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Master's thesis in Architecture.

Theme of the workshop:

Architecture, Technology and Environment.

THERMAL COMFORT AMELIORATION IN HOT & DRY CLIMATE HABITAT.

El-Rimal residential complex, Ouargla, Algeria.

PRESENTED BY

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Abstract

English:

This master thesis is concerned with the eco-design of a group of individual houses representing the architectural identity of the city of Ouargla. To do this, we applied an urban analysis combining typo-morphological and sensory analysis to be able to identify the features of the local architecture while studying the dimension of experience. Our analysis also shows that local architecture has a bioclimatic potential to achieve a better level of thermal comfort than that obtained by contemporary architecture which takes little or no account of local architecture. The eco-design of the group of individual houses is based on an architectural and urban composition inspired by the local architecture and optimised through dynamic thermal simulations.

Arabic:

تهتم أطروحة الماجستير هذه بالتصميم البيئي لمجموعة من المنازل الفردية التي تمثل الهوية المعمارية لمدينة ورقلة. للقيام بذلك ، قمنا بتطبيق تحليل حضري يجمع بين التحليل المورفولوجي المطبعي والحسي لنكون قادرين على تحديد ميزات العمارة المحلية أثناء دراسة بعد التجربة. يظهر تحليلنا أيضا أن العمارة المحلية لديها إمكانات مناخية حيوية لتحقيق مستوى أفضل من الراحة الحرارية من تلك التي تحصل عليها العمارة المعاصرة التي تأخذ في الاعتبار القليل أو لا تأخذ في الاعتبار العمارة المحلية. يعتمد التصميم البيئي لمجموعة المنازل الفردية على تكوين معماري وحضري مستوحى من العمارة المحلية وتم تحسينه من خلال المحاكاة الحرارية الديناميكية.

French :

Ce mémoire porte sur l'éco-conception d'un ensemble de maisons individuelles représentant l'identité architecturale de la ville de Ouargla. Pour ce faire, nous avons appliqué une analyse urbaine combinant analyse typo-morphologique et sensorielle pour pouvoir identifier les caractéristiques de l'architecture locale tout en étudiant la dimension de l'expérience. Notre analyse montre également que l'architecture locale a un potentiel bioclimatique pour atteindre un meilleur niveau de confort thermique que celui obtenu par l'architecture contemporaine qui prend peu ou pas en compte l'architecture locale. L'éco-conception du groupe de maisons individuelles repose sur une composition architecturale et urbaine inspirée de l'architecture locale et optimisée par des simulations thermiques dynamiques.

Keywords: *Thermal comfort, comfortable, hot climate, sustainable architecture, bioclimatic, habitat, dwellings, housing, eco-construction, hot and dry climate,*

Contents

List of figures and tables

1ST CHAPTER:

INTRODUCTION

1ST CHAPTER: INTRODUCTION

General introduction:

Architecture and environment are two interrelated fields that influence each other in many ways. Architecture is the art and science of designing and constructing buildings and spaces that respond to human needs, culture, and context, while environment is the natural and built surroundings that affect the quality of life, health, and well-being of living beings.

Throughout the different ages of humanity man has always tried to create favorable conditions for his comfort and activities, while trying to control his environment. From the primitive hut to the house of today, the dwelling reflects through its evolution the different solutions found by man to face the vagaries of the weather.

But lately we are suffering from global warming which is caused by energy consumption, as Buildings are responsible for 40% of global energy consumption and 33% of greenhouse gas emissions (Jean-Pascal, 2021). Therefore, designing and constructing energy-efficient buildings is a key strategy to reduce greenhouse gas emissions and mitigate climate change.

Some of the factors that affect the energy consumption of buildings are:

- The building orientation, which influences the amount of solar radiation and natural ventilation that the building receives For example, in Cairo, Egypt, a building with a southern facade consumes less energy than a building with a western facade (Ashmawy, 2017).
- The building envelope, which includes the walls, windows, roofs and floors that separate the indoor and outdoor environments. The envelope should provide adequate insulation, shading and air tightness to reduce heat losses and gains (Rovetto, 2023).
- The building system, which include the heating, ventilation and air conditioning (HVAC), Lightning, water heating and appliances that provide comfort and services to the occupants. The systems should be designed to use renewable energy sources, such as solar thermal collectors or heat pumps, and to operate efficiently and intelligently according to the demand and occupancy patterns (Unknown, How Building Design Impacts Energy Efficiency, 2022).

