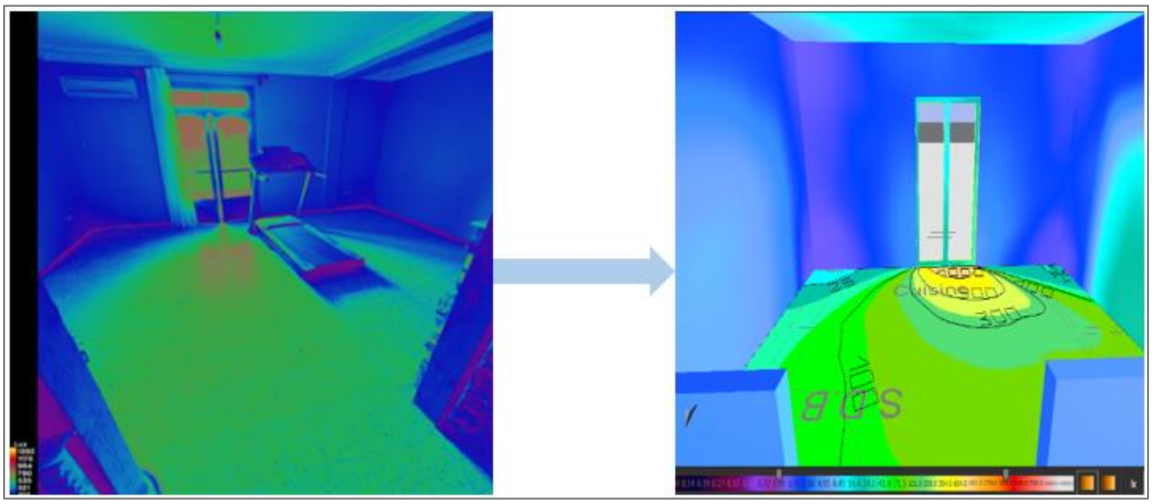


Figure 3.38 : Comparison of false color and DialuxEvo results.
(Source: author, 2023)

- **Comparison** :

Comparing the results of simulations and empirical measurements, it can be seen that the data are remarkably consistent both in the two rooms and in the two homes studied.

- **Validation** :

Following the concordance of the simulation results with the empirical data, we approve the use of the 'DialuxEvo' software for the continuation of the simulations concerning all the residences to be analyzed.

Proceed as follows:

The simulation is carried out during three specific annual periods, coinciding with the least favorable conditions of the year: June 21, December 21, and September 21. These periods are subdivided into three times of day: morning (9:00 a.m.), midday (12:00 p.m.) and afternoon (3:00 p.m.).

III.4.2.2. Moisture analysis *:*

- For moisture analysis in these houses, we first opted for the 'Ubakus' interface. It deals with the behavior of materials with respect to humidity.

The latter provides information on expected heat loss and possible moisture problems by entering all the layers of a building component into the value calculator (Ubakus, 2024).

The various layers of the home's walls are entered, along with the temperature inside and outside these walls.

Once the wall layers and their respective dimensions have been specified, the calculation process is initiated. Once completed, the result is available for downloading or printing in PDF format, including the various associated diagrams and explanatory comments.

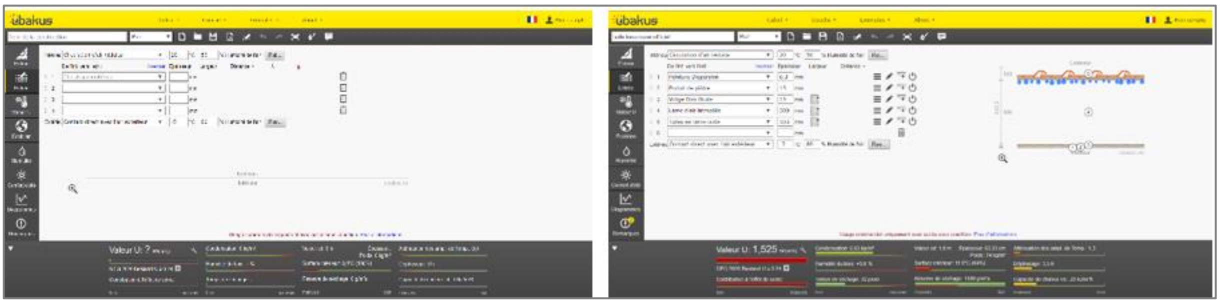


Figure 3.39 : Ubakus interface (Source: https://www.ubakus.de, 2023)

III.4.2.3. Wind analysis :

For natural ventilation, we used RWIND software, which uses a CFD (computer fluid dynamics) numerical model to simulate wind flows around and inside objects (3d volumes). (RWIND, 2024).

The simulation is carried out by determining the volume of the house, then determining the speed and direction of the prevailing winter and summer winds, and running the calculation.

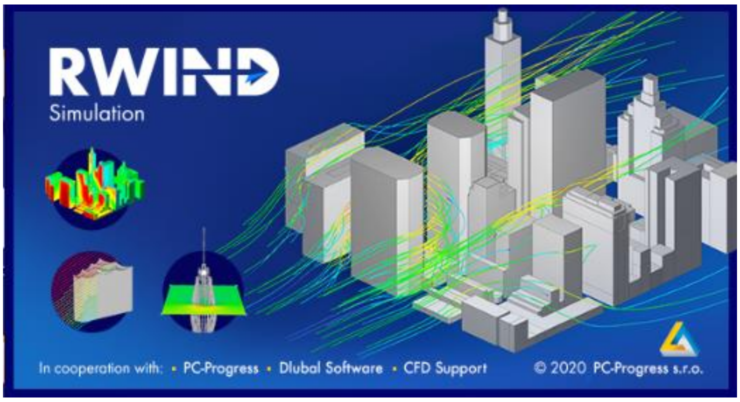


Figure 3.40 : RWIND software logo.
(Source: https://www.dlubal.com, 2023)

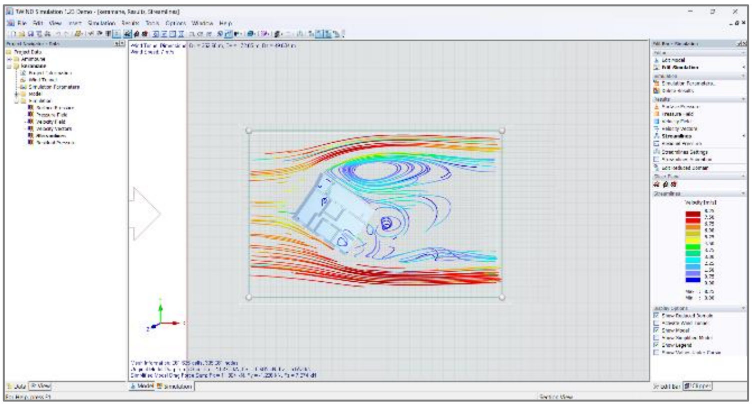


Figure 3.41 : RWIND software interface.
(Source: RWIND, 2023)

III.4.3. Correspondence :

In order to explore the interaction between the three criteria studied, i.e. natural light, building materials and natural ventilation, we opted for the 'Statsoft Statistica v10 Enterprise' software.

It is a professional tool designed for data scientists, statisticians and any data analyst who needs to extract useful information from data. It provides procedures for data analysis, data management, statistics, data mining, machine learning, text analysis and data visualization... It is an advanced analysis software originally developed by Statsoft and currently maintained by TIBCO Software Inc. (Statsoft, 2024).

Figure 3.42 : Statsoft Statistica software logo
(Source: Statistica Enterprise, 2023)

The methodology involves allocating the various rooms in different houses to the corresponding boxes, where four rooms are selected for each house, including the living room, kitchen and two bedrooms. The columns represent the variables, which are filled by the different values associated with the three parameters under examination. Then, at the intersection of each box and variable, "yes" is entered if the data match, otherwise "no" is noted. At the end of this step, we select the "matches" option and then opt for "multiple matches", thus obtaining the results in the form of a scatterplot.

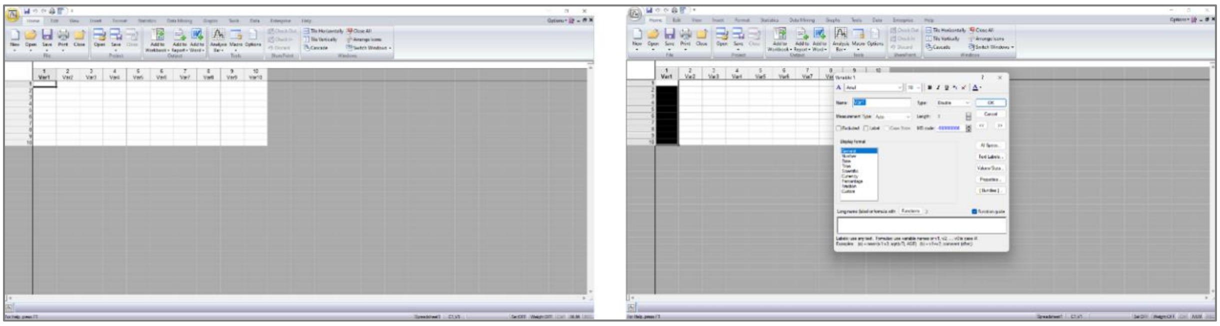
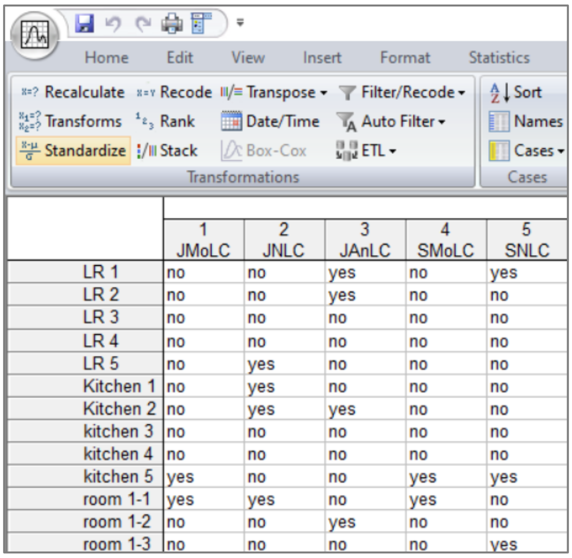


Figure 3.44 : Data entry steps (Source: Statistica Enterprise, 2023)



	1 JMoLC	2 JNLC	3 JAnLC	4 SMoLC	5 SNLC
LR 1	no	no	yes	no	yes
LR 2	no	no	yes	no	no
LR 3	no	no	no	no	no
LR 4	no	no	no	no	no
LR 5	no	yes	no	no	no
Kitchen 1	no	yes	no	no	no
Kitchen 2	no	yes	yes	no	no
kitchen 3	no	no	no	no	no
kitchen 4	no	no	no	no	no
kitchen 5	yes	no	no	yes	yes
room 1-1	yes	yes	no	yes	no
room 1-2	no	no	yes	no	no
room 1-3	no	no	no	no	yes

Figure 3.43 : Relationship between variables
(Source: Statistica Enterprise, 2023)

III.5 Interpretation of results :

III.5.1. Results of daylight analysis :

When analyzing daylighting, a general approach is taken to interpreting the results for each house. However, for illustrative purposes, I have deliberately selected the worst-case scenario from the observed cases. The other cases are exhaustively recorded in the appendix for further reference.

- Single-family homes in Keramane city:

Within this home, the rooms exhibit notable disparities in terms of lighting, with those facing south benefiting from considerable brightness, reaching up to 3500 lux, resulting in glare and excessive temperatures, particularly during the winter season. In contrast, other rooms are characterized by reduced luminosity, not exceeding 2 lux throughout the day and across the seasons.

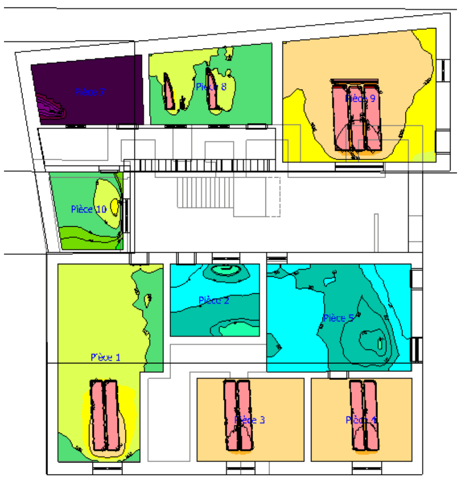


Figure 3.45 : Winter daylight results at 15:00
(Source: DialuxEvo, 2023)

- Colonial single-family homes in Beni-Ksila:

The residence's overall lighting levels are unfavorable, characterized by considerably reduced brightness in all seasons, with the exception of rooms 3 and 4, where lighting reaches excessive levels, peaking at 2000 lux in the mornings during the shoulder and winter periods.

This situation creates the need for protection from direct sunlight. For the rest of the house, lighting levels fluctuate between 50 and 200 lux.

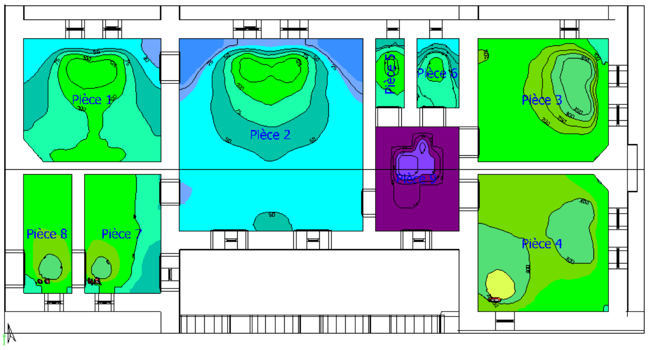


Figure 3.46: mid-season daylight results at noon
(Source: DialuxEvo, 2023)

- Colonial collective housing in Plateau Amimoune:

Room 1 does not benefit from direct lighting at any of the three times of year but maintains an adequate level of brightness in keeping with its function as a bedroom, except during the winter season when illuminance is significantly reduced. In the living room, light distribution is not uniform, with very high values, reaching up to 2000 lux, especially in winter, particularly during the morning to midday period. This leads to glare and overheating in summer.

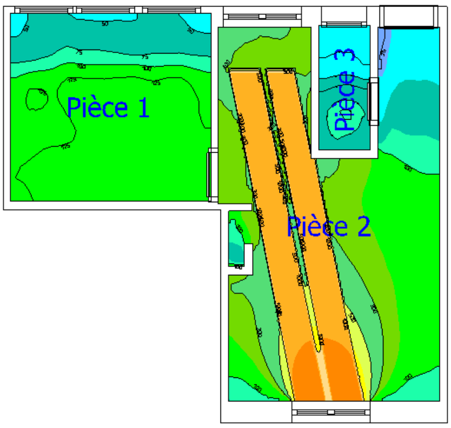


Figure 3.47 : Winter daylight results at 09:00
(Source: DialuxEvo, 2023)

- Post-colonial single-family housing in Gouraya:

Overall, illuminance levels in the residence are generally in line with standards during different periods of the day, but sometimes marked by excessive values of up to 4000 lux, mainly during the winter and shoulder seasons. This highlights the need to regulate the entry of sunlight to ensure optimum visual and thermal comfort inside these spaces.

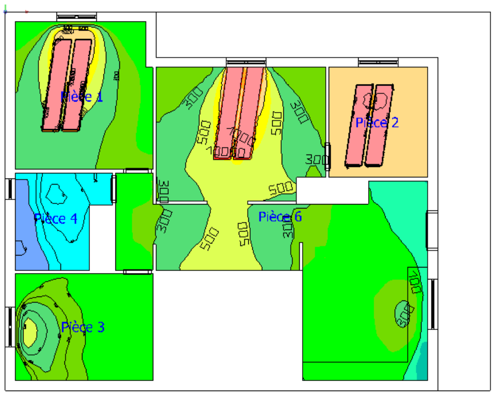


Figure 3.48 : Winter daylight results at 3:00 p.m.
(Source: DialuxEvo, 2023)

- Post-colonial collective housing in Sidi- Ali-Lebher:

The various rooms in the house do not show ideal light values during the day, oscillating between excessive and uniform lighting, reaching 1200 lux, thus requiring protective measures, and considerably reduced illumination, down to 100 lux, particularly observable in the clearance area.

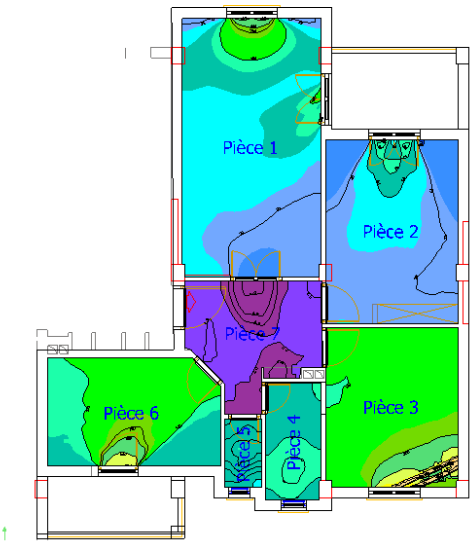


Figure 3.49 : Winter daylight results at 09:00
(Source: DialuxEvo, 2023)

Comparison :

- In the collective houses studied :

Multi-family houses show marked differences in terms of lighting. Some suffer from extreme variations in brightness inside the house (Sidi Ali Lebher house), requiring adjustments to maintain adequate visual comfort, while others experience uneven light distribution, with excessive levels in some areas and problems of glare and overheating (Amimoune).

- In the single-family homes surveyed :

In the study of single-family homes, significant variations were observed in terms of lighting levels. Some homes generally meet lighting standards, while others have excessive or unfavorable levels, often requiring regulation to ensure optimum comfort. Furthermore, differences can occur between different rooms in the same dwelling, underlining the importance of taking light direction and configuration into account when designing homes to ensure visual comfort and optimum temperature all year round.

Summary :

Architectural studies reveal disparities in lighting levels between multi-family and single-family houses. The former can suffer from extreme variations in brightness, while the latter often feature uneven light levels between rooms, requiring regulation to ensure optimum visual comfort.

III.5.2. Analysis results for building materials (exterior wall materials) :

III.5.2.1. Exterior walls *:*

- **Single-family homes in Keramane city :**

- The 50 cm thick wall, made of solid terracotta bricks, demonstrates favorable characteristics in terms of summer comfort and hygrometry, with the absence of humidity noted. However, its thermal insulation performance is unfavorable.
- As far as the temperature profile is concerned, the absence of water vapor condensation is corroborated by the discrepancy between the curves representing wall temperature and saturation temperature.

- Analysis of surface temperature trends over the course of the day reveals virtually constant indoor temperature stability, with a measured phase shift of 17.2 hours, representing the time required for heat to penetrate the material and reach the interior space.

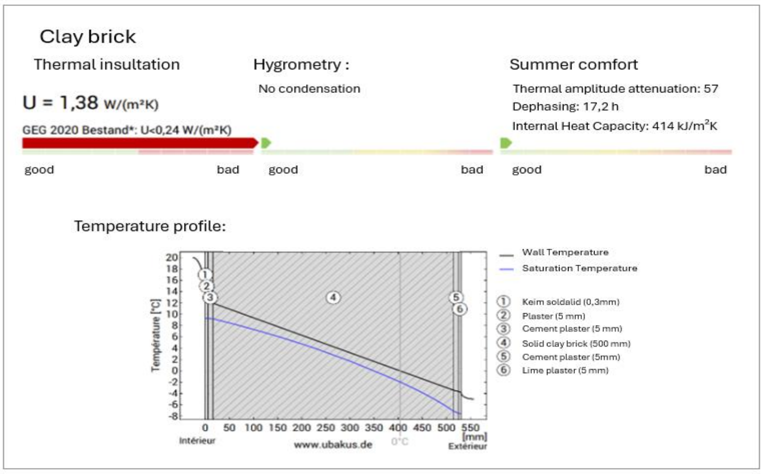


Figure 3.50 : Performance results for exterior walls
(Source: Ubakus.de, 2023)

- **Colonial single-family homes in Beni-Ksila:**

- The wall, with a substantial thickness of 53 cm, exhibits advantageous properties in terms of summer comfort and hygrometry, with an observed absence of damp. However, its thermal insulation is inadequate.
- Analysis of the temperature profile reveals an absence of water vapor condensation, as indicated by the non-overlap of the curves representing wall temperature and saturation temperature.
- As for the evolution of the surface temperature over the course of the day, an almost constant stability is observed for the interior temperature, with a phase shift of 11.2 hours, corresponding to the time required for the heat to penetrate the material and reach the interior space.

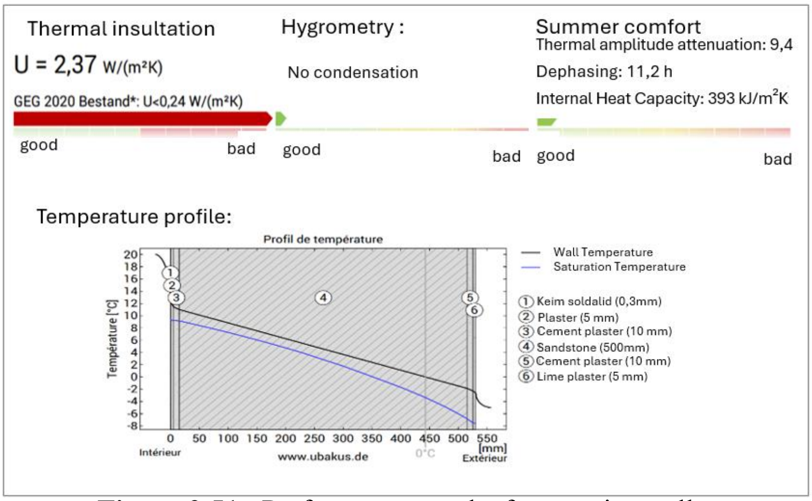


Figure 3.51 : Performance results for exterior walls.
(Source: Ubakus.de, 2023)

- **Colonial collective housing in Plateau Amimoune, post-colonial individual housing in Gouraya and post-colonial collective housing in Sidi- Ali-Lebher:**

- It has been observed that the wall, with an average thickness of 33 cm, offers satisfactory summer comfort and a favorable result in terms of hygrometry, with the absence of humidity detected, but presents insufficient thermal insulation.
- As far as the thermal profile is concerned, the two curves representing wall temperature and saturation temperature converge towards the outside of the wall, indicating the condensation of water vapor and therefore the presence of moisture.
- As for the evolution of surface temperature over the course of the day, the temperature of the interior surface remains practically constant throughout the day, with a phase shift of 11.3 hours, representing the time required for heat to penetrate the material and enter the interior space.

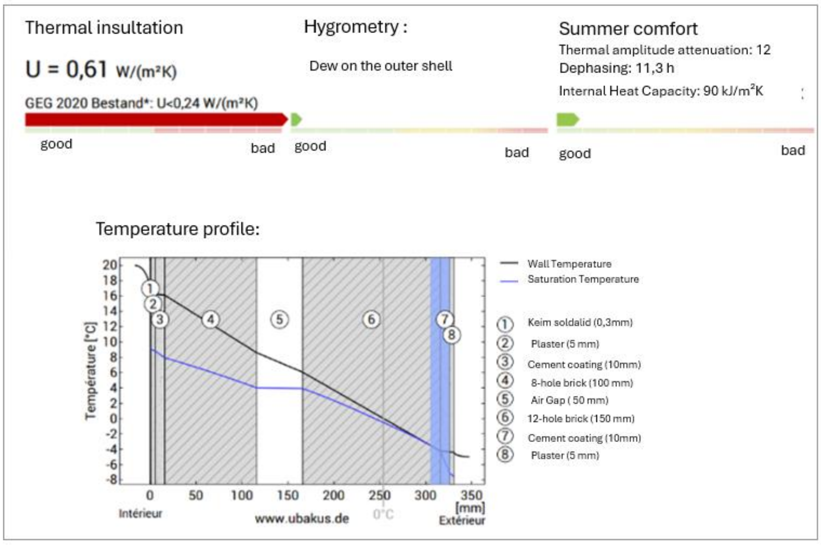


Figure 3.52 : Performance results for exterior walls
(Source: Ubakus.de, 2023)

Comparison :
All the walls, characterized by their different compositions, offer satisfactory summer comfort, with phase shifts varying between 11 and 17 hours. Favorable hygrometry is observed, particularly in the hollow clay brick wall, although all share the characteristic of deficient thermal insulation.

Summary :

In conclusion, the results reveal a general trend where the homes studied reveal deficiencies in terms of thermal insulation, despite variations in building materials and wall thickness. This shortcoming compromises the thermal comfort of homes and highlights the need for action to improve energy efficiency, particularly through insulation of building envelopes. This calls for reflection on the use of more efficient building materials and techniques to meet the growing demands for thermal comfort and durability of homes.

III.5.2.2. Roofs *:*

- **The Beni-ksila dwelling:**

- The analysis reveals that the roof has an average level of summer comfort, characterized by an average thermal phase shift, satisfactory hygrometry with an absence of humidity, but insufficient performance in terms of thermal insulation.
- As far as the temperature profile is concerned, the curves for wall temperature and saturation temperature do not overlap, indicating the absence of water vapor condensation and therefore of humidity.
- he analysis of surface temperature trends throughout the day reveals that the temperature of the interior surface remains relatively constant, with a thermal phase shift of 7.2 hours, representing the time required for heat to penetrate the material and reach the interior space.

-

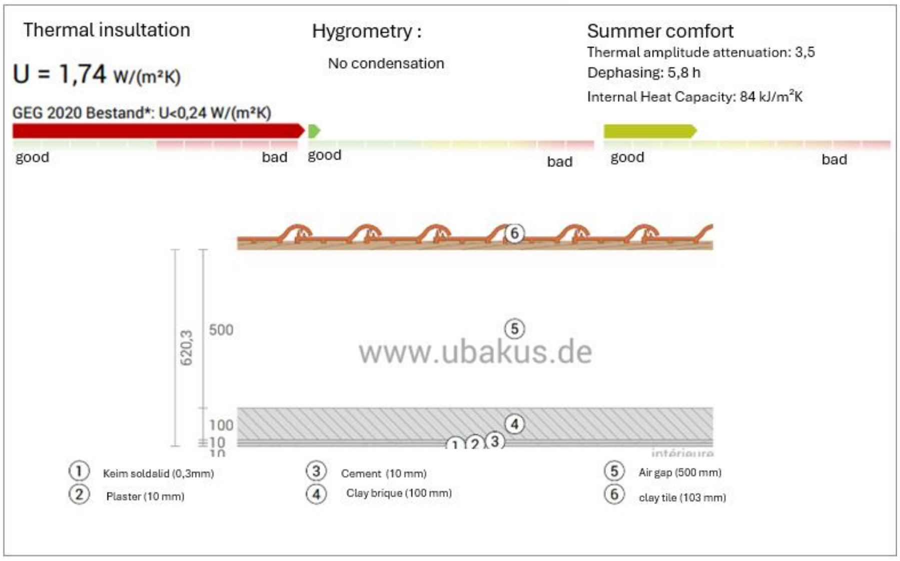


Figure 3.53 : Roof performance results (Source: Ubakus.de, 2023)

- **Housing in Keramane city :**

- Observation reveals that the roof offers poor summer comfort, good moisture resistance and mediocre thermal insulation.
- As far as the temperature profile is concerned, the curves for wall temperature and saturation temperature intersect, indicating the presence of water vapor condensation and therefore humidity.
- Regarding the evolution of surface temperature throughout the day, it is notable that the temperature of the interior surface remains relatively constant, with a thermal phase shift of 3.5 hours, representing the time required for heat to pass through the material and reach the interior space.
-

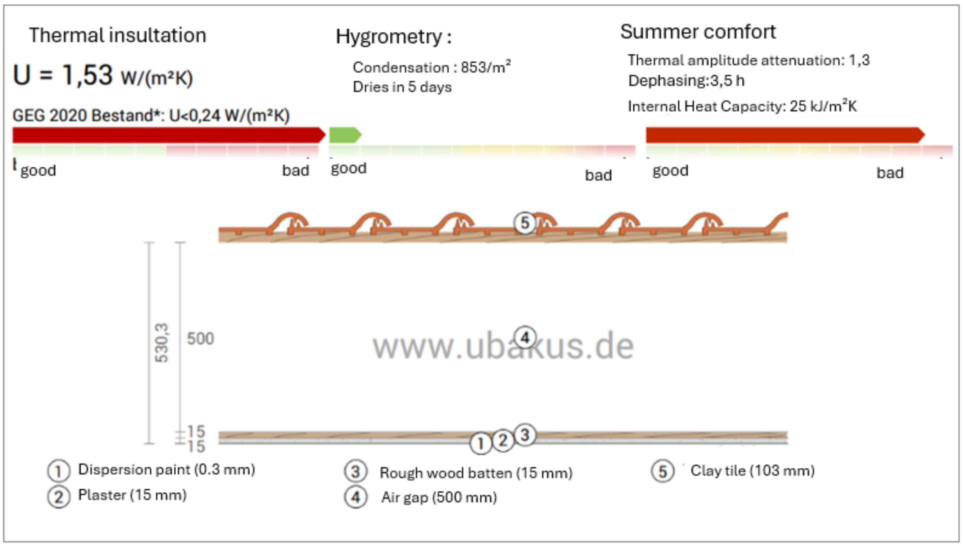


Figure 3.54 : Roof performance results (Source: Ubakus.de, 2023)

- **The house of Gouraya, Sidi Ali Lebher and Plateau Amimoune:**

- The analysis reveals that the roof has favorable characteristics in terms of summer thermal comfort but performs poorly against humidity and has insufficient thermal insulation.
- Regarding the temperature profile, it is observed that the two curves representing the wall temperature and the saturation temperature converge towards the outside of the wall, thus indicating the presence of water vapor condensation and consequently detectable humidity.
- As for the evolution of surface temperature over the course of the day, it is noted that the temperature of the interior surface remains virtually constant throughout the day, exhibiting a phase shift of 11.7 hours, defined as the time required for heat to penetrate a material and enter the interior space.

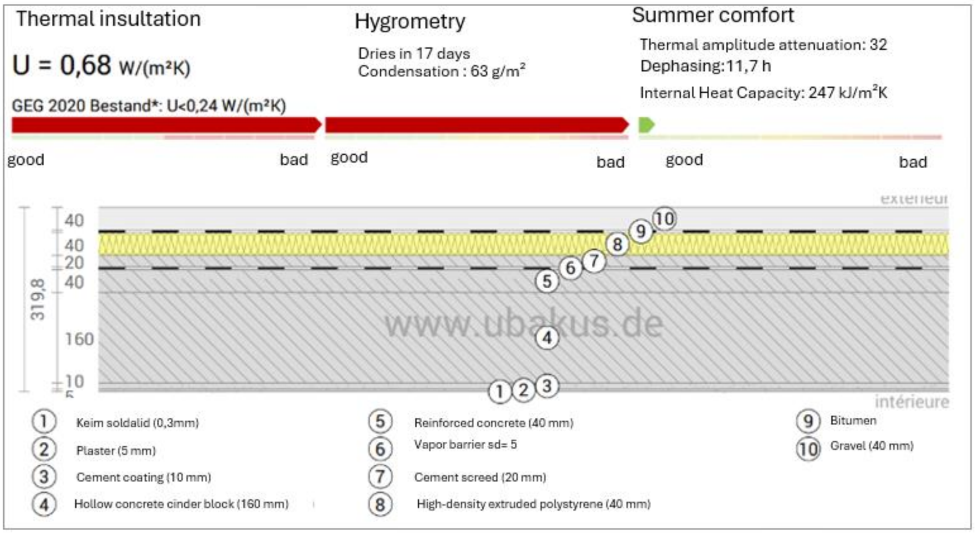


Figure 3.55 : Roof performance results (Source: Ubakus.de, 2023)

Comparison :

A comparison between the cases reveals that optimum summer thermal comfort is observed exclusively in the case of flat roofs, despite their mediocre performance in terms of hygrometry and thermal insulation. Sloping tile roofs, on the other hand, perform well in terms of hygrometry, but suffer from insufficient thermal insulation and poor summer comfort.

Summary :

Among the various roof types examined, the one that stands out for its performance is the combination of tile and solid clay brick. This type provides good hygrometry regulation and an average level of thermal comfort in summer. However, it suffers from insufficient thermal insulation, requiring the application of a thermally insulating material to achieve optimum performance.

III.5.3. Natural ventilation analysis results :

The reddish-orange lines seem to indicate areas of strong winds or high pressure (pressure zone), while the blue and purple lines probably represent areas of weaker winds or low pressure. (depression zone).

- **Single-family homes in Keramane city :**

The dwelling is partially exposed to prevailing winds, due to the presence of a wall with no openings. With regard to interior ventilation, it has been observed that the rooms do not benefit from optimal aeration, as the air flow does not show adequate circulation.

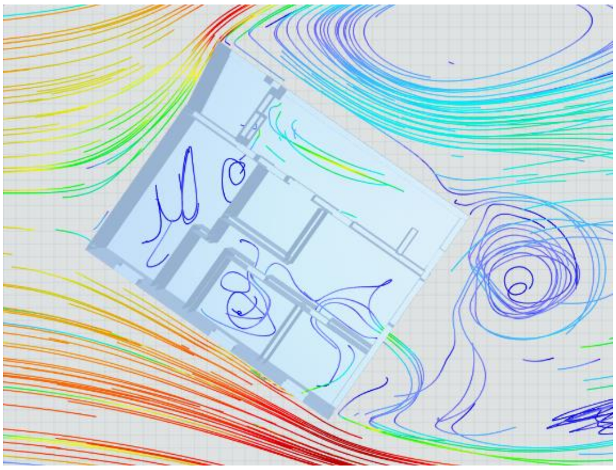


Figure 3.56 : Effect of prevailing winds on the Keramane house (Source: RWIND, 2023)

- **Colonial single-family homes in Beni-Ksila:**

The house is subject to partial exposure to winds; however, its internal circulation is deficient, with the notable exception of the kitchen, which benefits from adequate air circulation to the outside gallery, with limited routing through the living room.

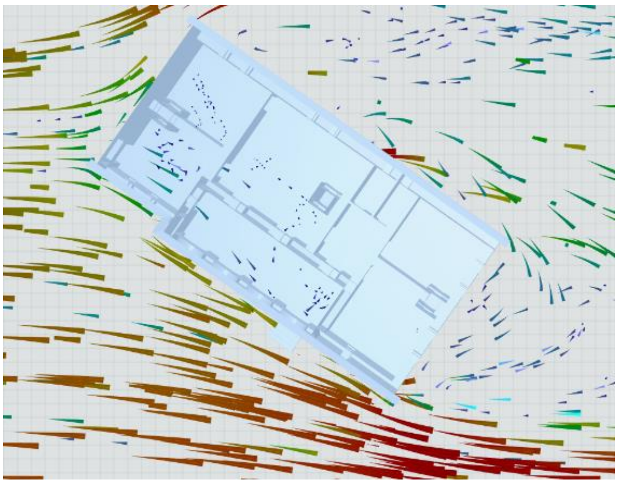


Figure 3.57 : Effect of prevailing winds on the Beni-ksila house (Source: RWIND, 2023)

- **Colonial collective housing in Plateau Amimoune:**

The residence is partially exposed to the influence of prevailing winds, and due to the absence of obstacles such as walls, this ensures effective natural ventilation inside, promoting even air circulation in all rooms.

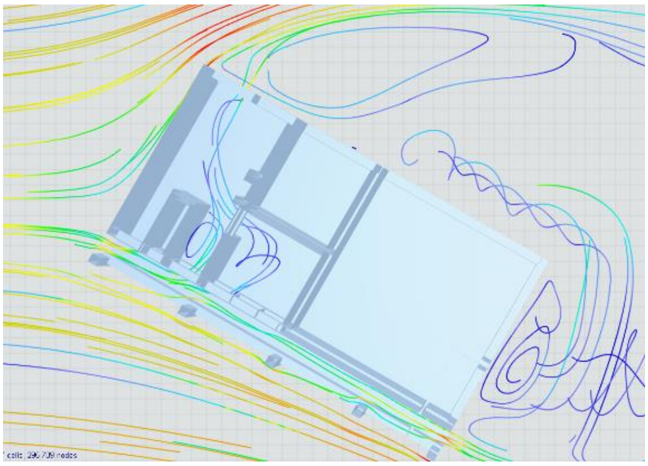


Figure 3.58 : Effect of prevailing winds on the Amimoune plateau house (Source: RWIND, 2023)

- **Post-colonial single-family housing in Gouraya**:

The house is impacted by prevailing winds through two walls, which favors air circulation in most rooms, except for two spaces where this circulation is less perceptible, and totally absent in the bathroom.

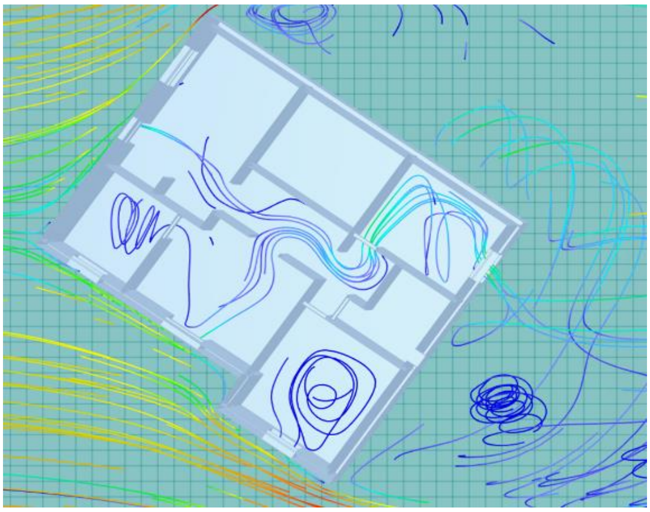


Figure 3.59 : Effect of prevailing winds on the Gouraya house (Source: RWIND, 2023)

- **Post-colonial collective housing in Sidi- Ali-Lebher:**

  Part of the house is exposed to prevailing winds, ensuring effective natural ventilation inside and uniform air circulation in all rooms.

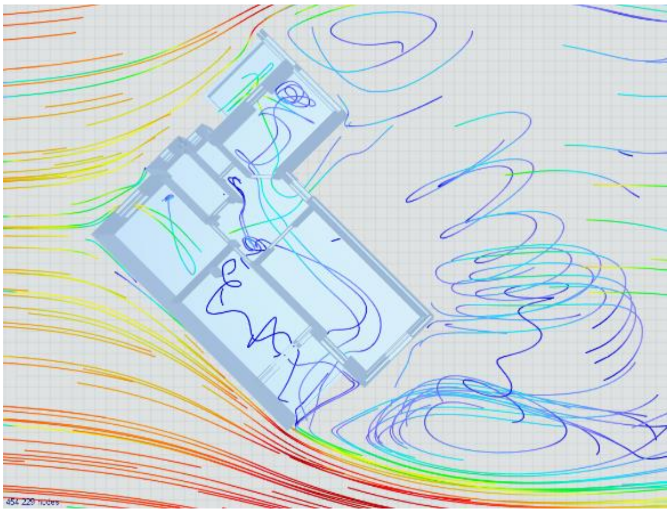


Figure 3.60 : Effect of prevailing winds on the Sidi Ali Lehber house (Source: RWIND, 2023)

Summary :

Various factors influence the effectiveness of natural ventilation in homes, such as wind exposure, architectural configuration and the presence of obstacles that impede air circulation. Careful planning and proper installation can play a part in improving thermal comfort and indoor air quality.

III.5.4. Correspondence :

The multiple correspondence analysis revealed that on the basis of the simulation data, there are two categories, which we will explain as follows:

- **Category 01**: in this category, light comfort in the morning is ensured, combined with thermal comfort (in summer) with good room ventilation, which is maintained when the house is exposed to the wind.

- **Category 02**: in this category, observations suggest a trend where the month of June generally offers better light comfort, (at midday and in the afternoon), while the months of September and December present less favorable conditions in terms of brightness at midday. However, in the afternoon, light comfort seems to be more constant throughout the year.

The two categories studied reveal distinct characteristics in terms of light and thermal comfort. In category 01, the presence of light comfort in the morning, combined with summer thermal comfort and efficient room ventilation, when the home is exposed to the wind. By contrast, category 02 shows seasonal variability in light comfort, with conditions generally more favorable in June at midday and in the afternoon, while September and December show poor light comfort at midday. However, the latter appears to be more stable in the afternoon throughout the year.

The variation in the angular position of the sun during different periods of the day and seasons is evidence of this observation, as are the consequences for visual comfort, which depend on the orientation of the home and the light control devices used. For example, in summer, the sun reaches its zenith, making it easier to regulate solar radiation in openings, compared with other seasons when its lower position makes this regulation more complex.

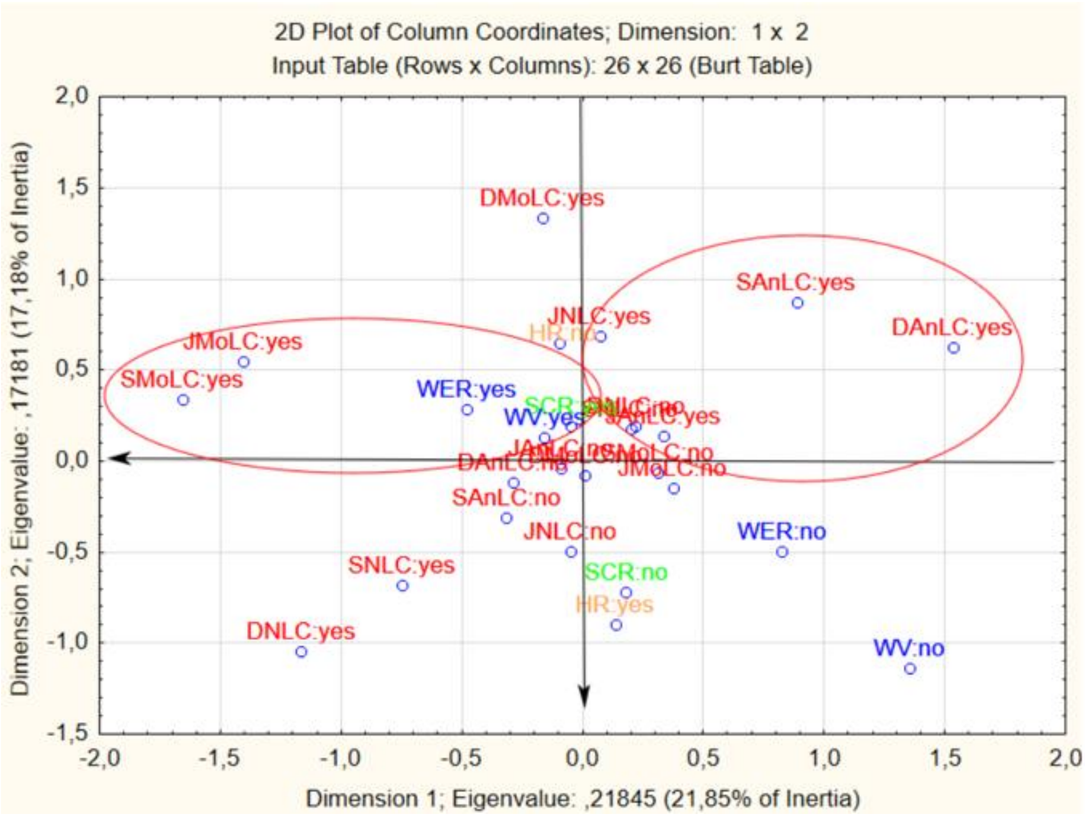


Figure 3.61 : Multiple correspondance results
(Source: Statistica entreprise, 2023)

III.6. Recommendations :

III.6.1. Specific recommendations :

III6.1.1. The Keramane house *:*

- In relation to natural light :

Rooms suffering from insufficient year-round light comfort should reorient their openings to maximize natural light or use devices such as skylights or light pipes... in cases where the introduction of new openings is not possible (as in the case of room 7). Spaces with non-uniform lighting, such as room 1, could benefit from anidolic lighting systems, light shelves... On the other hand, areas exposed to excessive brightness, resulting in glare, would require control devices such as reflective blinds or special glazing, or even awnings, to mitigate this effect.

- In relation to building materials :

Vertical walls offer satisfactory hygrometry and summer comfort, but insufficient thermal insulation, which justifies the need to insulate them with thermally insulating materials to optimize their performance. As for the roof, although it maintains adequate hygrometry, it suffers from poor thermal phase shifting and insufficient thermal insulation, requiring the addition of thermal insulation and the use of materials with appropriate thermal phase shifting.

- In relation to natural ventilation :

When it comes to insufficient ventilation in the kitchen, action needs to be taken to ensure adequate ventilation. This may involve installing a window on the opposite side of the room to promote through-ventilation, adding a chimney to facilitate air renewal, or possibly adopting a controlled mechanical ventilation (CMV) system.

III.6.1. 2. The Beni-ksila house *:*

- In relation to natural light :

Overall, this residence suffers from insufficient natural lighting, mainly due to the small size of the windows, which limits the penetration of natural light. To improve this situation, we recommend enlarging the openings, while ensuring protection from direct sunlight inside the dwelling.

- In relation to building materials :

In the case of walls and roofs, thermal insulation is deficient, requiring appropriate insulation using various insulating materials such as glass wool, rock wool, hemp wool or expanded polystyrene. These measures are designed to improve the home's thermal performance and achieve optimum insulation levels.

- In relation to natural ventilation :

The house benefits from adequate ventilation thanks to its chimneys. However, it is necessary to protect the house against prevailing winds in summer and winter, using trees placed in the directions corresponding to these winds.

6.1.3. The Plateau Amimoune house *:*

- In relation to natural light :

It's imperative to guard against excess solar radiation entering the living room and kitchen by using devices such as reflective blinds or awnings....

- In relation to building materials :

Vertical walls have poor thermal performance, justifying the need to insulate them with appropriate thermal insulation materials. Similarly, it is essential to apply adequate thermal insulation to the roof, while incorporating moisture-resistant materials such as glass wool or cork...

- In relation to natural ventilation :

Natural ventilation is guaranteed, so there's nothing to worry about.

III.6.1.4. The Gouraya house *:*

- In relation to natural light :

Overall, the home enjoys good lighting comfort, but it is essential to control openings to prevent glare caused by excessive sunlight penetration. This can be achieved by using devices such as awnings, reflective blinds, or special glazing...

- In relation to building materials :

Vertical walls have poor thermal performance, justifying the need to insulate them with appropriate thermal insulation materials. Similarly, it is essential to apply adequate thermal insulation to the roof, while incorporating moisture-resistant materials such as glass wool or cork...

- In relation to natural ventilation :

Ventilation of the house is satisfactory, but it is necessary to guard against winter and summer winds by planting windbreak trees, such as cypress, to effectively protect the house.

III.6.1.5. The house of Sidi Ali Lebher *:*

- In relation to natural light :

It is imperative to take steps to protect against the impact of the sun's rays, using the systems mentioned above. To remedy the lack of light in the hallway, it is advisable to bring in light from other rooms by installing glazed doors, such as those in the kitchen and living room.

- In relation to building materials :

As far as building materials are concerned, vertical walls have unsatisfactory thermal insulation, requiring the application of thermal insulation materials. The same applies to the roof, which must also be thermally insulated, with the addition of moisture-resistant materials.

- In relation to natural ventilation :

As far as natural ventilation is concerned, although the house benefits from good ventilation, it is necessary to protect against winds coming from the sea by using windbreak trees, for example.

III.6.2. General recommendations :

III.6.2.1. Relative to natural lighting *:*

- It's a good idea to orientate the openings in the various rooms of the house so as to maximize the incidence of natural light, considering seasonal variations. At the same time, control devices such as blinds or awnings should be provided to regulate undesirable effects such as overheating and glare.
- Spatial organization should favor south-facing living spaces, with bedrooms oriented towards the east and west cardinal points, while allowing for the creation of buffer spaces in the northern part.
- When direct access to natural light is impossible, we recommend alternative lighting systems such as skylights, or artificial lighting solutions that distribute light evenly throughout the room, such as anidolic lighting systems...