- The occupant behavior, which refers to the actions and preferences of the people who live or work in the building. The behavior can affect the energy consumption by adjusting the thermostat settings (Beltramino, 2021). Algeria is experiencing an acute housing crisis whose thermal comfort does not seem to be the major concern of designers. In four decades of independence, the urban and architectural

landscape of Algerian agglomerations has undergone an unprecedented change; No city or village has escaped this constructive model (collective housing). This phenomenon is characterized by a high demand or quantity has taken precedence over quality due to lack of time. This type of collective housing causes the problem of climate integration which involves considerable energy consumption. The energy crisis has suddenly highlighted the importance of the volume of fuel used for heating and cooling, due to this consumption which affects the operating cost of buildings and also the entire economy of the country (Djafri, 2021).

Problematic:

The concern to build quickly and in large quantities has favored this type of collective housing and ignored totally other typologies such as individual housing which is needed especially in southern Algeria where we have vast areas to expand.

In addition, very little thoughtful attempt to adapt this kind of construction to the climatic conditions of the region, where the same organization and the same ground plan is repeated throughout the Algerian cities where we can clearly see the inexistence of locale style in the envelope of the building as well as the absence of comfort especially thermal comfort therefore because of this unsuitability to ensure well-being and comfort, the user will resort to mechanical heating and air conditioning devices and which result in exaggerated energy consumption.

- So how can we ensure thermal comfort in the buildings of southern regions (Ouargla)? and what are the elements that can improve this type of comfort?

Hypothesis:

The problem posed and the various questions led us to formulate:

1.The introduction of local materials can improve thermal comfort.

2.The use of architectural elements can influence thermal comfort.

Objectives:
The aim of our research is to:

1. The elements that influence thermal comfort.
2. Understanding thermal behavior.
3. Look for reviews that improve thermal comfort.

The objective is to test the thermal behavior of a contemporary collective building located in Ouargla city center vis-à-vis external climatic conditions. This concerns the study of climatic conditions and the indoor temperature of collective housing. Whose interior comfort remains linked to the thermal environment that is established between the human body and the nearby environment, which depends on many criteria: wall temperature, air temperature, air movement, humidity.

Method of work:
In order to succeed in our work, we started a work process divided into three parts;

- The first part which is based on the bibliographic search of books, master's theses and doctorates of website and book PDF version as well as videos and architectural articles.
- The second part results in a field trip of the selected examples with taking photos and surveys necessary for a better understanding of behavior.
- Last step an analysis of the data collected and proposal of solutions.