III.6.2.2. Relative to building materials *:*

- We recommend the use of materials with high thermal inertia, such as stone, capable of absorbing and releasing heat progressively, thus guaranteeing optimum thermal comfort, especially in summer.
- The use of moisture-resistant materials is recommended to ensure the comfort of occupants and the durability of the structure.
- Efficient insulation of house walls using thermally insulating materials such as glass wool or cork is essential.
- We recommend the use of natural materials such as stone, wood and terracotta, because of their renewable nature and low environmental impact.

III.6.2.3. relative to natural ventilation *:*

- Particular attention must be paid to the orientation of the house to minimize its direct exposure to prevailing winds.
- The use of windbreaks, such as plant walls, can be effective in mitigating the harmful effects of direct winds
- It's advisable to encourage internal air circulation by avoiding excessive obstacles that could impede its smooth flow.

- Adequate natural ventilation must be ensured in all rooms of the house, especially those prone to moisture accumulation such as the kitchen and bathroom.
- Through-ventilation is to be preferred for its beneficial effects on indoor air quality.
- Where natural ventilation is inadequate, the use of chimneys or mechanical ventilation systems is recommended to facilitate air renewal.
- Other ventilation systems, such as Canadian wells or double-flow ventilation systems, can be considered to ensure optimum performance of the ventilation system.

III.6.3. Multifunctional bioclimatic greenhouse:

The integration of multifunctional greenhouses on the south-facing facades of buildings is of significant importance, drawing on a conceptual heritage from horticultural greenhouses that promote a microclimate favorable to plant growth. According to research by Gratia and De Herde (2007), these structures play a crucial role in regulating humidity and temperature in adjacent areas, thereby contributing to occupant comfort.

According to the work of Liébard and De Herde (2006), these buildings are designed to optimize the use of natural resources such as sunlight and heat, as transitional spaces promoting solar absorption, where radiation is converted into heat via the greenhouse effect. Their design is carefully adapted to local climatic conditions, aiming to maximize solar gain in winter while preventing overheating in summer.

In agreement with these same authors, it should be noted that these structures are not intended for residential use in their own right, but rather envisaged as expansion zones or extensions, while possibly encouraging plant growth.

Liébard and De Herde point out that the optimal orientation for these greenhouses is towards the south, and their ideal configuration is characterized by a slender silhouette, with a depth of less than 2.5 meters and a height of two levels.

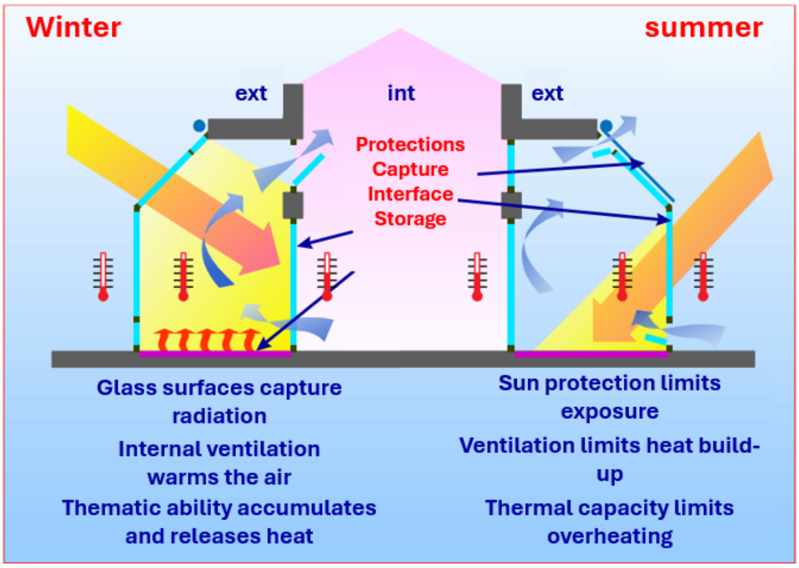


Figure 3.62 : Greenhouse operation in summer and winter
(Source: Liébard & De Herde, 2006)

The figure above shows how certain areas function in winter and summer. In winter, solar radiation heats the greenhouse air and preheats the fresh air. This provides an occasional place to stay despite wide temperature variations and acts as a buffer space to reduce heat loss to the outside. In summer, external solar shading and continuous ventilation limit the overheating of these spaces.

Figure 3.64 : House greenhouse (Source: https://www.ryde.nsw.gov.au, 2023)

Figure 3.63 : The Oxford Ecohouse greenhouse. (Source:tgbezine.greenbuilding.co.uk, 2023)

By combining these recommendations, it will be possible to create a bioclimatic home that combines comfort, energy efficiency and environmental preservation.

Conclusion :

According to the results of the home analysis, based on specific criteria including building materials, ventilation, and natural lighting, none of the five homes examined demonstrated optimum performance simultaneously for all three criteria. However, it is possible to identify construction elements and techniques that are conducive to satisfactory results. For example, the use of thick stone and clay walls (observed in the houses at Beni-ksila and Keramane), which offer excellent thermal inertia, as well as the adoption of sloping tile roofs, a clever layout of interior spaces to encourage efficient natural ventilation, These include good orientation and adequate spacing between buildings (as seen in the Gouraya house), the creation of a patio (as in the Keramane house) and the use of ventilation chimneys (in the Beni-Ksila house). In addition, the judicious orientation of the house and the design of its openings, combined with protective devices such as balcony overhangs (as observed in Sidi-Ali-Lebher), were also identified as factors contributing to improved performance in terms of thermal comfort and indoor environmental quality.

CHAPTER IV

Project Section

Introduction :

Designing bioclimatic residences for tourism in a coastal region such as the wilaya of Bejaia, characterized by its extensive and captivating coastline, requires a meticulous approach and exhaustive analysis. Careful site selection is an essential element, based on a rigorous assessment of the many factors impacting the viability and sustainability of the project. Location, accessibility, topographical features, land ownership, attractive landscaping and nearby tourist destinations must all be scrupulously examined. Each element contributes to shaping a favorable environment, promoting a habitat in symbiosis with its surroundings and in line with residents' aspirations.

In this chapter, we focus on the development of a bioclimatic approach for a project comprising collective, semi-collective and individual housing on the coast of the wilaya of Bejaia, more precisely in the commune of Tichy. A preliminary stage consists of an in-depth analysis of the project site, with a view to understanding its characteristics, advantages, and constraints, culminating in a structural diagram of the site.

In addition, in the light of the lessons learned from various examples in our field of study, an exploration is carried out to integrate the operational principles of these cases into our thinking and design, through the formulation of different scenarios. This approach also enables us to propose a program of action on two scales, both urban and architectural.

IV.1. Analysis of the site :

IV.1.1. Geographical location :

The site is located to the north of the commune of Tichy, around 12 km from the town of Bejaia. It is accessible from National Road No. 09 (RN09).

Figure 4.2 : Demarcation of the commune of Tichy.
(Source: Google earth pro processed by author, 2023)

Figure 4.1 : Location of the commune of Tichy in relation to the wilaya of Bejaia
(Source: Wikipedia, 2023)

IV.1.2. Selection criteria :

This site was chosen because it corresponds perfectly to our research theme of bioclimatic housing for tourist use, considering the following factors:

- **Geographical location**: About 100 meters from the sea, in the coastal zone.
- **Accessibility**: Easily accessible via the RN 09 trunk road linking the wilayas of Bejaia and Sétif.
- **Site characteristics**: The plot is regular and relatively flat, with three small sheds and a detached house that can be demolished.
- **Land ownership**: The land is privately owned, allowing unrestricted operation in an area not dedicated to tourist expansion.
- **Landscape quality:** offering panoramic views of the mountains and the sea, situated between the two.
- **Tourist appeal**: Positioned between two tourist infrastructures, the Hammadites hotel and the Capritour tourist village.

IV.1.3. Delimitation and immediate surroundings :

The plot is bordered to the east by the Hammadites hotel, to the west by the Capritour tourist village, to the north by the Hammadites beach (Mediterranean Sea) and to the south by the RN 09.

A few single-family homes are located to the south of the plot, along with a few tourist residences and hotels, as well as a forestry department and a civil protection unit.

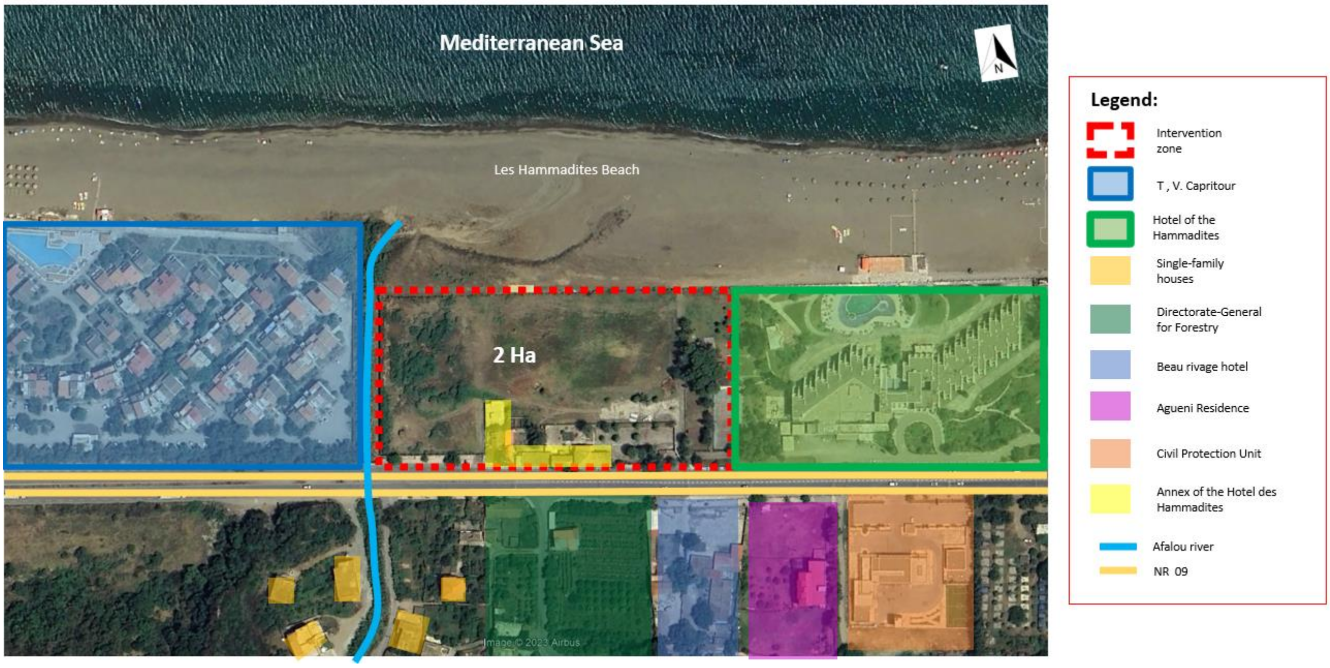


Figure 4.3 : plot boundary and immediate surroundings,
(Source: Google Earth processed by the author, 2023)

IV.1.4. Ambience outside the site :

Site ambiances are mentioned in this picture :

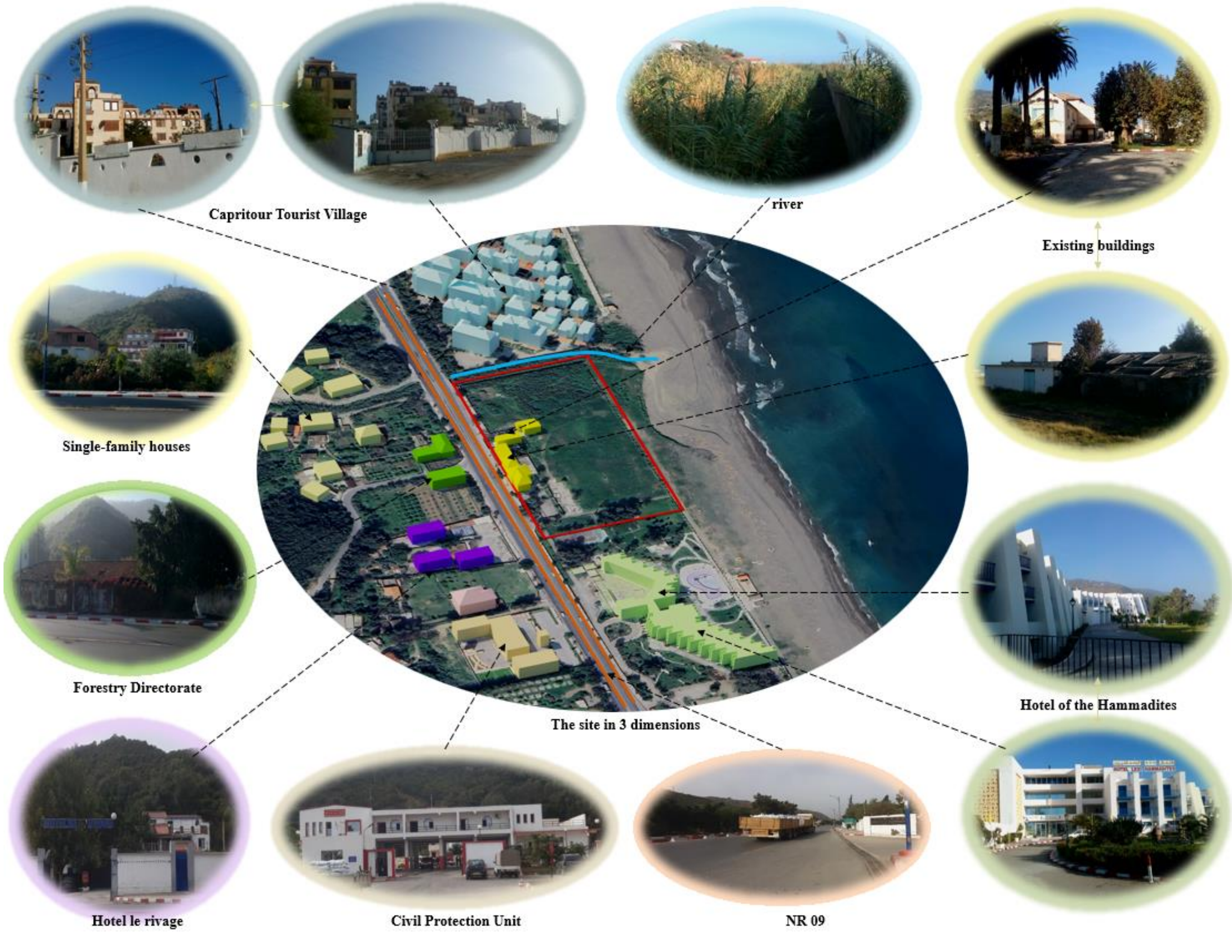


Figure 4.4 : Outdoor environment of the site (Source: Author, 2024)

IV.1.5. Schematic cross-section of the site :

The plot takes up an intermediate and separating position between the mountains and the sea.

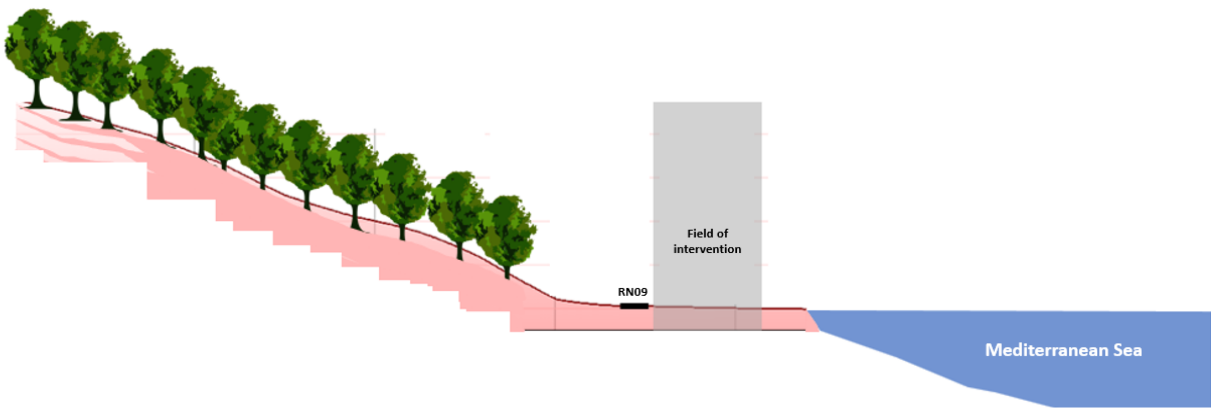


Figure 4.5 : Schematic section of the site.
(Source: Author, 2023)

The site boasts interesting views either to the sea or to the mountains, and it is therefore worthwhile directing the view towards the latter two.

Figure 4.7 : view towards the sea.
(Source: Author, 2023)

Figure 4.6 : view towards the mountain.
(Source: Author, 2023)

IV.1.6. Topographical sections :

The plot slopes gently along both longitudinal and transverse axes. It is relatively flat.

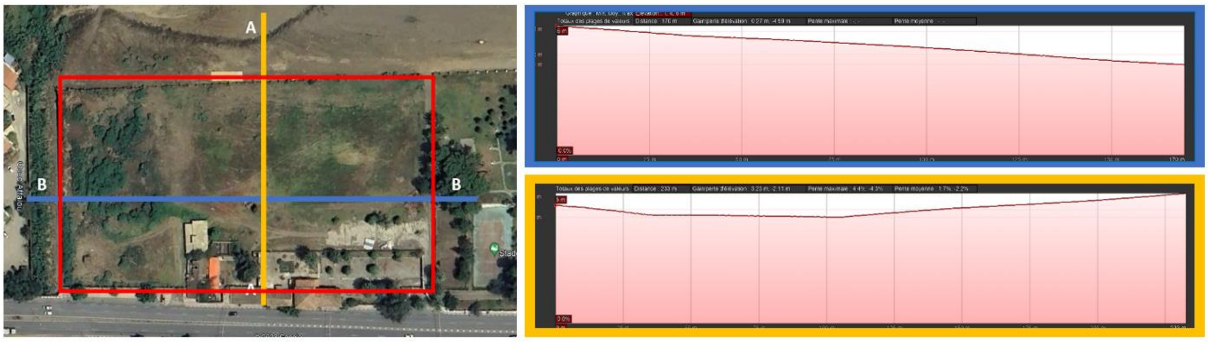


Figure 4.8 : Longitudinal and cross-sectional topography of the plot.
(Source: Google Earth processed by author, 2023)

IV.1.7 Sun path and prevailing winds :

IV.1.7.1. Sunshine *:*

Using the 'sunearth' interface, an exhaustive analysis was carried out of the solar path on the site in question. The conclusions drawn indicate that the said location benefits from optimum solar exposure, attributable to the absence of elevated structures, and by consequently, no shading effects are observed.

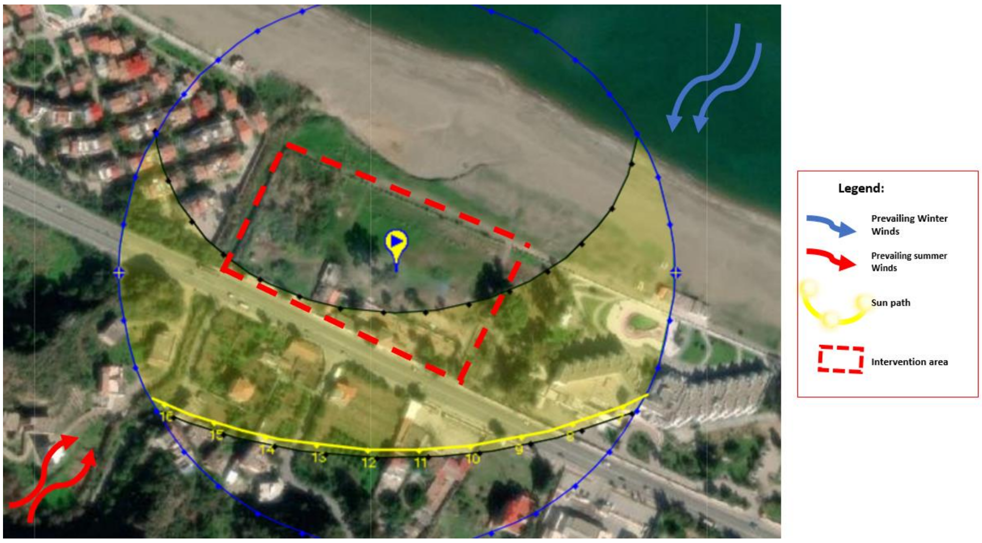


Figure 4.9 : Sun path of the plot.
(Source: sunearth.com processed by author, 2023)

IV.1.7.2. Prevailing summer and winter winds :

Using the "Autodesk Forma: cloud-based software for planning and preliminary design" interface, a predominant wind analysis was conducted to determine the main wind directions on the plot, both in winter and summer.

From the wind rose obtained, it was observed that the plot is directly exposed to summer winds coming from the Mediterranean side, with a medium speed, while winter winds come from the south-west, characterized by a notable speed. Consequently, despite the presence of a mountain to the south of the plot acting as a screen, it is imperative to protect against the latter.

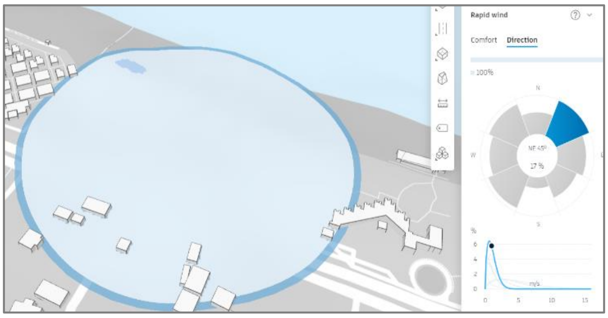


Figure 4.10 : Direction of prevailing summer winds (Source: Autodesk Forma, 2024)

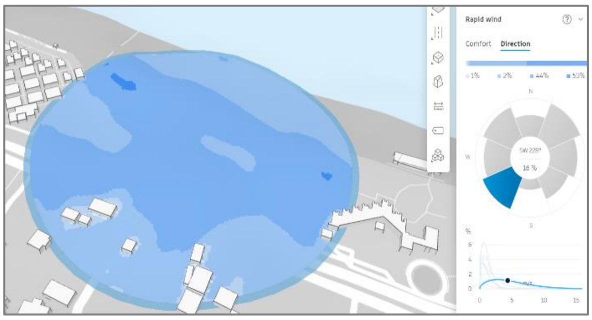


Figure 4.11 : Direction of prevailing winter winds (Source: Autodesk Forma, 2024)

IV.1.8. Shape and dimensions :

The plot has a regular rectangular shape and a surface area of 2 hectares,
It is 95 m from the sea.

Figure 4.12 : plot shape and dimensions.
(Source: Google Earth pro processed by author, 2023)

IV.1.9. Advantages and disadvantages of the site:

IV.1.9.1. Benefits *:*

- It is well served by the n09 trunk road.
- Between the sea and the mountains
- Strategic location between the Hammadites hotel and the tourist village of Capritour
- Breathtaking sea and mountain views

IV.1.9.2. Disadvantages *:*

- Noise generated by road traffic n09.
- Critical climatic conditions
- The passage of a wadi and the risk of its overflowing
- Tsunami risk

IV.2. structure diagram:

After analyzing the site, we synthesize all the information in this diagram:

In 2D :

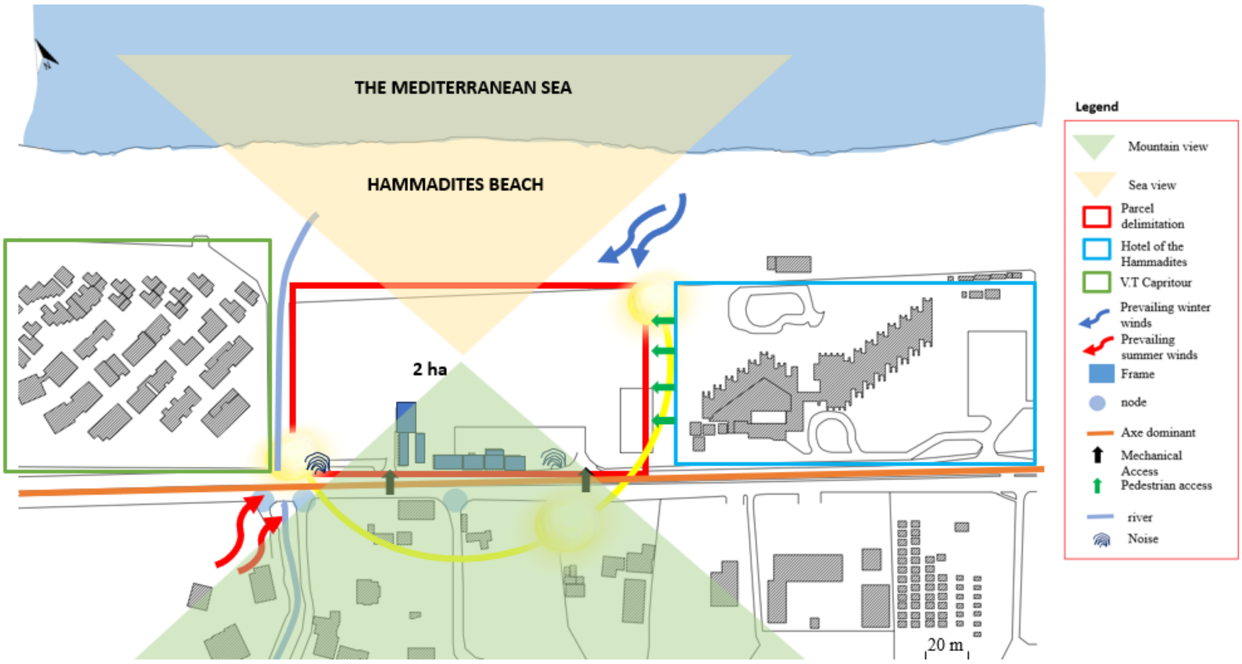


Figure 4.13 : Existing 2D structure diagram.
(Source: Author, 2023)

In 3D :

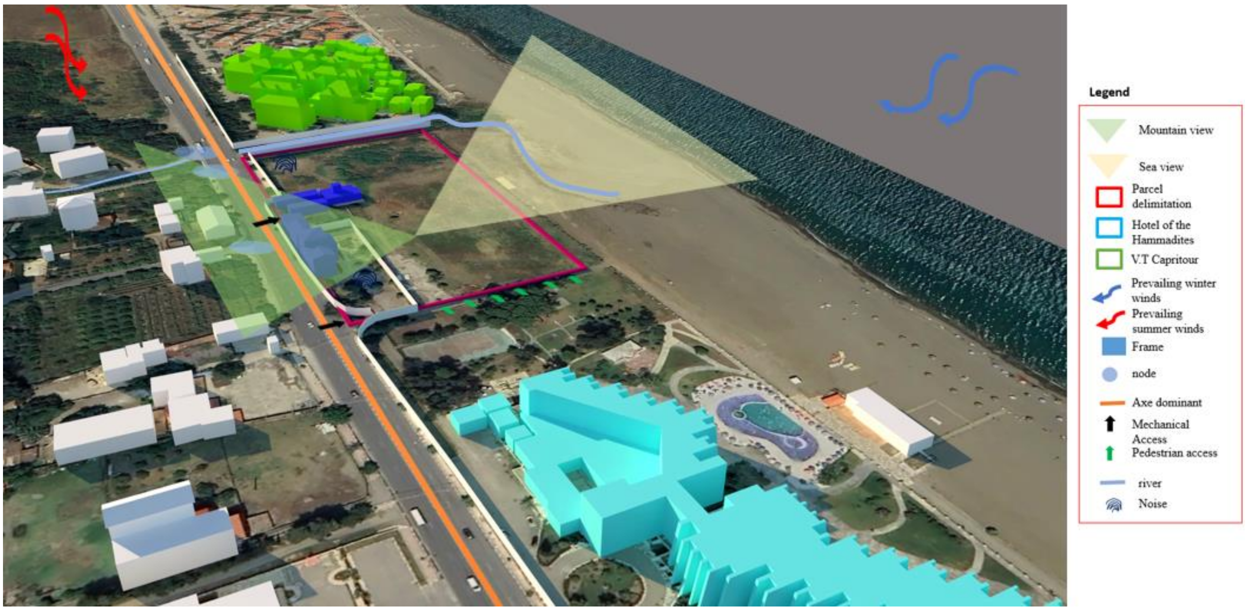


Figure 4.14 : Existing 3D structure diagram.
(Source: Author, 2023)

IV.3. Analysis of examples :

Before embarking on the design of the project, it is crucial to examine local and international examples dealing with themes similar to our own. This analysis will enable us to draw inspiration, discover the various concepts and methods used, and thus define a program for the urban and architectural part of the project.

Finding the ideal model of bioclimatic architecture in our region was crucial to our research. Faced with the challenges of limited resources, we opted for the very first bioclimatic home to be built in Algeria. It represents a solution adapted to the local constraints of sustainable building.

In addition, two international examples of bioclimatic construction were examined. Firstly, an individual house designed by the illustrious Frank Lloyd Wright, harmoniously integrating its natural surroundings. Secondly, semi-collective housing in Cambridge, UK, offering a different perspective.

Here is a detailed analysis of these cases:

IV.3.1. Prototype house in Souidania :

A cooperative venture between CDER (Centre de Développement de Énergies Renouvelables) and CNERIB (Centre National d'Etudes et de Recherches Intégrées du Bâtiment), the project has been selected to create a highly energy-efficient rural habitat on the CNERIB site in Souidania.

- **Technical data :**

Table 4-1 Project data sheet
(Source: Author,2023)

Completion date	2007
Opening date	2010
Location	Souidania, Algiers, Algeria
Project manager	CNERIB - CDER
Owner	MED-ENEC
Surface	90 m²

Figure 4.18 : Souidania house
(Source: Hamidat, 2016)

- **Situation:**

It is located in the south-eastern part of the Souidania commune (south-west of the capital).

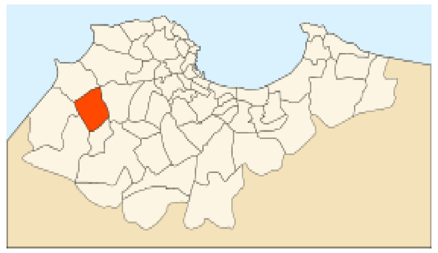


Figure 4.16 : Location of Souidania commune in relation to the wilaya of Algiers
(Source: Wikipedia, 2023)

Figure 4.15 : Location of the project in relation to the commune of Souidania (Source: Google Earth pro, processed by author, 2023)

- **Immediate surroundings and accessibility :**

Access to the project is via the housing estate, located along a tertiary road leading to the main axis, the route de la wilaya (W133). The project site is characterized by a dispersed mass layout, offering good air circulation. It is bounded to the north by a boundary wall, to the east by internal distribution routes, to the south by the city stadium, and to the west by the national center for integrated building studies and research.

Figure 4.17 : Location and immediate surroundings of the project.
(Source: Google earth pro processed by author, 2023)

- **Form :**

It is rectangular in shape, with a pitched gable roof.

- **Orientation:**

It is rectangular in shape, with a pitched gable roof.

Figure 4.20 : orientation of the project with the path of the sun
(Source: Google Earth processed by author, 2023)

- **Internal organization :**

A residential project, this F3 house is located in a rural area of Souidania. It comprises two bedrooms, a living room, WC, bathroom, kitchen, and veranda. The first bedroom faces southwest, while the second faces northwest. The living room benefits from a large south-facing window, to maximize natural lighting by letting in as much light as possible. There is also a French window to the east. The kitchen is on the east side, while the bathroom and toilet face north.

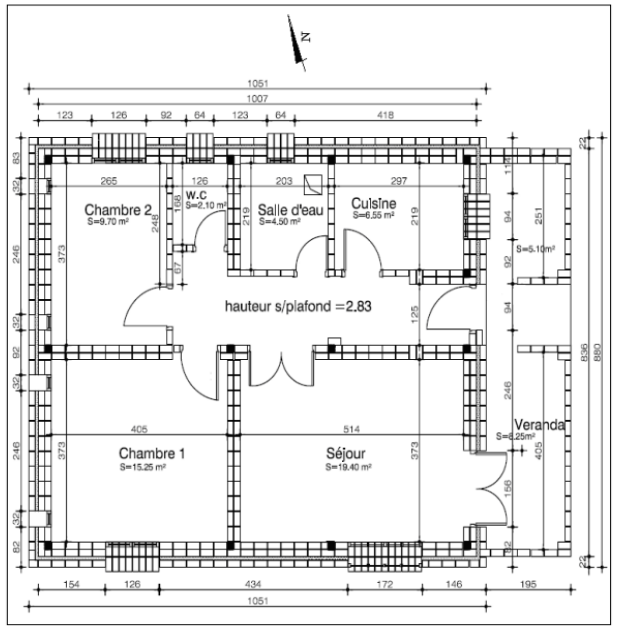


Figure 4.19 : House plan
(Source: Derradji et al., 2023)

- **Building materials :**

Table 4-2 : Building materials
(Source Mekhoukh and Addalou, 2020),

	Composition	Epaisseur (m)	R = e/λ (m2k/W)	Rg (m2k/W)	U (W/m2.K)
Mur Extérieur	1. BTS 2. Polystyrène 3. BTS	0,14 0,09 0,29	0,11 2,25 0,22	2,58	3,22
Plancher Bas	1. Béton lourd 2. Polystyrène expansé 3. Béton lourd 4. Mortier + sable 5. Carrelage	0,05 0,06 0,15 0,03 0,02	0,03 1,50 0,09 0,03 0,01	1,65	1,16
Plancher Haut	1. Tuile en terre cuite 2. Chevrons 3. Comble 4. Couche de mortier 5. Polystyrène expansé 6. Béton lourd 7. Voûtain en plâtre	0,03 0,16 0,08 0,04	0,02 4,00 0,05 0,11	4,18	2,94

Wood frame, red tile for the roof, compressed and stabilized earth brick for the load-bearing walls.

BTS, a local material, is the concrete of stabilized earth.

- **Summary :**

The house's design incorporates ecological principles to ensure comfort without mechanical equipment. Rectangularly oriented towards the north-west, it benefits from the warmth of the sun in winter, avoiding overheating in the afternoon. The gable roof allows fresh air to circulate. Thick, stabilized earth walls absorb night-time coolness and diffuse it during the day. Wooden windows minimize heat loss. This sustainable design, well adapted to the local climate, reduces the need for air conditioning, saves energy and provides a healthy, pleasant home.

IV.3.2. Single-family house (Jacob II house by Frank lloyd Wright)

Seven years after building a Usonian-style house for the Herbert Jacob family, Frank Lloyd Wright was asked to design a second residence. This time, the request was to adapt the house to the cold northern climate. To meet this challenge, Wright created a concept he called "The Solar Hemicycle". This scheme involves a circular structure that buries itself on the north side and opens onto a recessed garden, forming a south-facing glazed cavity. The embankment to the north and the thick stone wall act as protection against the prevailing winds, providing the house with warmth in winter and coolness in summer (Wikiarquitectura, n. d).

- **Technical data :**

Table 4-3 House data sheet
(Source: Author, 2023)

Completion date	1944
Opening date	1948
Location	Middleton, Wisconsin, USA.
Project manager	Frank Lloyd Wright
Owner	Herbert and Katherine Jacobs
Surface	80 m²

Figure 4.23 : Jacob II house,
(Source: green-cincinnati.com, 2023)

- **Situation**

The Jacobs II house is located in the southern part of the state of Wisconsin (Wisconsin is in the northern part of the United States), in a rural setting, with access from Old Sauk Road via Shawn trail.

Figure 4.28 : Wisconsin situation
(Source: https://www.brecks.com, 2023)

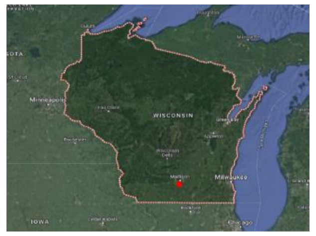


Figure 4.27 : Location of house
(Source: Google Earth processed by author, 2023)

- **Delimitation and accessibility**

Bounded by Old Sauk Road to the north, Shawn Trail to the east, homes to the west and south.

Figure 4.30 : boundary and immediate surroundings.
(Source: Google Earth processed by Auteur, 2023)

- **Form :**

The house has a compact shape that resembles a semicircle, with a 120º circumferential arc where the ends of the wall and planters complete this form. This architectural singularity has earned it the nickname "Solar Hemicycle".

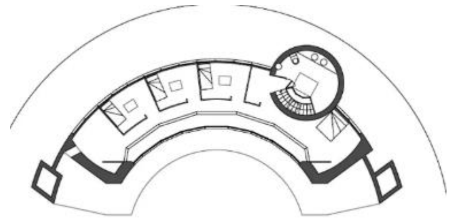


Figure 4.22 : House plan.
(Source: Syken, 2020)

The inner garden is excavated to around 1.5 meters below the original floor in the room. The earth material extracted during this work was used to fill in the northern slope. As a result, a difference in level is created between this underground garden and the outside environment, which prevents draughts and promotes the circulation of calming air, providing a comfortable atmosphere

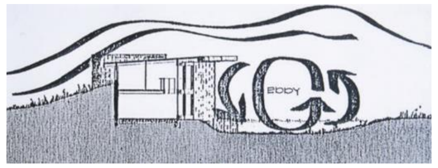


Figure 4.24 : Wind effect on the house
(Source: Syken, 2020)

- **Orientation:**

The house is designed with an opaque wall to the north to protect it from the wind and outside view, while the glazed facade faces south to benefit from the sunshine and retain heat throughout the day. Herbert Jacobs recounts an anecdote in which Frank Lloyd Wright assured him that, thanks to this design, he could stand in the garden of his house, sheltered from the wind, and light his pipe without worry, thus creating a zone of refuge protected from the cold northerly winds.

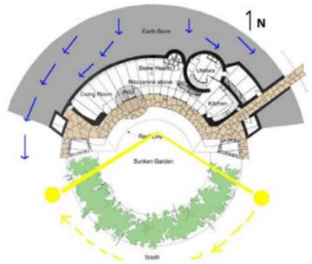


Figure 4.32 : orientation of the house (Source: Syken, 2020)

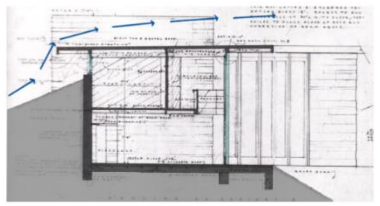
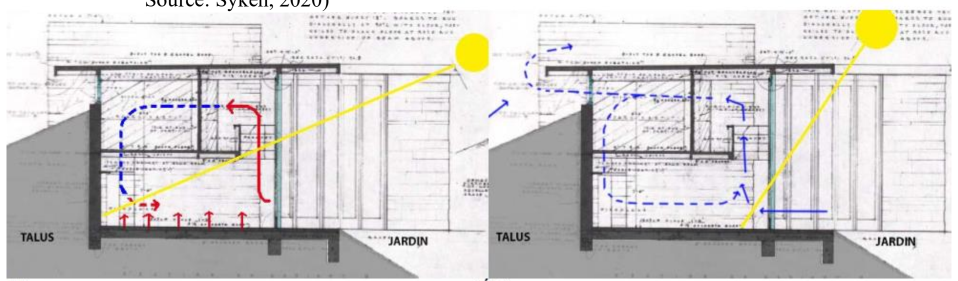


Figure 4.29 : Wind protection (Source: Syken, 2020)



Hiver Été

Figure 4.31 : Sun protection (Source: Syken, 2020)

- **Internal organization :**

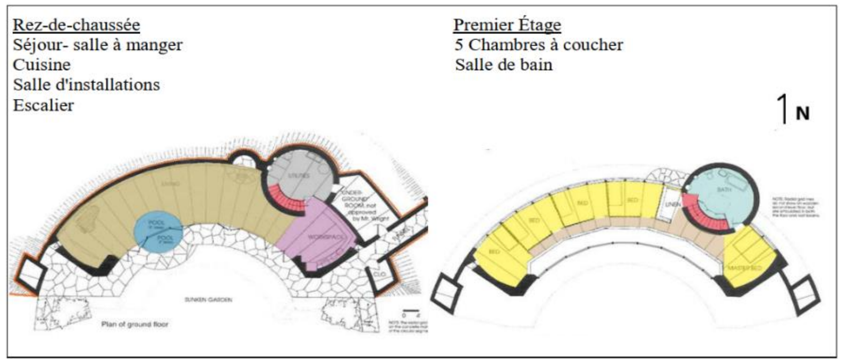


Figure 4.21 : Interior layout of the house (Source: Syken, 2020)

The apartment has two floors: the first floor is completely open, with living room, kitchen, staircase, and utility room. The second floor is set back from the first floor, leaving a 1.15-meter gap from the south glass curtain wall, creating an adjacent double height that connects the two floors. There are five bedrooms and one bathroom on this floor.

- **Building materials :**

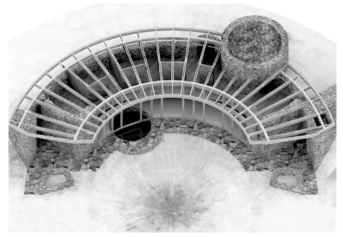


Figure 4.25 : House construction system
(Source: Syken, 2020)

Figure 4.26 : Building materials.
(Source: Syken, 2020)

The house's load-bearing vertical walls are made of a double wall of limestone (90cm) and wooden pillars in the southern section, which form the glazed façade. The roof structure is composed of wooden beams.

- **Summary :**

The "Maison Jacobs II", designed by Frank Lloyd Wright, incorporates innovative bioclimatic principles. Its compact, semi-circular shape captures the maximum amount of sunlight, minimizing heat loss. The orientation of the house and the layout of the rooms ensure natural ventilation. Large south-facing windows and integrated underfloor heating optimize passive solar gains. In addition, the design aims to blend into the environment, reducing the house's ecological footprint.

IV.3.3. Highsett: bioclimatic semi-collective housing in Cambridge :

Highsett is a residential area developed between 1959 and 1964 in Cambridge, England, on a 4-hectare site. It comprises three types of housing: Quad apartments, L-shaped houses, and a cul-de-sac of townhouses. The area benefits from a privileged location outside the center of Cambridge and an existing mature landscape. Each home has a well-sheltered private garden or courtyard, creating a clear division between private and public space. (Urbed, 2006)

Table 4-5 : House data sheet (Source: Author, 20023)

Completion date	1959
Opening date	1964
Location	Hills road, Highestt, Cambridge/ England
Project manager	Eric Lyons and partners
Owner	Status
Surface	P : 7780 m² - c : 148 m²

Figure 4.33 : Houses (Source: modernism-in-metroland.co.uk, 2023)

- **Situation:**

The complex is located in Hills Road, Highsett Cambridge in the east of England.

Figure 4.42 : Highsett Cambridge location. (Source: Wikimedia, 2023)

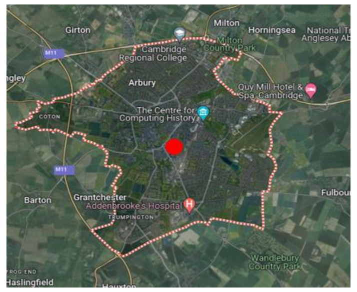


Figure 4.35 : Location of house (Source: Google Earth processed by Author, 2023)

- **Delimitation and accessibility :**

The homes are located in a residential area, surrounded by a group of houses to the east and west, Tension Ave and houses to the north and Hills Road to the south. They are accessible from all three roads: Hill and Glisson and Tension

Figure 4.34 : Delimitation and immediate surroundings of the house (Source: Google Earth processed by Author, 2023)

- **Orientation:**

Table 4-4 House orientation (Source: Author, 2023)

type	orientation
	north/south
	South-East/North-West
	North-east/south-west
	East/West

The homes have four different orientations.

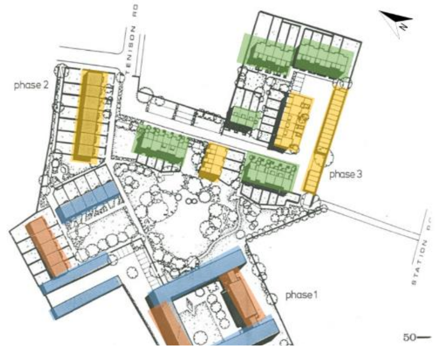


Figure 4.41 : orientation of homes. (Source: urbed, 2006 processed by author, 2023)

- **Plans and sections :**

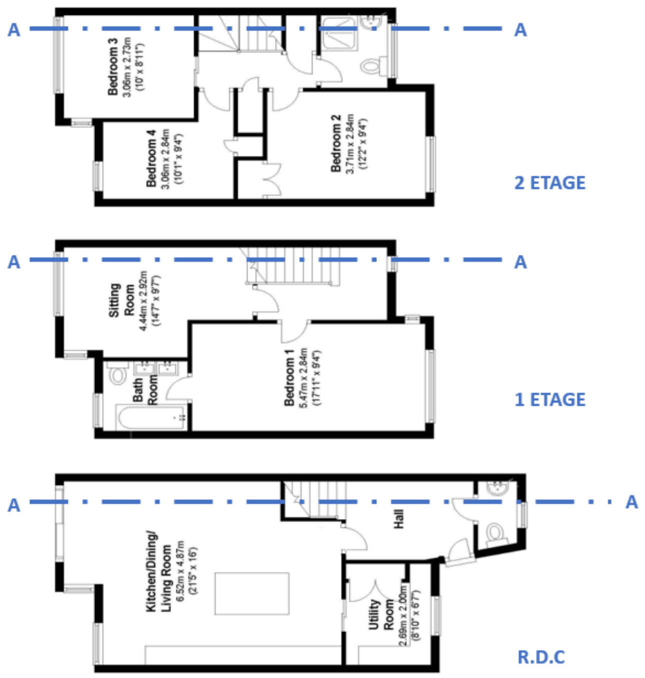


Figure 4.37 : House plans (Source: mediaonthemarket.com, 2023)

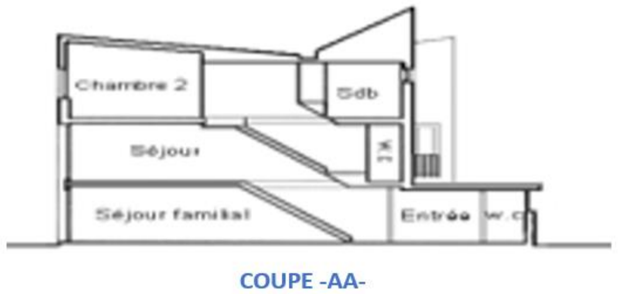


Figure 4.36 : Cross-section of housing (Source: mediaonthemarket.com, 2023)

- **Building materials :**

The house is built of gabled brick, the roofs slope inwards towards a central gutter, and roof glazing is used to light the bathrooms and staircases.

- **Sun paths and prevailing**

Figure 4.38 : sun path. (Source: urbed, 2006 processed by author, 2023)

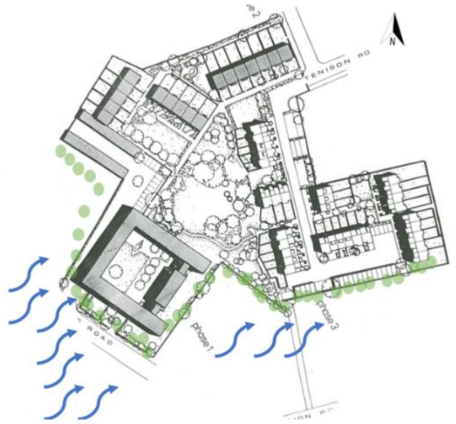


Figure 4.39 : wind direction. (Source: urbed, 2006 processed by author, 2023)

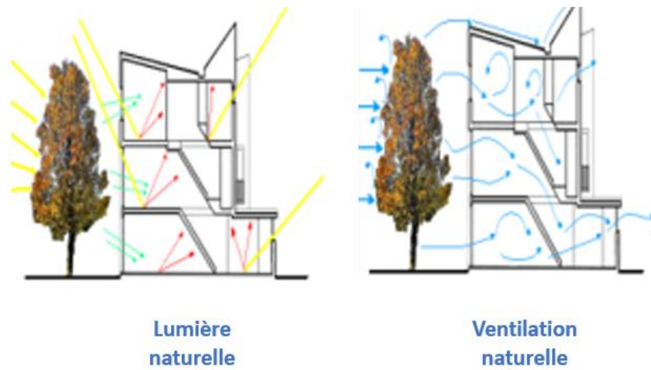


Figure 4.40 : Effect of wind and solar radiation on the home. (Source: mediaonthemarket.com, 2023)

- **Summary :**

The houses are planned to benefit from maximum sunlight and natural ventilation, generally facing south-east and south-west, with the use of trees to protect against prevailing winds and excessive sunlight. Natural lighting is favored by sloping roofs and dormer windows. Draughts are created by the layout of openings to optimize natural ventilation.
Three types of housing, combining density and tranquility, integrate spaces which contribute to the semi-collective aspect of the project, offering a sustainable, harmonious living environment.

General summary :

Based on the analysis of these three examples, the principles to be followed in my own project, which is the bioclimatic housing complex, are :

- Optimization of sunlight and natural ventilation:
  - Orient homes to the southeast and southwest to benefit from the sun.
  - Use trees as a barrier against prevailing winds and excessive sunlight.
  - Promote natural lighting with pitched roofs and dormer windows.
  - Create draughts by positioning openings for effective natural ventilation.
- Integration of private outdoor spaces for a semi-collective look:
  - Combining density and tranquility in housing design.
  - Integrate private outdoor spaces to promote the semi-collective aspect of the project.
  - Offer a sustainable and harmonious living environment by promoting conviviality and community life.
- Innovation and environmental integration :
  - Design compact shapes to capture maximum sunlight and reduce heat loss.
  - Ensure effective natural ventilation through the orientation and layout of rooms.
  - Optimize passive solar gain with large south-facing windows and integrated underfloor heating.
  - Reduce the ecological footprint by integrating green principles into design.
- Design adapted to the local climate for comfort without mechanical equipment:
  - Orient homes to benefit from the sun's warmth in winter and avoid overheating in the afternoon.
  - Promote fresh air circulation with a gable roof.
  - Propose a composition of exterior walls for efficient thermal performance.

IV.4. Proposed program :

Based on the analysis of these examples, and some prerequisites, I proposed the following two-part program: urban and architectural.

IV.4.1. Urban area :

Table 4-6 : Urban area program (Source: Author, 2024)

<table>
<tr><th>Spaces</th><th colspan="2">Subspaces</th><th colspan="2">Partial surface</th><th>Total surface area</th></tr>
<tr><td rowspan="5">Built space</td><td rowspan="3">Homes</td><td>H. collective</td><td>780 m^2</td><td rowspan="3">3880 m^2</td><td rowspan="5">3980 m^2</td></tr>
<tr><td>H. semi-collective</td><td>1500 m^2</td></tr>
<tr><td>H. Individual</td><td>1600 m^2</td></tr>
<tr><td colspan="2">Technical rooms</td><td colspan="2">50 m^2</td></tr>
<tr><td colspan="2">Guard post</td><td colspan="2">50 m^2</td></tr>
<tr><td rowspan="10">Unbuilt space</td><td colspan="2">Parking lots</td><td colspan="2">545 m^2</td><td rowspan="10">24000 m^2</td></tr>
<tr><td colspan="2">Green spaces</td><td colspan="2">9200 m^2</td></tr>
<tr><td rowspan="6">Relaxation areas</td><td>Children's play area</td><td colspan="2">1200 m^2</td></tr>
<tr><td>Play area for adults</td><td colspan="2">1500 m^2</td></tr>
<tr><td>Family consumption areas</td><td colspan="2">1200 m^2</td></tr>
<tr><td>Family pool</td><td colspan="2">1400 m^2</td></tr>
<tr><td>Open-air theater</td><td colspan="2">600 m^2</td></tr>
<tr><td>Public rest area</td><td colspan="2">500 m^2</td></tr>
<tr><td rowspan="2">Traffic areas</td><td>Pedestrian traffic</td><td colspan="2">6000 m^2</td></tr>
<tr><td>Mechanical traffic</td><td colspan="2">1900 m^2</td></tr>
</table>

IV.4.2. Architectural part :

Based on the analysis of the various examples and prerequires, I proposed a detailed program for the three homes to be designed as follows:

IV.4.2.1. Collective housing *:*

Table 4-7 : Surface program for multi-family houses (Source: Author, 2024)

designation	Surface
stay	20 - 30 m^2
S.A.M	10 - 12m^2
hall	10 - 12 m^2
kitchen	8 - 12 m^2
Room 01	14 -16 m^2
Room 02	14 -16 m^2
Conjugal suite	20 -24 m^2
Bathroom	4- 6 m^2

PL		0.8 - 1 m²
Living area		**96.8 - 129 m²**
Loggia		15 - 20 m²
Balcony		3 - 4 m²
Surface area		**114.8 - 153 m²**

IV.4.2.2. Semi-collective houses *:*

Table 4-8 : Surface program for homes semi-collective (Source: Author, 2024)

designation	**Surface**
stay	25 - 30 m²
hall	8 - 10 m²
kitchen	12 -16 m²
S.A.M	12 - 14 m²
Room 01	12 -16 m²
Guest room	16 - 24 m²
Conjugal room	16 - 24 m²
Bathroom	6 - 8 m²
W.C	4 - 5 m²
PL	0.8 - 1.2 m²
Living area	**111.8 - 148.2**
Entrance porch	1.5 - 3 m²
Balcony	6 - 8 m²
cellar	5 - 8 m²
Surface area	**124.3 - 157.2 m²**

IV.4.2.3. Single-family homes *:*

Table 4-9 : Surface program for single-family homes (Source: Author, 2024)

designation	**Surface**
stay	25 - 30 m²
Hall and stairs	10- 15 m²
kitchen	12 - 16 m²
S.A.M	10- 15 m²
Room 01	12 - 16 m²
Room 02	12- 16 m²
Bathroom	5 - 6 m²
W.C	4 - 5 m²
PL	0.6 - 0.8 m²
Living area	**90.6 - 120 m²**
Entrance porch	1.5 - 3 m²
balcony	5 - 8 m²
Veranda	30 - 35 m²
Surface area	**127 - 166 m²**

IV.4.3. Spatial and functional organigrams :

Based on the analysis of examples, and some prerequisites, I proposed these three spatial and functional organigrams for the three proposed typologies :

- **Single-family homes :**

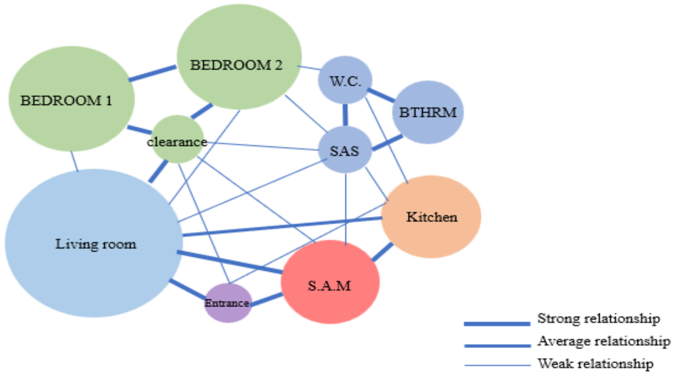


Figure 4.43 : Spatial-functional organization chart for single-family homes (Source: Author,2024)

- **Semi-collective houses :**

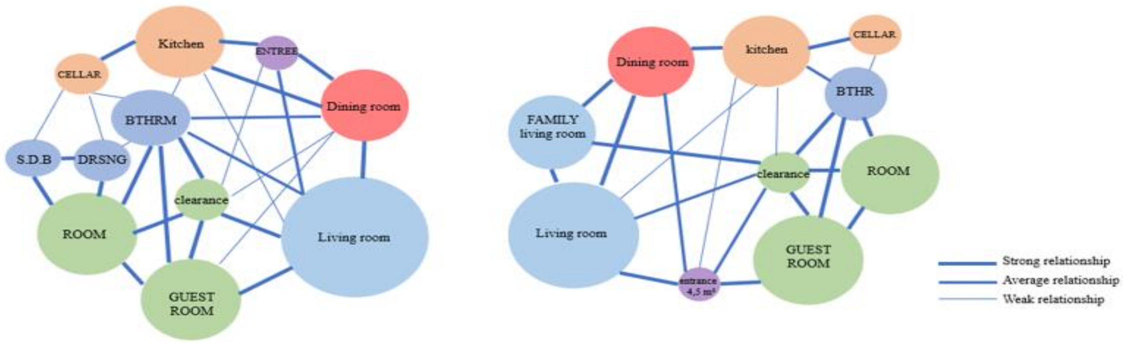


Figure 4.44 : Spatial and functional organization chart for semi-collective houses. (Source: Author, 2024)

- **Multi-family housing :**

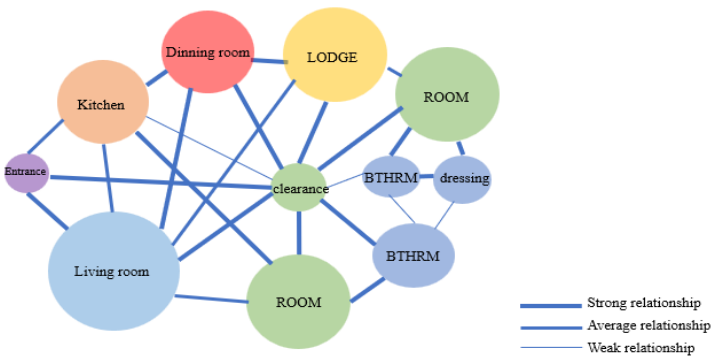


Figure 4.45 : Spatial and functional organization chart for multi-family houses (Source: Author, 2024)

IV.5. Proposed structure diagram :

After analyzing the site and a number of examples, and after careful consideration, I've come up with this schematic diagram of a few actions represented in two and three dimensions.

In 2D :

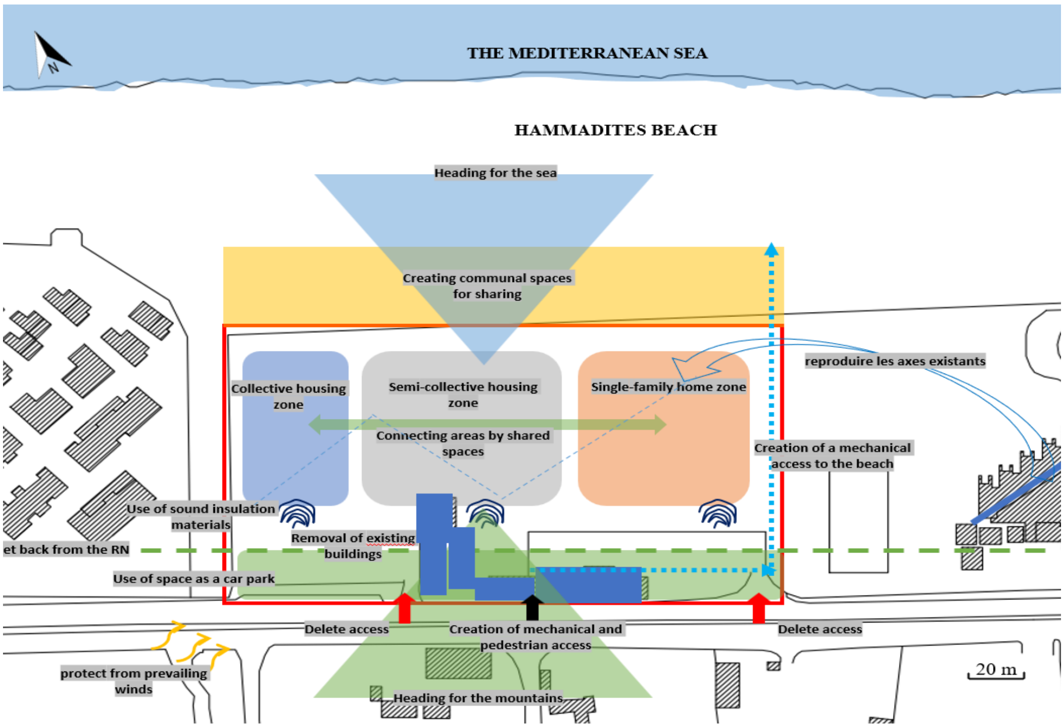


Figure 4.46 : Proposed 2D structure diagram (Source: Author, 2024)

In 3D :

Figure 4.47 : Proposed 3D structure diagram (Source: Author, 2024)

IV.6. Proposed scenarios :

IV.6.1. First scenarios :

The first scenario involves creating three zones corresponding to the three proposed typologies. These zones are connected by common spaces using organic and sinuous compositional lines, but they recall the straight compositional lines existing on the site

In 2D :

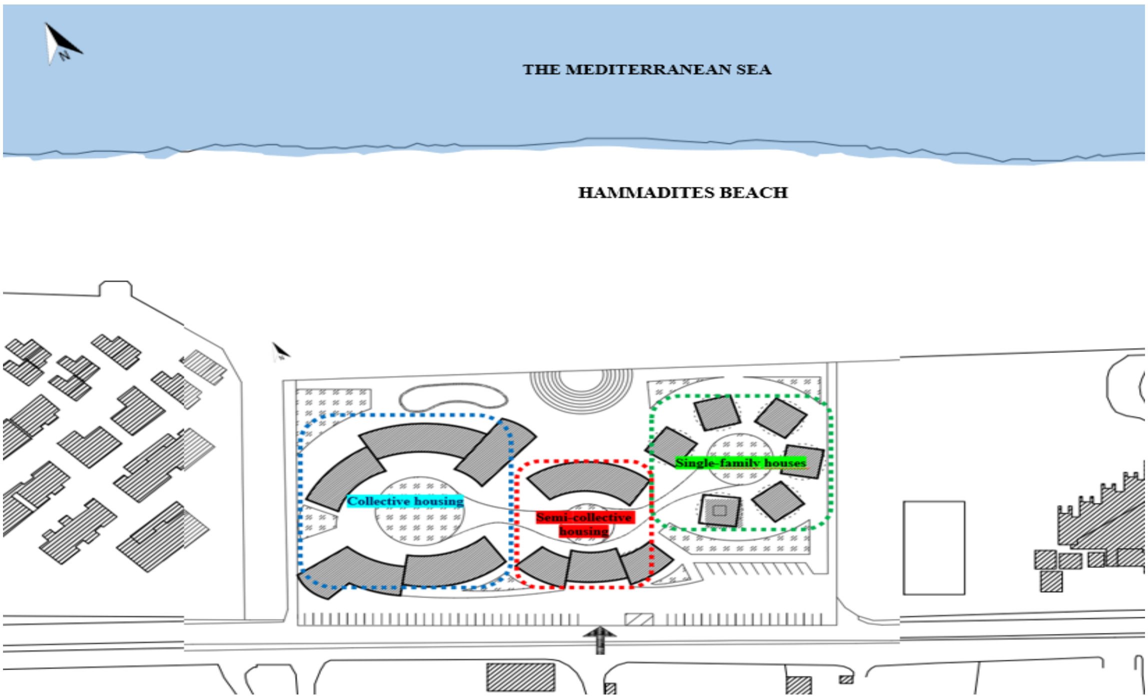


Figure 4.48 : Proposed 2D scenario 1 (Source: Author, 2024)

In 3D :

Figure 4.49 : Proposed 3D scenario 1 (Source: Author, 2024)

IV.6.2. Second scenario :

The second scenario involves placing the dwellings in a linear arrangement following the compositional axes of the surrounding buildings. The collective and semi-collective dwellings are connected by common spaces, with small connections to the individual dwellings that maintain an aspect of privacy by being positioned around their own common spaces.

In 2D :

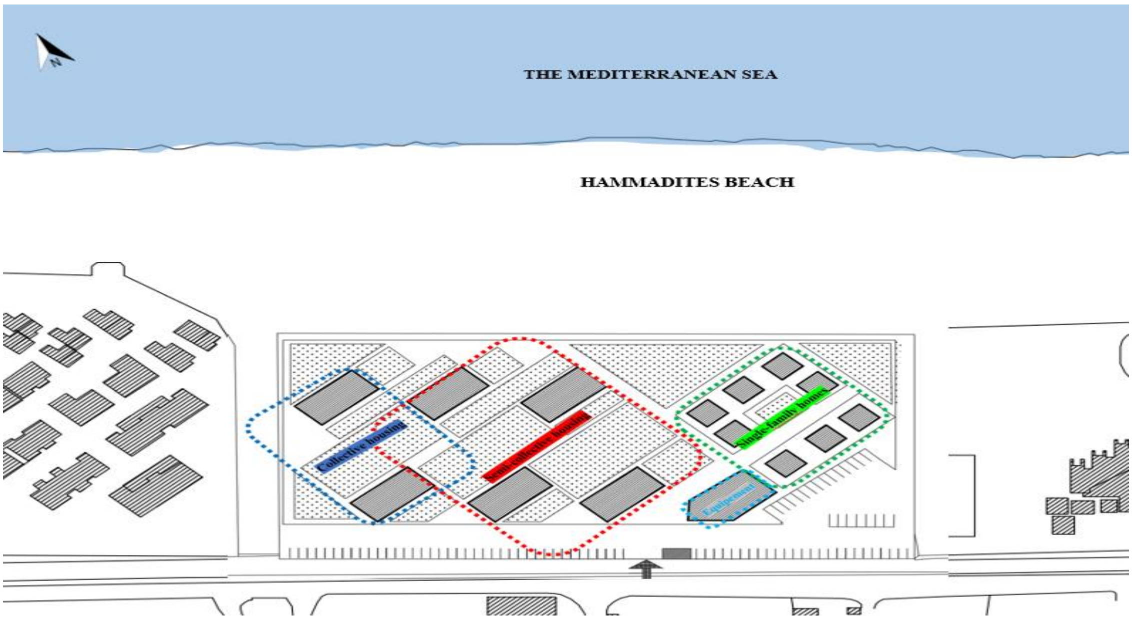


Figure 4.50 : Proposed 2D scenario 2 (Source: Author, 2024)

In 3D :

Figure 4.51 : Proposed 3D scenario 2 (Source: Author, 2024)

IV.6.3. Third scenario :

The third scenario resembles the second but with a difference: it connects the common space of the individual dwellings with that of the semi-collective and collective dwellings. This involves changing the arrangement of the individual dwellings to a circular composition, which allows for the linking of these spaces.

In 2D :

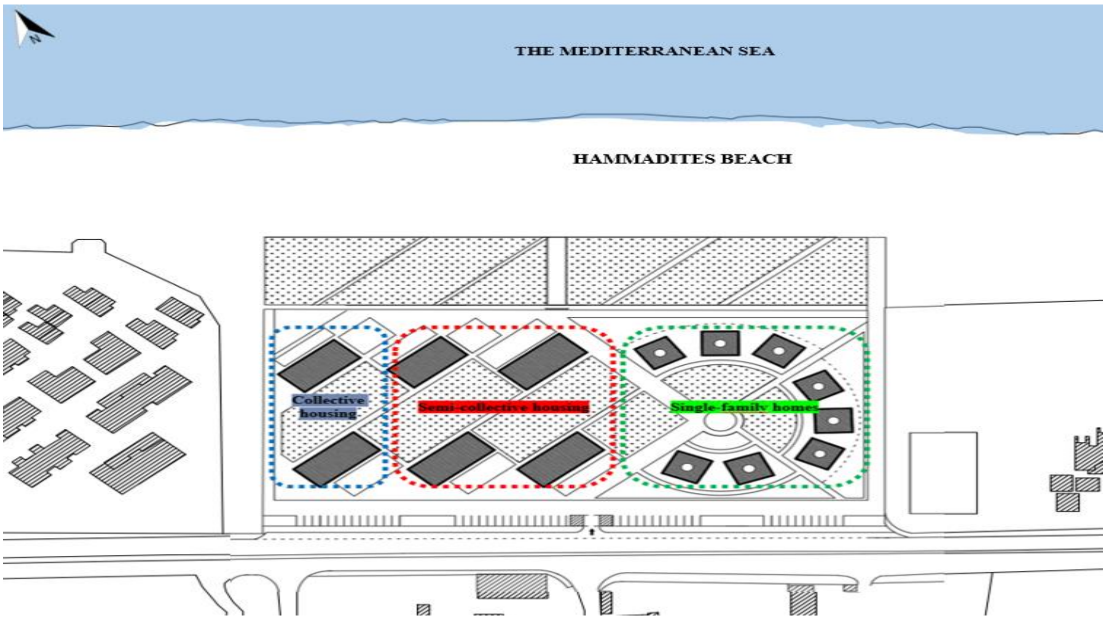


Figure 4.52 : Proposed 2D scenario 3 (Source: Author, 2024)

In 3D :

Figure 4.53 : Proposed 3D scenario 3 (Source: Author, 2024)

IV.6.4 Selected scenario :

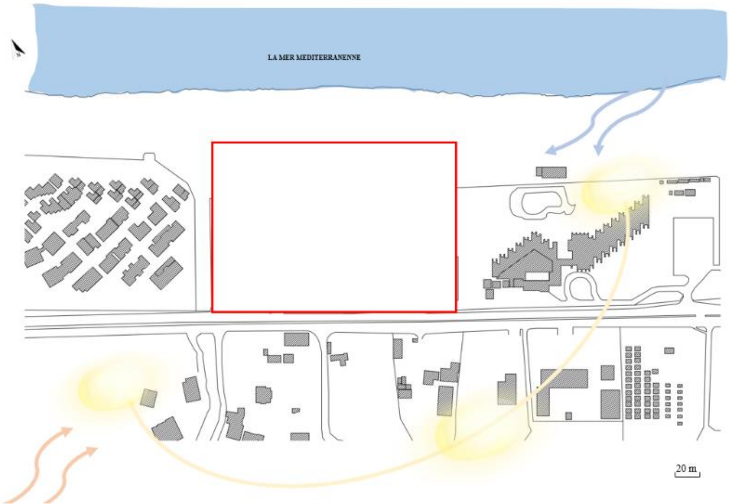
Scenario number three was chosen because it respects both the natural environment (climatic conditions: prevailing winds, sunshine) and the existing built environment. In fact, this scenario proposes regular geometric shapes structured along existing axes, which structure the buildings in the immediate environment, unlike the first scenario. Moreover, it ensures the connection between the three public spaces relating to the three types of housing proposed - individual, semi-collective and collective - unlike the second scenario, where the public space for individual housing is not connected to the rest of the public spaces. In this way, the third scenario optimally meets the required conditions, justifying its choice for the development of the project.

IV.7. Ideation and morphogenesis :

IV.7.1. The urban area :

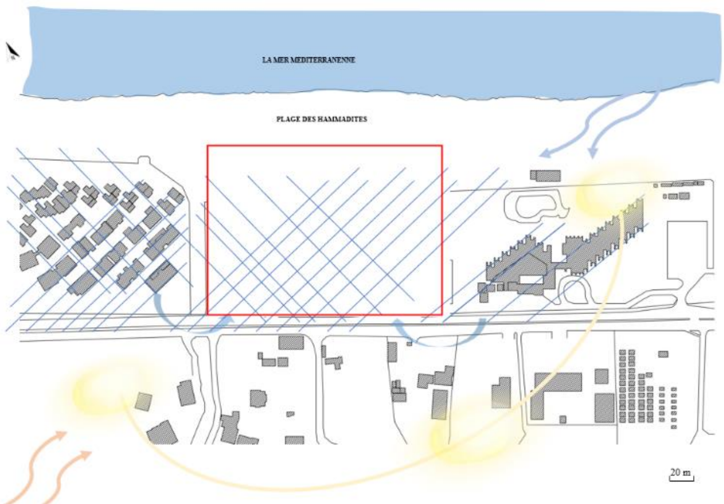
This section looks at the idea and morphogenesis of the urban layout of the plot, from its initial demarcation to the organization of the housing blocks.

The various steps are presented in diagrammatic form, with brief explanatory notes.



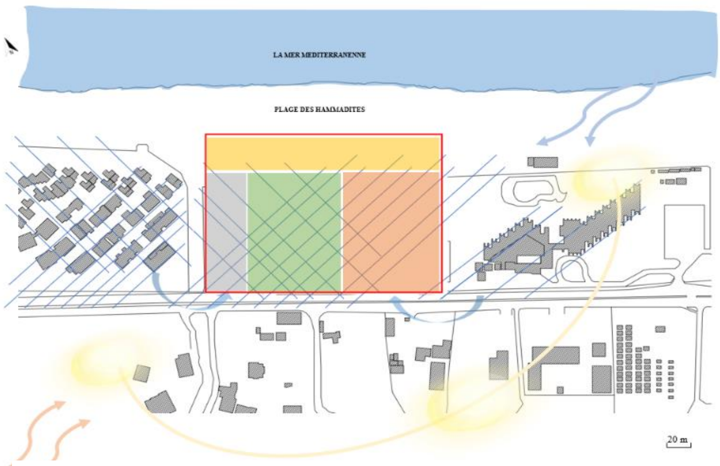
Delimitation of the plot and its immediate surroundings and environmental data.

Figure 4.54 : plot boundary (Source: Author, 2024)



Reproduction of existing composition axes and their projection onto the plot.

Figure 4.55 : Composition axes (Source: Author, 2024)



Division of the plot into four zones corresponding to the three housing typologies (collective housing represented in grey, semi-collective in green and individual in red) as well as the recreation area (development of a section of beach (yellow)).

Figure 4.56 : Plot zoning (Source: Author, 2024)

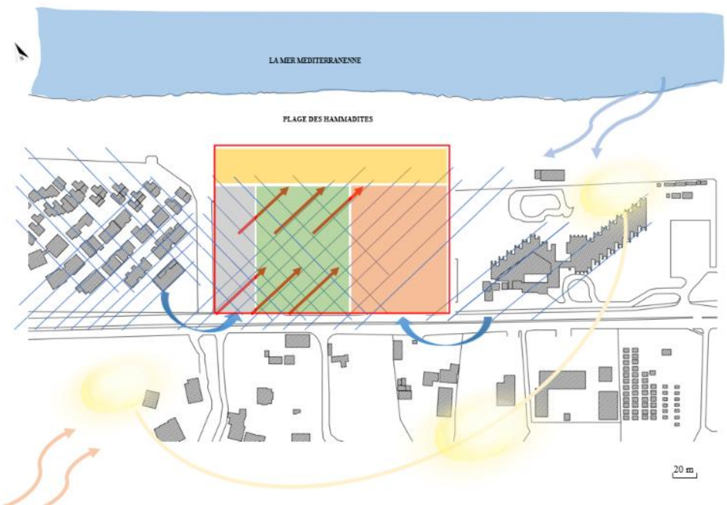


Figure 4.59 : Creating views.
(Source: Author, 2024)

Creation of visual openings (red arrows) also corresponding to the direction of prevailing winds).

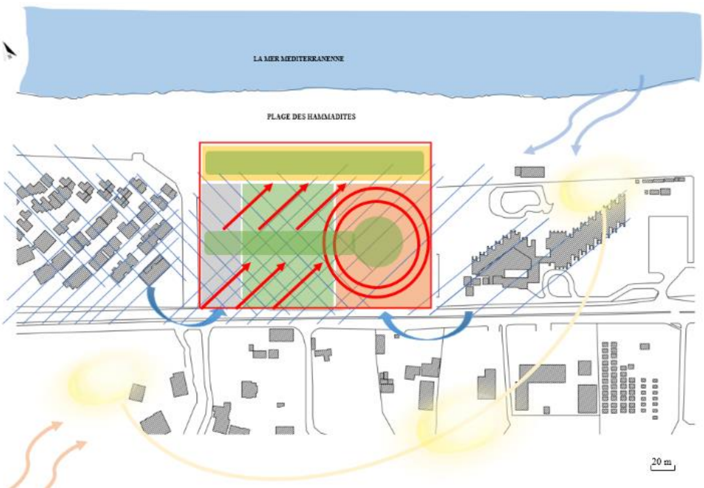


Figure 4.58 : Landscaping shapes.
(Source: Author, 2024)

Integration of a circular form of development into the linear form, with the creation of a link between the two.

Figure 4.57 : positioning of buildings.
(Source: Author, 2024)

Repetition of rectangular shapes for multi-family and semi-collective houses and square shapes for single-family one's.

In 3D :

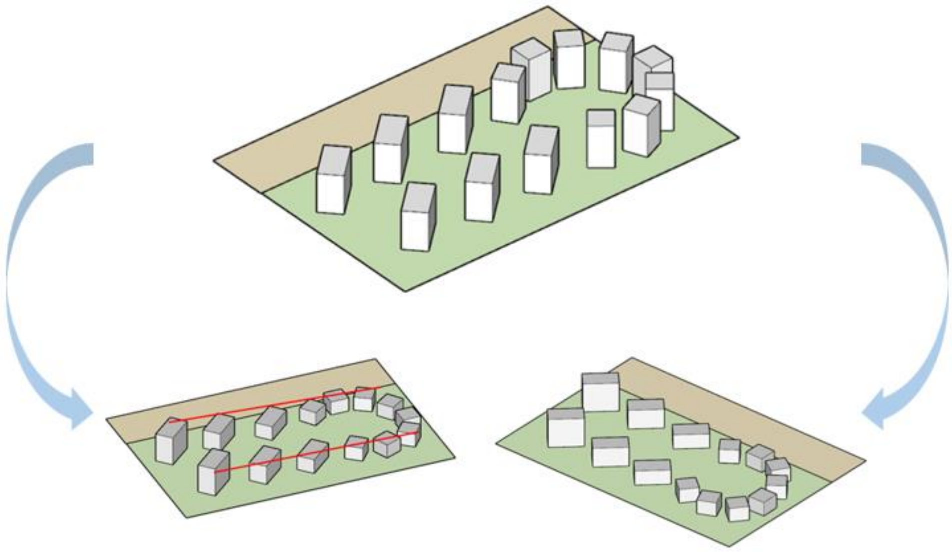


Figure 4.60 : Gradual spatial arrangement (Source: Author, 2024)

The proposal aims to establish a gradual spatial arrangement where collective residential buildings will be configured with a higher elevation than individual house, while intermediate residential structures will be characterized by intermediate heights, thus establishing an altimetric continuum of architectural verticality.

IV.7.1.1 Verification of spatial organization by simulation *:*

Following the proposal of a spatial planning scheme, I undertook an evaluation of the orientation of the buildings in relation to the solar trajectory and the prevailing winds, using Autodesk's 'Forma' tool.

The aim of this simulative approach is to analyze the impact of illuminance on residences in both summer and winter, as well as orientation with respect to prevailing winds during these seasons.

The results obtained indicate that the architectural configuration satisfies lighting requirements, with adequate exposure of the buildings in both summer and winter, as well as ventilation requirements, as the buildings are not subject to undesirable air flows.

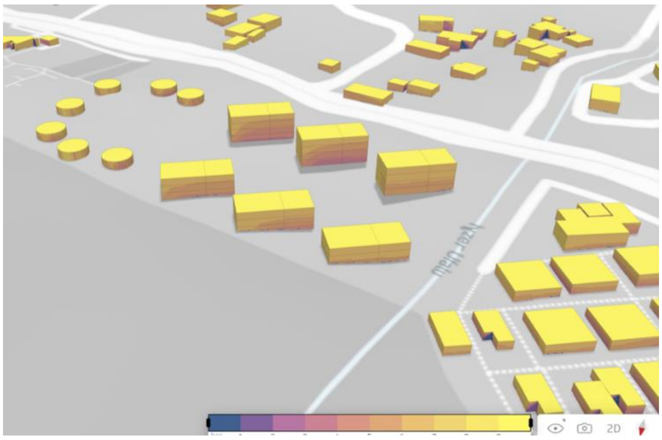


Figure 4.62 : Result of winter sunshine simulation (Source: Autodesk Forma, 2024)

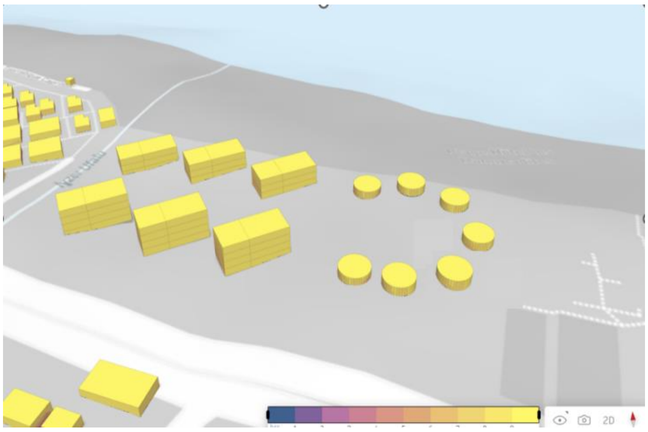


Figure 4.61 : Summer sunshine simulation results (Source: Autodesk Forma, 2024)

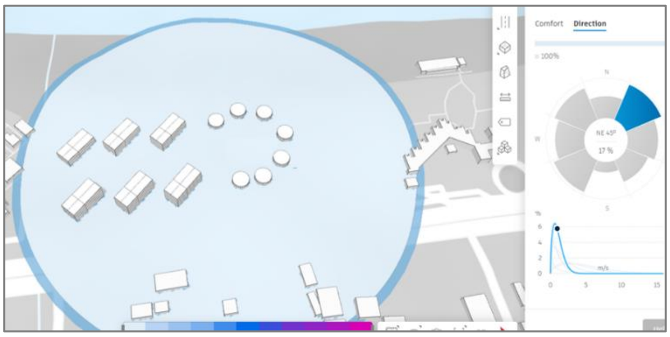


Figure 4.64 : Result of prevailing wind direction in summer (Source: Autodesk Forma, 2024)

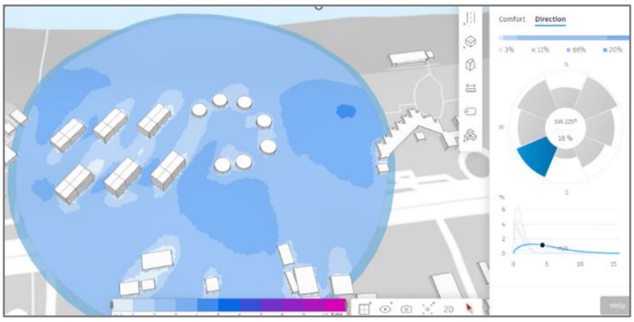


Figure 4.63 : Result of winter prevailing wind simulation (Source: Autodesk Forma, 2024)

IV.7.2. Architectural section :

Here's the initial idea and genesis of the three types of housing: collective, semi-collective and individual.

IV.7.2.1.Single-family homes :

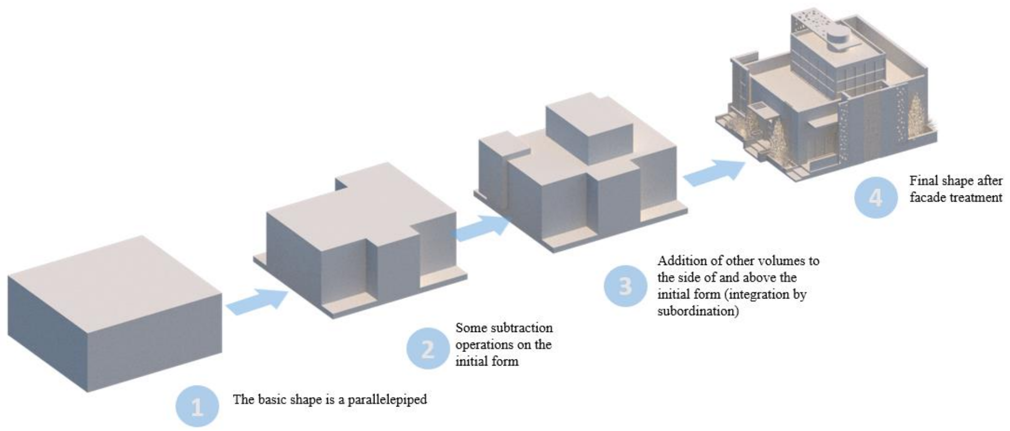


Figure 4.65 : Morphogenesis of the single-family home (Source: Author, 2024)

IV.7.2.2. Semi-collective houses :

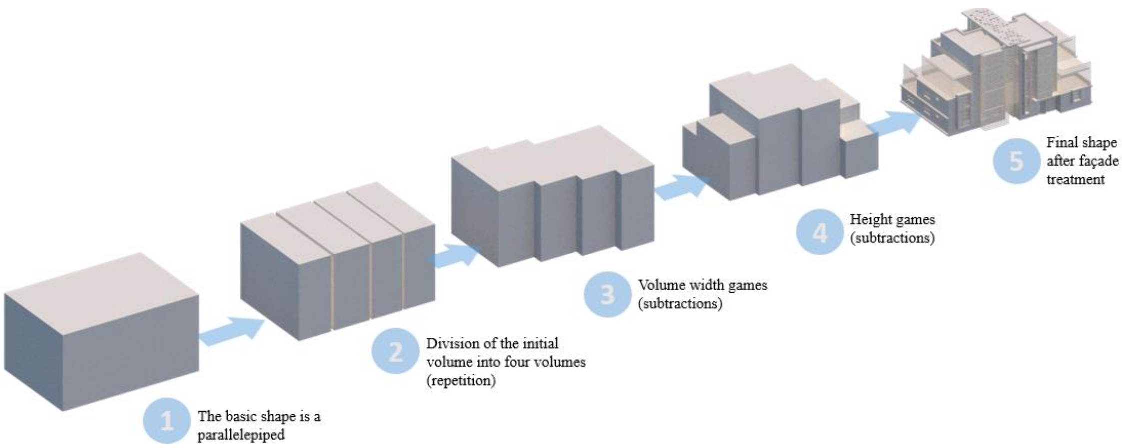


Figure 4.66 : Morphogenesis of semi-collective housing (Source: Author, 2024)

IV.7.2.3. Multi-family housing

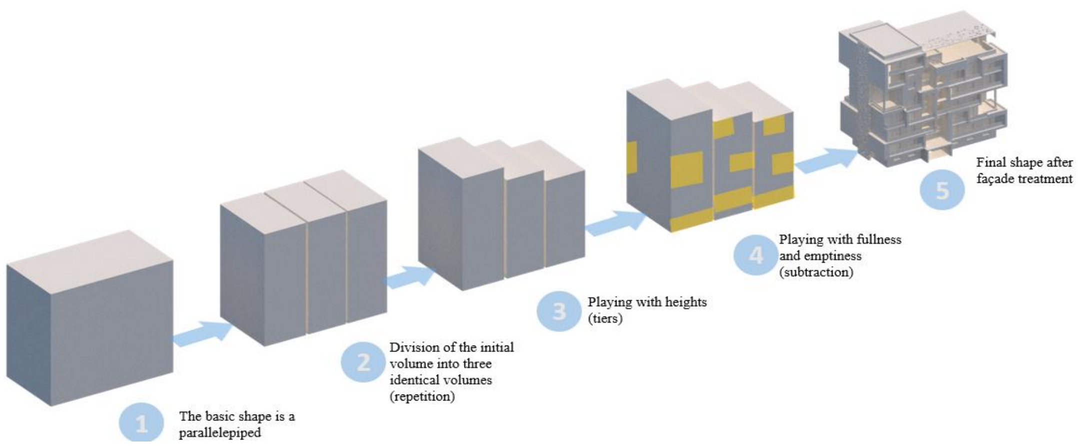


Figure 4.67 : Morphogenesis of collective housing (Source: Author, 2024)

IV.7.3. Simulation verification :

Having drawn up the architectural plans and carried out their three-dimensional form, our study focused on verifying two fundamental parameters discussed in this dissertation: daylighting and building materials (detailed analysis of which will be covered in the following section). With this in mind, a level of semi-collective housing was selected for an in-depth assessment of its daylighting, with the aim of determining whether it meets adequate illumination standards, thus avoiding excessively bright or insufficient lighting conditions.

The assessment was carried out at three different times of the year: summer, mid-season and winter (June 21, September 21 and December 21 respectively), chosen to represent the least favorable days in terms of illuminance. In addition, the survey was carried out at three different times of day: morning (9am), midday (12pm) and afternoon (3pm).

The results obtained were deemed satisfactory, demonstrating a general adequacy of daylighting in most interior spaces, with no noticeable presence of dark or over-lit areas.

The following figure illustrates a specific simulation case, while the other simulations are presented in the appendix.

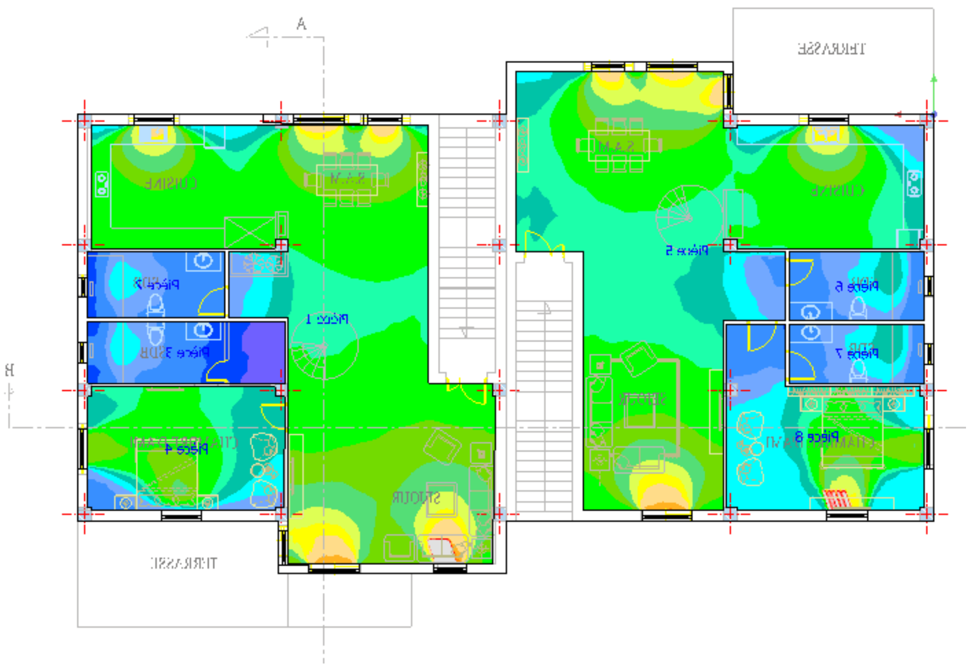


Figure 4.68 : Simulation verification of the semi-collective house in mid-season at noon (Source: DialuxEvo, 2024)

IV.8. Project details :

IV.8.1. Building materials :

IV.8.1.1. Constructive system *:*

For a stable, durable construction that withstands the thermal conditions of the site, we used a reinforced concrete structure, combining the two materials concrete and steel. The former is a compressive material that does not resist tension, while the latter resists tension, so their combination produces a material with high tensile and compressive strength.

- The structural framework: we have three structural frameworks, corresponding to the three typologies designed.
- Infrastructure: we opted for shallow foundations (insulated and threaded footings)
- Superstructure: for columns, we opted for a pre-dimensioning of 45*45 cm for collective housing and 40*40 cm for semi-collective and individual housing. Beam dimensions vary according to span.

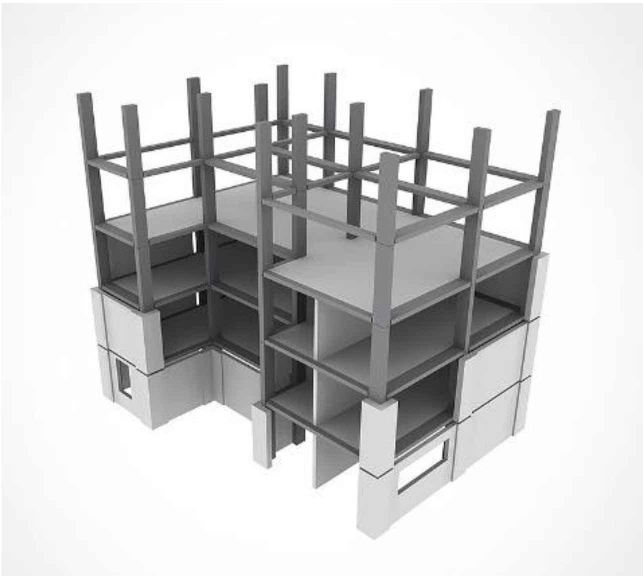


Figure 4.69 : Example of a column-beam construction system (Source: www.ebawe.de/fr , 2024)

IV.8.1.2. Composition of exterior walls *:*

With a view to optimizing the energy performance of building envelopes and following the analysis of a body of work in the practical section, we have recommended a double-wall composition for vertical exterior walls. The outer sheet, acting as facing, is made of solid clay bricks 24 cm thick. A 6 cm ventilated air space, containing 4 cm thick expanded polystyrene panels for thermal insulation, separates this outer sheet from a 10 cm thick inner sheet of perforated bricks (8 holes). The total thickness of the composition is thus 45 cm.

For the horizontal external floors, the chosen solution consists of a slab composed of 16 cm-thick polystyrene joists, topped with a 4 cm concrete compression screed. Complementary expanded polystyrene panels are also integrated, in addition to the traditional bituminous foil insulation.

An examination of the characteristics of these wall compositions, carried out using the 'Ubakus' simulation interface, demonstrates their good performance, with satisfactory thermal insulation, adequate hygrometric behavior for both compositions, and a phase shift of around 17 hours for vertical exterior walls.

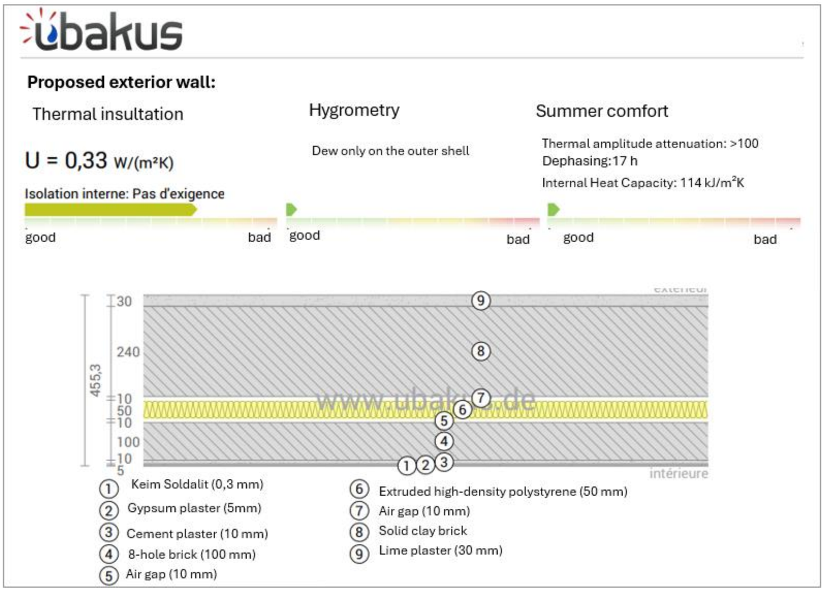


Figure 4.70 : Proposed exterior wall performance.
(Source: Ubakus.de, 2024)

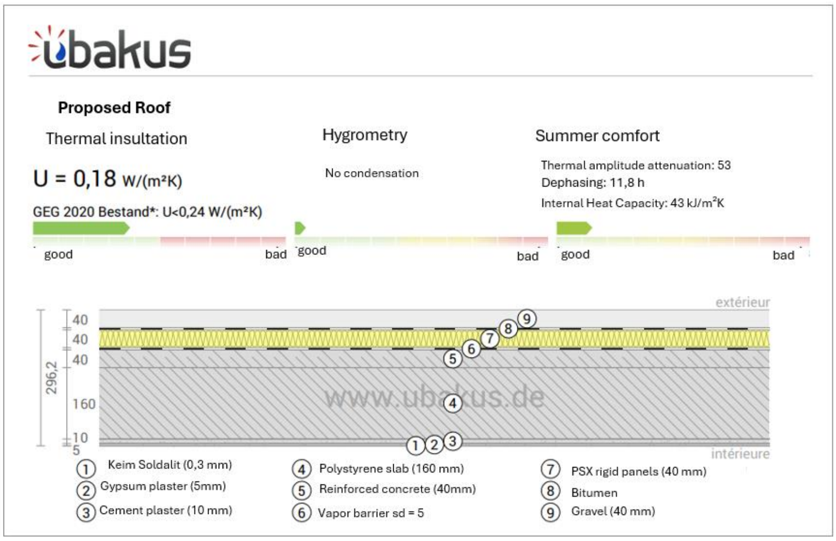


Figure 4.71 : Performance of the proposed roof.
(Source: Ubakus.de, 2024)

IV.8.1.3. Windows and doors :

Windows and doors, while necessary for the transition between interior and exterior, are also points of heat and sound loss. Their composition must therefore be carefully chosen. 4+16+4 mm double-glazed windows with air space and insulated wood doors with polyurethane foam cores have been selected to optimize thermal and acoustic insulation performance and ensure protection and safety.

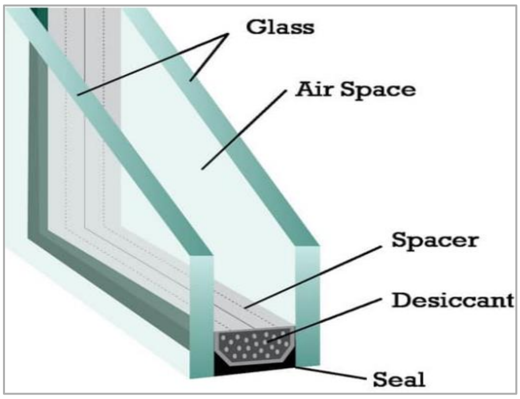


Figure 4.73 : Double-glazed window
(Source: https://majesticglass.com, 2023)

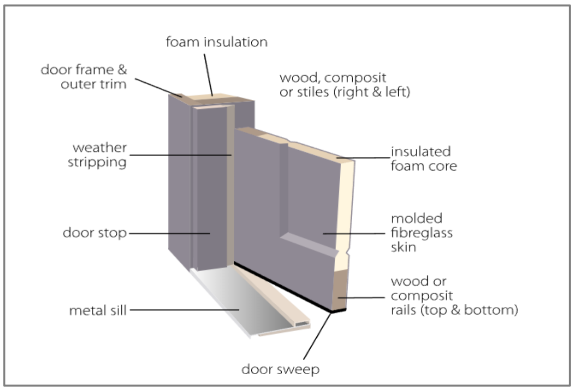


Figure 4.72 : insulated door.
(Source: bayviewwindows.ca, 2024)

IV.8.2. Thermal and acoustic comfort :

IV.8.2.1. Bioclimatic greenhouse :

We have decided to adopt two categories of bioclimatic greenhouses, one designed specifically for single-family homes, while the other is intended for collective and semi-collective housing. The first model is integrated above the structure of the house (terrace) and features a rotating mechanism to follow the path of the sun. The second type, on the other hand, is attached to south-facing balconies.

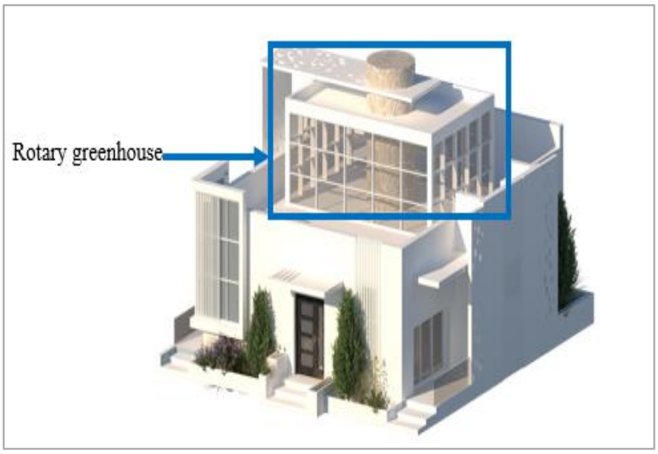


Figure 4.75 : Rotating greenhouse
(Source: Author, 2024)

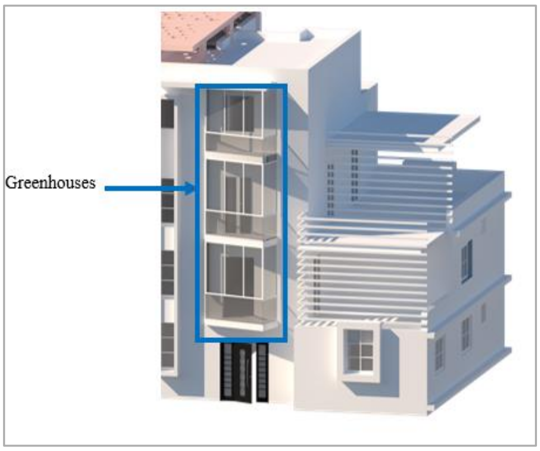


Figure 4.74 : fixed greenhouse.
(Source: author, 2024)

IV.8.2.2. Trombe wall :

The Trombe wall, named after the French engineer Félix Trombe, is a passive solar heating system based on the principle of thermal mass. It consists of a solid, dark masonry exterior wall with a glazed facade creating an air gap. The sun's rays pass through the glazing and heat the wall, whose mass stores heat during the day. This heat is then released back into the home by radiation and natural convection during the night, thus pre-heating the premises. This system is used on south-facing balconies in collective and semi-collective housing, as well as in greenhouses in single-family homes.

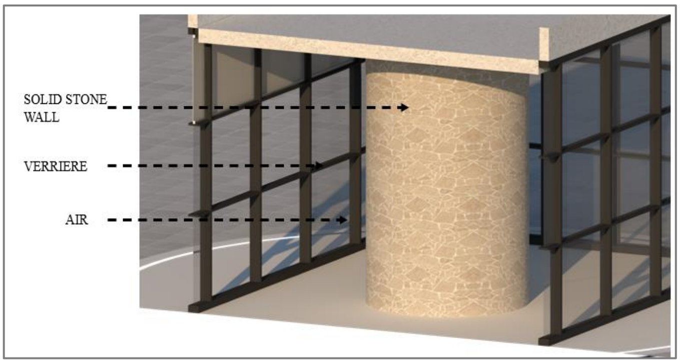


Figure 4.76 : Proposed waterspout wall
(Source : Author, 2024)

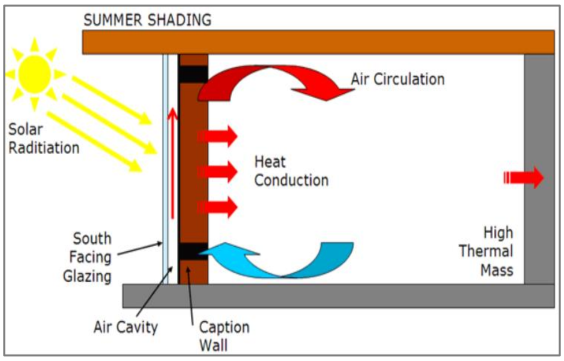


Figure 4.77 : Trombe Wall principle
(Source: suryaurza.com, 2024)

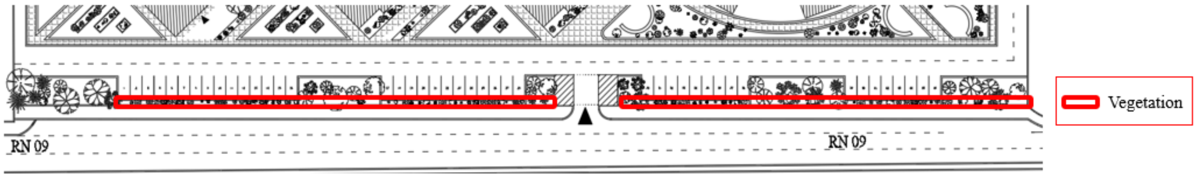
IV.8.2.3. thermal insulation :

As part of the thermal insulation measures adopted, we opted for a double-skinned external wall structure, consisting of an interstitial cavity filled with expanded polystyrene panels, a material renowned for its insulating properties. In addition, the floors were fitted with the same type of panels, ensuring a high-performance thermal envelope for the entire building. (see exterior wall details)

IV.8.2.4. Acoustic insulation :

The fact that our plot of land is located just a few meters from Route Nationale No. 09, a road with a high frequency of traffic, obliges us to propose acoustic insulation systems in order to minimize noise pollution and ensure acoustic comfort, as well as inside the house by insulating between floors and insulating downpipes, for which we have opted for :

- Creation of vegetation barriers on the side facing the road where the parking lot is located, creating a buffer space to minimize external noise.
- Use soundproofing materials such as double-glazed windows and polystyrene panels.



-

Figure 4.78 : Plant barrier against road noise (Source: Author, 2024)

IV.8.2.5. Ventilation :

For ventilation, we opted for natural ventilation, combining cross ventilation and stack ventilation (for the stairwells), to create a fresh, healthy, and comfortable indoor environment.

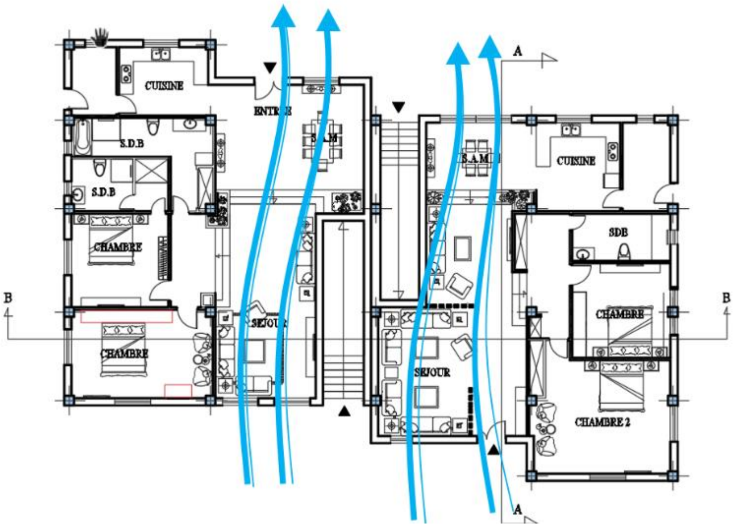


Figure 4.79 : cross ventilation.
(Source: Author, 2024)

IV.8.2.6. Sun protection :

To mitigate the impact of excessive solar radiation, particularly during the summer season, we have chosen to implement various shading devices, including :

- The installation of projections on facades to create shaded areas and protect them from direct sunlight.
- The introduction of deciduous tree species around the perimeter of buildings, to act as sunshades in summer and provide adequate sunlight in winter.
- The use of devices such as vertical sunshades and moucharabiehs on facades to ensure optimum thermal and visual comfort.

Figure 4.81 : Sun breakers proposed for the project.
(Source: Author, 2024)

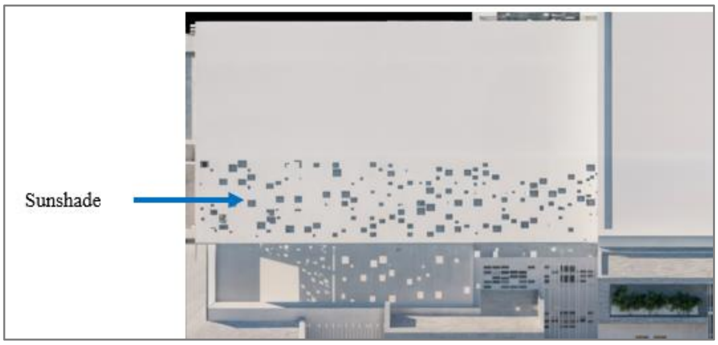


Figure 4.80 : Roof-level sunshade
(Source : Author, 2024)

IV.8.3. Ecology :

IV.8.3.1. Vegetation *:*

Deciduous trees make excellent natural sun breakers thanks to their dense summer foliage, which blocks direct rays, and their winter defoliation, which allows low-lying rays to penetrate and provide heat. Trees such as narrow-leaf ash, pomegranate, etc. are generally planted close to the windows on the south/west side and at a certain distance from the house, as are hedges on balconies.

Figure 4.82 : Vegetation in the balcony.
(Source: leaderplant.com ,2024)

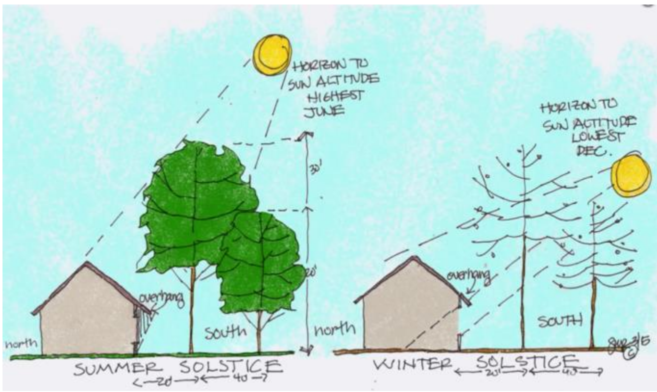


Figure 4.85 : The effect of vegetation on the home in summer and winter (Source: https://www.purdue.edu, 2024)

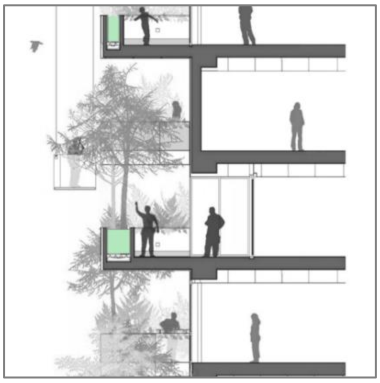


Figure 4.84 : Cross-section showing the arrangement of trees in the balconies.
(Source: Archdaily , 2024)

Figure 4.83 : Vegetation on the balconies of apartment buildings in (Author , 2024)

IV.8.3.2. Water management *:*

Rainwater collected from roofs using gutters is channeled into underground tanks, where it undergoes filtration treatment before being reused for domestic and watering purposes.

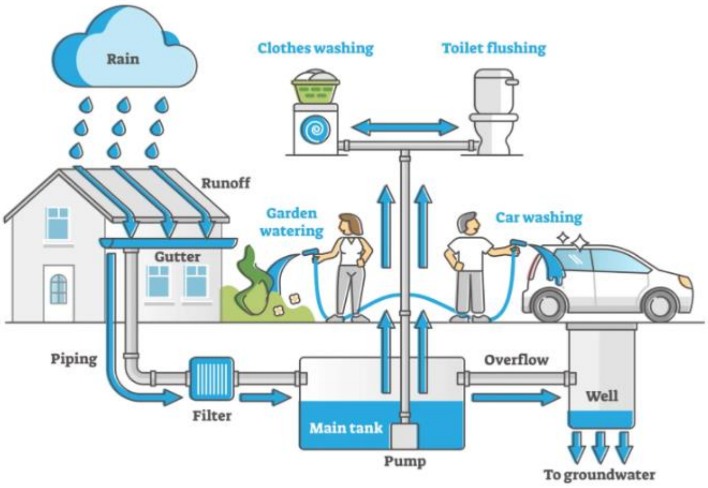


Figure 4.86 : Rainwater harvesting system
(Source: sacleanwater.com , 2024)

IV.8.3.3. Energy management *:*

To reduce primary energy consumption, we have implemented a sustainable strategy by harnessing local renewable energies. We have installed photovoltaic and solar thermal panels to capture solar energy, as well as wind power systems to convert wind energy into electricity. This integrated approach minimizes our dependence on fossil fuels and reduces our environmental impact. This strategy is represented in the individual homes containing the greenhouse, while the solar panels are present in all the homes.

IV.8.3.4. Waste management *:*

A selective sorting system with dedicated garbage cans for recyclable and non-recyclable waste is installed in common areas, complemented by a garbage can room near the entrance to facilitate collection.

Figure 4.87 : Sorting system.
(Source: zerowastefrance.org , 2024)

IV.8.3.5. Flooring :

Pedestrian walkways use permeable paving that limits runoff, recharges the water table, reduces the risk of flooding, filters rainwater and is more aesthetically pleasing than asphalt.

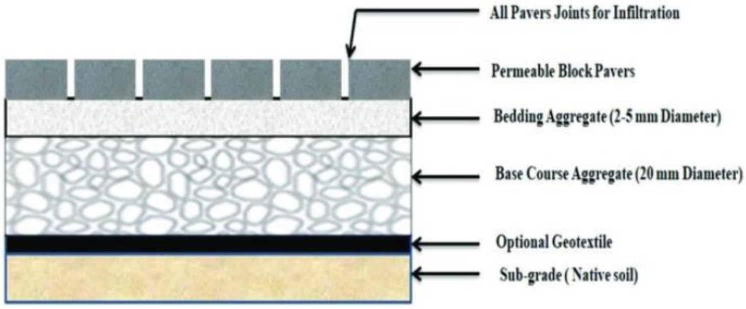


Figure 4.88 : Composition of permeable paving
(Source: Shafique , 2018)

IV.8.3.6. Ecological parking *:*

They are pre-turfed parking lots that use a permeable, vegetated surface to promote sustainable stormwater management, reduce urban heat islands and enhance landscape integration, thus combining environmental sustainability with aesthetic quality.

Figure 4.89 : Ecological parking lot (Source: o2d-environnement.com , 2024)

IV.8.3.7. Development of a watercourse *:*

The integration of a watercourse around 3 meters wide into the development, as it can offer aesthetic benefits while helping to mitigate flood risk, or from an aesthetic point of view, this watercourse adds a natural and peaceful dimension to the urban environment, creating an attractive and harmonious living environment for residents offering areas of relaxation and recreation for the local community. In terms of flood management, even a watercourse of this size can play a crucial role in absorbing and diverting some of the stormwater during heavy rainfall, helping to reduce the risk of flooding in the area.

Figure 4.91 : Example of a river (Source: i.pinimg.com , 2024)

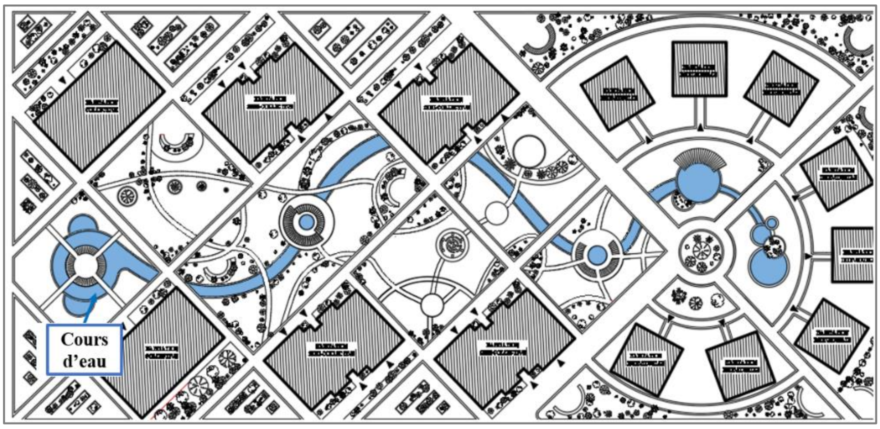


Figure 4.90 : A watercourse in a public space. (Source: Author, 2024)

Conclusion :

Within this chapter, the development of an architectural project dedicated to bioclimatic housing in a coastal environment has been undertaken. The project encompasses three distinct housing typologies: collective, semi-collective and individual. Its location is of crucial importance, being ideally situated by the sea, in the immediate vicinity of the beach, while occupying an intermediate position between this natural feature and a mountainous rise. What's more, its geographical location is of considerable tourist interest, being positioned between two renowned tourist sites in the wilaya of Bejaia: The Hammadites hotel and the Capritour tourist village. Its accessibility is also facilitated by its position along the RN 09, linking the wilayas of Bejaia and Setif.

The assimilation of theoretical and empirical data enabled me to fully grasp the specific characteristics of the coastline and the various parameters of bioclimatic architecture. This understanding was crucial in integrating these elements into the design of the project, ensuring that it faithfully reflects its environment and climatic characteristics. The various strategies and principles of bioclimatic architecture were thus applied in the design, ensuring harmony between the building and its environmental context.

A simulation-based validation of two essential parameters of bioclimatic architecture, namely building materials and the use of natural light, was undertaken. The results obtained testify positively to the appropriate implementation of the research data in the proposed project.

GENERAL CONCLUSION

General conclusion :

Bioclimatic coastal architecture is a conceptual approach to enhancing building design in response to the climatic conditions unique to coastal environments. These marine regions have a distinct microclimate that is influenced by their closeness to the water and by sea winds. The cardinal ideas of this strategy are to take use of the benefits of this moderate climate by utilizing natural components such as sea breezes, sunshine, and relative humidity. This comprehensive concept seeks to reduce energy consumption for heating, cooling, and artificial lighting while ensuring inhabitants' optimal thermal and visual comfort.

The study project aims to address coastal construction in the city of Béjaïa. The major objectives are to study bioclimatic housing in a marine context and discover coastal house typologies in Béjaïa to inspire new ideas.

To accomplish this, the dissertation is separated into three sections. The first is essentially theoretical, with two chapters: the first deals with habitat and coastline, while the second discusses the bioclimatic approach, its principles, and techniques, as well as thermal and visual comfort.

The second part presents the shoreline of the Béjaïa wilaya and analyses related housing typologies using an in-situ analysis and computer simulation. The goal is to identify the challenges inherent in house in this environment, and then to identify a typology appropriate for coastal climatic conditions, by analysing the results of three major parameter analyses: natural light, construction materials, and natural ventilation. The findings highlighted difficulties associated with high humidity and natural light, which can be excessive or insufficient. This section finishes with guidelines for designing projects in this setting.

The third component focuses on developing a dwelling project in a coastal location in Béjaïa that is tailored to local climatic circumstances, drawing on theoretical and practical knowledge from earlier sections. The concept includes three housing typologies - community, semi-collective, and individual - in a tourism area near the sea. It blends bioclimatic building concepts while respecting the residential function, as well as a unique system of intelligent bioclimatic greenhouses for individual homes. Simulation analysis of chosen houses yielded positive findings, demonstrating the proper use of research data in the proposed project.

Furthermore, bioclimatic architecture stands out for its potential to overcome conventional geographical limits, whether coastal or desert. It takes a contextualized approach, considering the specific environment in which it is constructed. This discipline best adapts to its built surroundings by carefully balancing environmental and climatic principles. As a result, a thorough understanding of the environmental and climatic data inherent in the site is required. This method not only capitalizes on the site's inherent advantages, but it also decreases energy consumption while providing the best possible comfort for residents.

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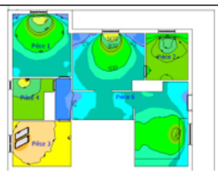
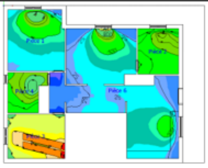
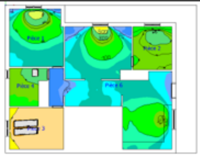
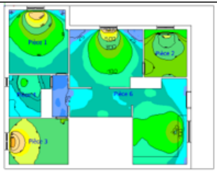
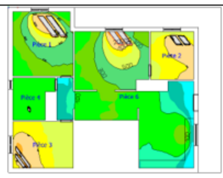
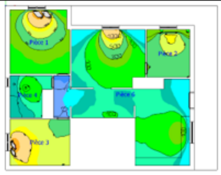
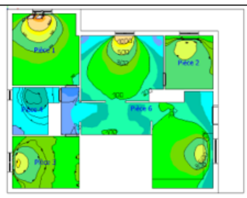
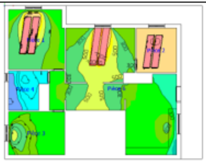
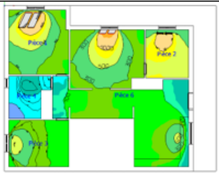
APPENDICES

Appendices :

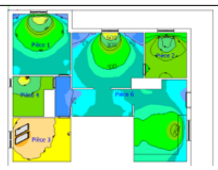
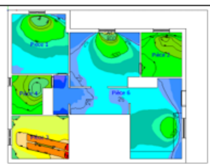
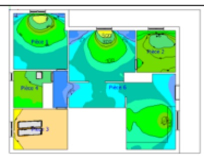
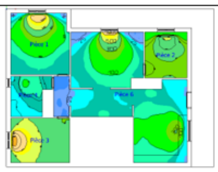
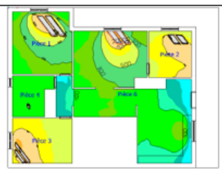
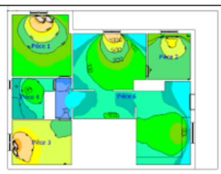
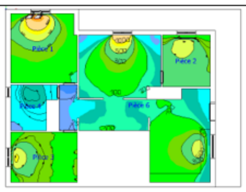
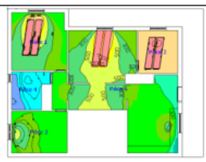
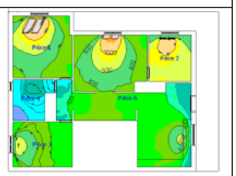
- ## Daylight simulations using ‘DialuxEvo’ :

HOUSE IN GOURAYA :

	SUMMER	WINTER	MID-SEASON
9.00			
12.00			
15.00			

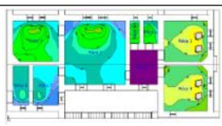
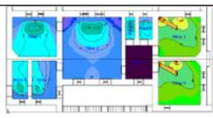
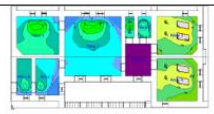
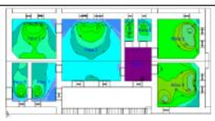
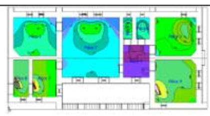
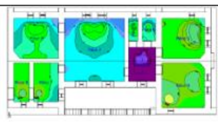
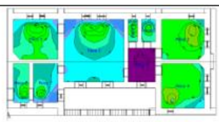
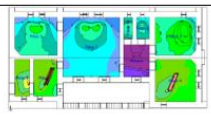
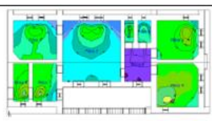
The house in general has average values during the periods of the day, with other excessive values sometimes reaching 4000 lux, especially in winter and mid-season, including the need to control the incoming solar rays to ensure visual and thermal comfort inside these spaces,

HOUSE IN GOURAYA :

	SUMMER	WINTER	MID-SEASON
9.00			
12.00			
15.00			

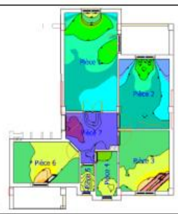
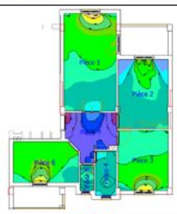
The house in general has average values during the periods of the day, with other excessive values sometimes reaching 4000 lux, especially in winter and mid-season, including the need to control the incoming solar rays to ensure visual and thermal comfort inside these spaces,

HOUSE IN BENIKSILA :

	SUMMER	WINTER	MID-SEASON
9.00			
12.00			
15.00			

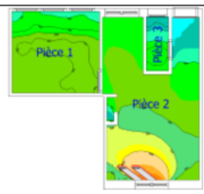
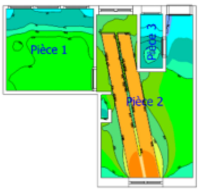
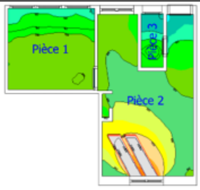
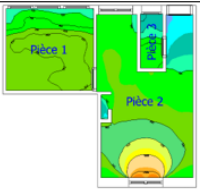
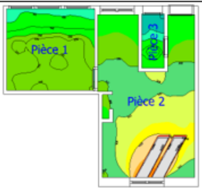
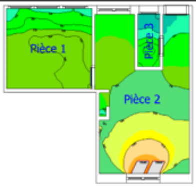
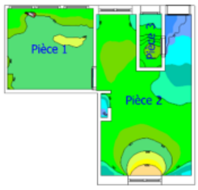
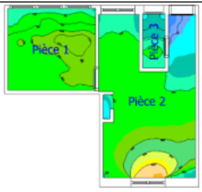
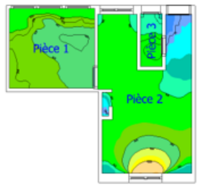
The house does not have good values, in general it has very low lighting during the seasons, except for bedrooms 3 and 4 which have excessive lighting in the morning reaching in mid-season at 2000 lux during the morning, so the need to protect oneself from direct sunlight, the rest of the house has values between 50 and 200 lux

HOUSE IN SIDI ALI LEBHER :

	SUMMER	WINTER	MID-SEASON
9.00			
12.00			
15.00			

The rooms do not have good values during the day, either excessive and uniform lighting (1200 lux) which therefore requires protection, or very low illuminance, (100 lux)

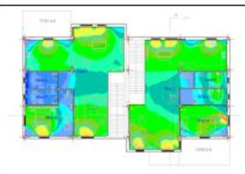
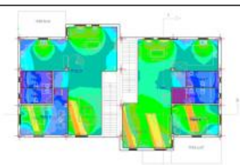
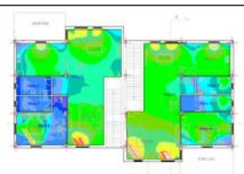
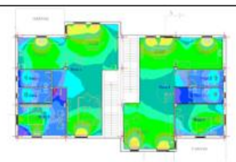
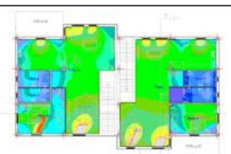
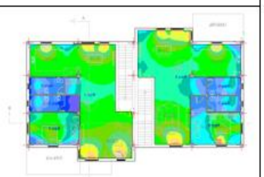
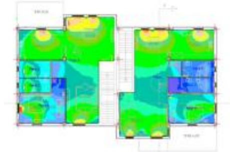
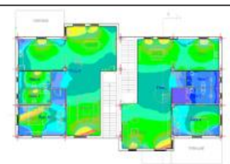
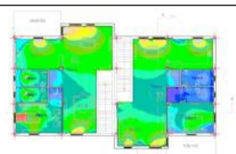
HOUSE IN PLATEAU AMIMOUNE

	SUMMER	HIVER	MID-SEASON
9.00			
12.00			
15.00			

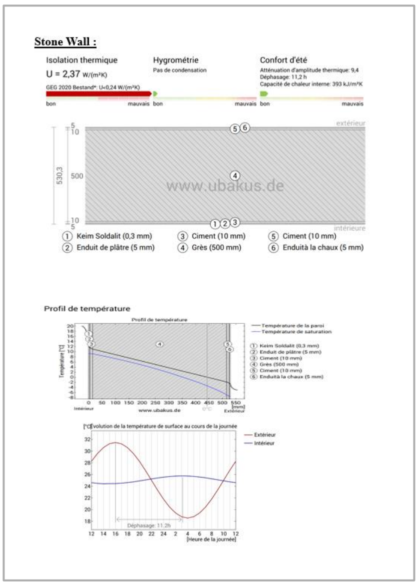
During the three seasons, room 1 does not receive direct lighting, but it has a good illumination that corresponds to its function as a bedroom, except in winter, the illumination is very low

For the living room, it does not have uniform lighting, with very increased values (up to 2000 lux) especially during the period from morning to noon, and therefore it is the effect of glare, overheating in summer...

SEMI-COLLECTIVE HOUSE PROPOSED

	SUMMER	HIVER	MID-SEASON
9.00			
12.00			
15.00			

- **Building materials analysis using site interface 'Ubakus' :**



Stone Wall :

Isolation thermique

U = 2,37 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

bon mauvais

Hygrométrie

Pas de condensation

bon mauvais

Confort d'été

Atténuation d'amplitude thermique: 9,4

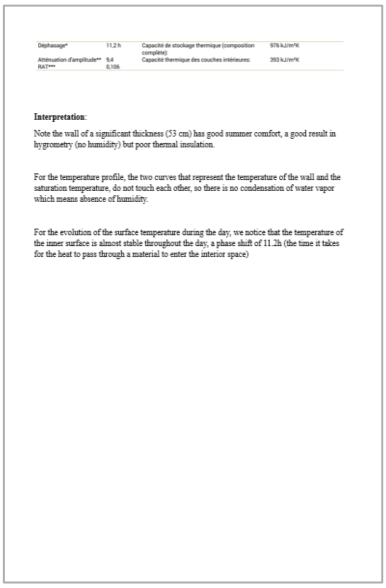
Déphasage: 11,2 h

Capacité de chaleur interne: 393 kJ/m²K

bon mauvais

① Keim Soldalit (0,3 mm)
② Enduit de plâtre (5 mm)
③ Ciment (10 mm)
④ Grès (500 mm)
⑤ Ciment (10 mm)
⑥ Enduità la chaux (5 mm)

Profil de température



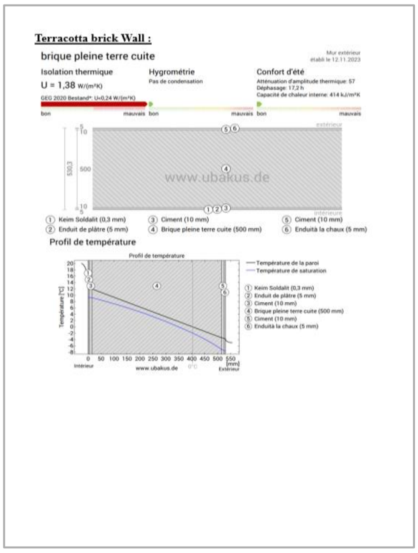
Déphasage*	11,2 h	Capacité de stockage thermique (composition complète):	976 kJ/m²K
Atténuation d'amplitude**	9,4	Capacité thermique des couches intérieures:	393 kJ/m²K
RAT***	0,106		

Interpretation:

Note the wall of a significant thickness (53 cm) has good summer comfort, a good result in hygrometry (no humidity) but poor thermal insulation.

For the temperature profile, the two curves that represent the temperature of the wall and the saturation temperature, do not touch each other, so there is no condensation of water vapor which means absence of humidity.

For the evolution of the surface temperature during the day, we notice that the temperature of the inner surface is almost stable throughout the day, a phase shift of 11.2h (the time it takes for the heat to pass through a material to enter the interior space)



Terracotta brick Wall :

brique pleine terre cuite

Mur extérieur
établi le 12.11.2023

Isolation thermique

U = 1,38 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

bon mauvais

Hygrométrie

Pas de condensation

bon mauvais

Confort d'été

Atténuation d'amplitude thermique: 57

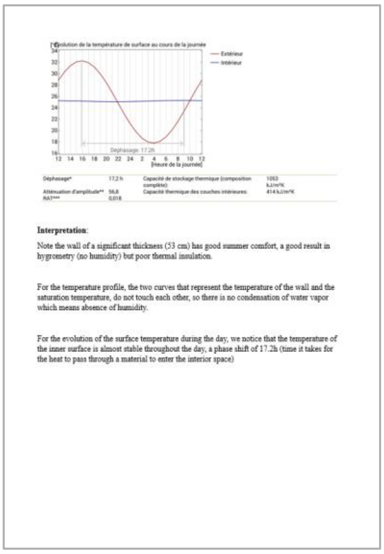
Déphasage: 17,2 h

Capacité de chaleur interne: 414 kJ/m²K

bon mauvais

① Keim Soldalit (0,3 mm)
② Enduit de plâtre (5 mm)
③ Ciment (10 mm)
④ Brique pleine terre cuite (500 mm)
⑤ Ciment (10 mm)
⑥ Enduità la chaux (5 mm)

Profil de température



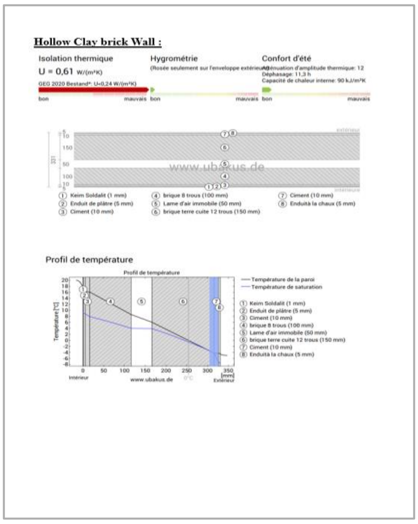
Déphasage*	17,2 h	Capacité de stockage thermique (composition complète):	1053 kJ/m²K
Atténuation d'amplitude**	56,8	Capacité thermique des couches intérieures:	414 kJ/m²K
RAT***	0,018		

Interpretation:

Note the wall of a significant thickness (53 cm) has good summer comfort, a good result in hygrometry (no humidity) but poor thermal insulation.

For the temperature profile, the two curves that represent the temperature of the wall and the saturation temperature, do not touch each other, so there is no condensation of water vapor which means absence of humidity.

For the evolution of the surface temperature during the day, we notice that the temperature of the inner surface is almost stable throughout the day, a phase shift of 17.2h (time it takes for the heat to pass through a material to enter the interior space)



Hollow Clay brick Wall :

Isolation thermique

U = 0,61 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

bon mauvais

Hygrométrie

(Rosée seulement sur l'enveloppe extérieure)

bon mauvais

Confort d'été

Atténuation d'amplitude thermique: 12

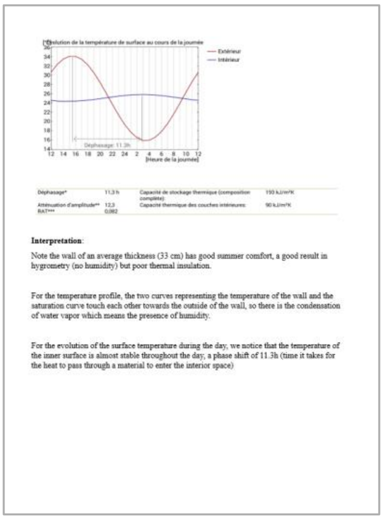
Déphasage: 11,3 h

Capacité de chaleur interne: 90 kJ/m²K

bon mauvais

① Keim Soldalit (1 mm)
② Enduit de plâtre (5 mm)
③ Ciment (10 mm)
④ brique 8 trous (100 mm)
⑤ Lame d'air immobile (50 mm)
⑥ brique terre cuite 12 trous (150 mm)
⑦ Ciment (10 mm)
⑧ Enduità la chaux (5 mm)

Profil de température



Déphasage*	11,3 h	Capacité de stockage thermique (composition complète):	193 kJ/m²K
Atténuation d'amplitude**	12,3	Capacité thermique des couches intérieures:	90 kJ/m²K
RAT***	0,082		

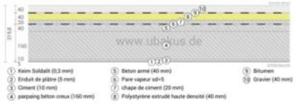
Interpretation:

Note the wall of an average thickness (33 cm) has good summer comfort, a good result in hygrometry (no humidity) but poor thermal insulation.

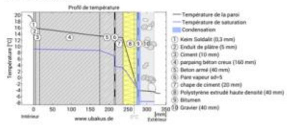
For the temperature profile, the two curves representing the temperature of the wall and the saturation curve touch each other towards the outside of the wall, so there is the condensation of water vapor which means the presence of humidity.

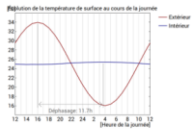
For the evolution of the surface temperature during the day, we notice that the temperature of the inner surface is almost stable throughout the day, a phase shift of 11.3h (time it takes for the heat to pass through a material to enter the interior space)

Flat roof :



Profil de température





Déphasage*	11,7 h	Capacité de stockage thermique (composition complète):	435 kJ/m²K
Atténuation d'amplitude**	32,5	Capacité thermique des couches intérieures:	247 kJ/m²K
RAT***	0,031		

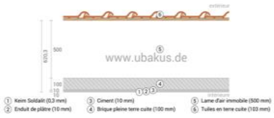
Interpretation:

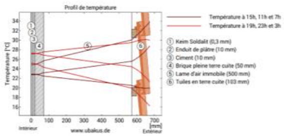
The roof has good summer comfort, poor performance against humidity and poor thermal insulation.

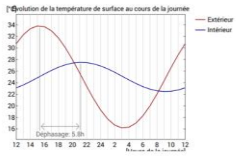
For the temperature profile, the two curves representing the temperature of the wall and the saturation curve touch each other towards the outside of the wall, so there is the condensation of water vapor which means the presence of humidity.

For the evolution of the surface temperature during the day, we notice that the temperature of the inner surface is almost stable throughout the day, a phase shift of 11.7h (time it takes for the heat to pass through a material to enter the interior space)

Tile roof 1 :







Déphasage*	5,8 h	Capacité de stockage thermique (composition complète):	175 kJ/m²K
Atténuation d'amplitude**	3,5	Capacité thermique des couches intérieures:	84 kJ/m²K
RAT***	0,286		

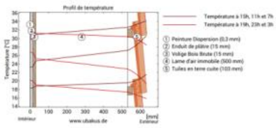
Interpretation:

The roof has average summer comfort (average phase shift), a good hygrometry result (absence of humidity) and poor thermal insulation.

For the temperature profile, the two curves representing the temperature of the wall and the saturation temperature do not touch each other, so there is no condensation of water vapor which means the absence of humidity.

For the evolution of the surface temperature during the day, we notice that the temperature of the interior surface is almost stable throughout the day, a phase shift of 7.2h (time it takes for the heat to pass through a material to enter the interior space)

Tile roof 2 :



Déphasage*	3,5 h	Capacité de stockage thermique (composition complète):	71 kJ/m²K
Atténuation d'amplitude**	1,3	Capacité thermique des couches intérieures:	25 kJ/m²K
RAT***	0,745		

Interpretation:

It is noticeable that the roof has poor summer comfort, a good result in terms of humidity (no humidity) and poor thermal insulation.

For the temperature profile, the two curves representing the temperature of the wall and the saturation temperature touch each other, so there is condensation of the water vapor which means the presence of humidity.

For the evolution of the surface temperature during the day, we notice that the temperature of the interior surface is almost stable throughout the day, a phase shift of 3.5h (the time it takes for the heat to pass through a material to enter the interior space)

Table of contents :

Résumé :

Dans les régions côtières, les bâtiments sont inévitablement confrontés à des conditions climatiques singulières, comme l'illustre l'exemple de Béjaïa, où prévalent une humidité atmosphérique élevée, des vents maritimes forts et un ensoleillement intense. Face à ces défis environnementaux, l'architecture bioclimatique émerge comme une approche innovante, basée sur un design architectural en symbiose avec l'environnement local. Cette méthodologie vise à optimiser l'utilisation des ressources naturelles telles que les brises marines et le rayonnement solaire, contribuant ainsi à réduire la consommation énergétique tout en assurant un confort thermique et visuel optimal pour les occupants.

L'objectif principal de cette recherche est d'identifier une typologie de logement adaptée au contexte côtier de Béjaïa, qui sera mise en œuvre dans le projet de fin d'année par la conception d'un ensemble de maisons collectives, semi-collectives et individuelles à Tichy, en parfaite harmonie avec les caractéristiques spécifiques du site.

Pour ce faire, une étude purement théorique a été réalisée, fournissant une compréhension approfondie de l'habitat, du littoral, ainsi que de l'approche bioclimatique, de ses principes et stratégies, et du confort. Cette analyse théorique a été combinée avec une étude de terrain analysant cinq résidences typiques de différentes typologies sur le littoral de Béjaïa. Le but était de trouver la typologie optimale pour l'emplacement et d'identifier ses bonnes qualités. Pour atteindre cet objectif, trois aspects importants de la conception bioclimatique ont été étudiés : les matériaux de construction, la lumière naturelle et la ventilation naturelle. Cette analyse était basée sur des mesures in situ complétées par des simulations numériques utilisant le logiciel DialuxEvo pour l'analyse de la lumière du jour, RWIND pour l'analyse du vent, et l'interface web Ubakus pour l'évaluation des matériaux de construction, avec des résultats interprétés pour chaque paramètre.

Après avoir entrepris ces investigations théoriques et empiriques approfondies, les résultats ont été soigneusement appliqués au projet de fin d'année. Les simulations informatiques ultérieures de l'éclairage naturel et des propriétés des matériaux de construction ont validé la véracité des décisions prises. En effet, les résultats obtenus démontrent éloquemment l'adéquation optimale entre la proposition architecturale et les contraintes environnementales du site, démontrant la validité de cette approche conceptuelle bioclimatique, qui assure un habitat offrant un confort thermique et visuel idéal à ses occupants.

Mots-clés : Littoral, Architecture bioclimatique, Béjaïa, Conditions climatiques, Confort thermique, Confort visuel.

ملخص :

في المناطق الساحلية، تواجه المباني حتمًا ظروفًا مناخية فريدة، كما يتضح من مثال بجاية، حيث تسود رطوبة جوية عالية، ورياح بحرية قوية، وأشعة شمس كثيفة. في مواجهة هذه التحديات البيئية، تظهر الهندسة المعمارية البيومناخية كنهج مبتكر، يعتمد على التصميم المعماري في تناغم مع البيئة المحلية. تهدف هذه المنهجية إلى تحسين استخدام الموارد الطبيعية مثل النسيم البحري والإشعاع الشمسي، مما يساعد على تقليل استهلاك الطاقة مع ضمان راحة حرارية وبصرية مثلى للسكان .

الهدف الرئيسي من هذا البحث هو تحديد نوعية سكنية ملائمة للسياق الساحلي لبجاية، سيتم تنفيذها في مشروع السنة النهائية من خلال تصميم مجموعة من المنازل الجماعية ونصف الجماعية والفردية في تيشي، بما يتماشى تمامًا مع الخصائص المحددة للموقع .

لتحقيق ذلك، تم إجراء دراسة نظرية بحتة، توفر فهمًا عميقًا للموئل والساحل، بالإضافة إلى النهج البيومناخي ومبادئه واستراتيجياته والراحة. تم دمج هذا التحليل النظري مع دراسة ميدانية لتحليل خمس مساكن نموذجية من أنواع مختلفة على شاطئ بجاية. كان الهدف هو العثور على النوعية المثلى للموقع وتحديد جودتها الجيدة. لتحقيق هذا الهدف، تم التحقيق في ثلاثة جوانب مهمة للتصميم البيومناخي: مواد البناء، الضوء الطبيعي، والتهوية الطبيعية. استند هذا التحليل إلى قياسات ميدانية مدعومة بمحاكاة رقمية باستخدام برنامج DialuxEvo لتحليل ضوء النهار، و RWIND لتحليل الرياح، وواجهة الويب Ubakus لتقييم مواد البناء، وتم تفسير النتائج لكل معلمة.

.بعد إجراء هذه التحقيقات النظرية والتجريبية الشاملة، تم تطبيق النتائج بعناية على مشروع السنة النهائية. أثبتت المحاكاة الحاسوبية اللاحقة للإضاءة الطبيعية وخصائص مواد البناء صحة القرارات المتخذة. في الواقع، تظهر النتائج التي تم الحصول عليها ببلاغة التوافق الأمثل بين الاقتراح المعماري وقيود البيئة الخاصة بالموقع، مما يبرهن على صحة هذا النهج المفاهيمي البيومناخي، الذي يضمن موئلاً يوفر راحة حرارية وبصرية مثالية لسكانه.

الكلمات المفتاحية: الساحل، الهندسة المعمارية البيومناخية، بجاية، الظروف المناخية، الراحة الحرارية، الراحة البصرية.