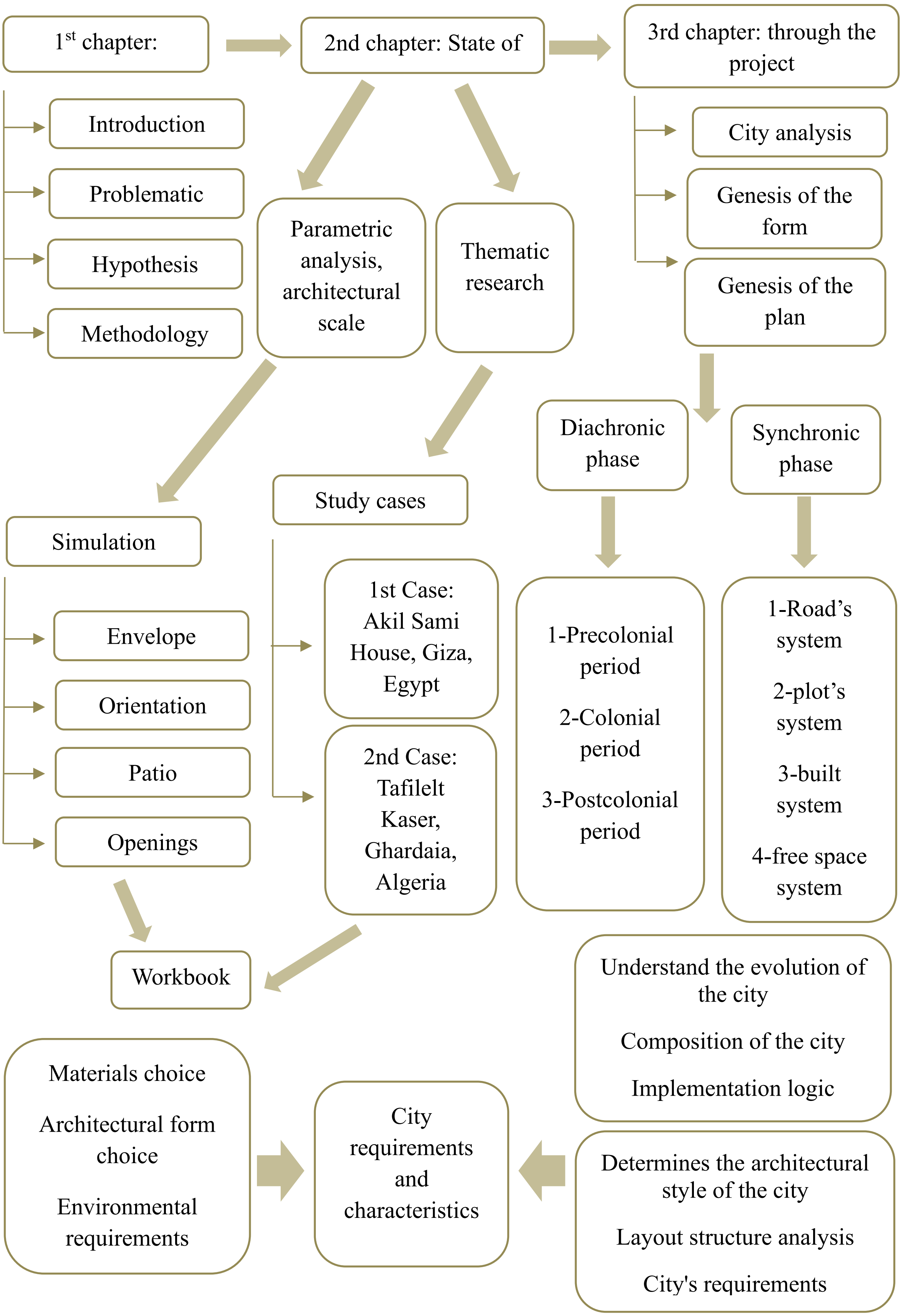

Figure 1: Thesis structure (Author,2023)

2ND CHAPTER:

STATE OF ART

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1. Concepts definition:

In order to understand the theme of our thesis let's start by defining some concepts:

- *Comfort:*

It can be defined as a state of physical ease and mental calmness or a feeling of contentment and satisfaction , it often refers to security and well-being that comes from being in a comfortable or familiar environment or situation (Miller, 2009), it can also refer to physical objects or activities that provide a feeling of relaxation, such as comfortable clothing, soft blankets, or soothing music (Kolcaba, 2003). Ultimately, what brings comfort varies from a person to another depending on gender and age, it can encompass a wide range of physical, emotional, and psychological factors in order to achieve it.

- *Types of comfort:*

in general, we have four types explained in the table below:

Table 1: Synthesis of comfort types definitions (author, 2023).

Types	What is it?	How to achieve it?	Factors
Visual comfort	Is a term used to describe the quality of lighting in a space that creates a pleasant visual experience, it refers to the ability of lighting to provide appropriate levels of illumination that allow people to see clearly and comfortably.	Is achieved through a combination of factors, including appropriate light levels, colour rendering, glare control, and light distribution.	Lightning Colours temperature Glare Contrast Ergonomic
Acoustic comfort	It refers to the ability of a space to provide appropriate levels of sound insulation, noise reduction, and acoustic balance to ensure that people can communicate, work, learn, or relax without being disturbed.	Achieving acoustic comfort can involve a combination of design strategies and technologies, such as using acoustic panels, soundproof curtains, or white noise generators.	Noise level Sound quality Reverberation Frequency response
Olfactory comfort	It refers to the ability of a space to provide appropriate levels of air quality, ventilation, and odour control to ensure that people can breathe comfortably and enjoy a pleasant aroma.	Achieving olfactory comfort can involve a combination of strategies and technologies, such as using air purifiers, proper cleaning practices, and natural or artificial air fresheners.	Cleanliness Air quality Personal preference
Thermal comfort	It refers to the state of mind that expresses satisfaction with the thermal environment. It is a subjective assessment of how comfortable a person feels with the temperature, humidity, and airflow of their surroundings.	Achieving thermal comfort is essential for maintaining the health and well-being of individuals in indoor and outdoor environments.	Air temperature Radiant temperature Humidity Air movement Clothing

- *How to achieve thermal comfort?*

Achieving thermal comfort in general requires creating an environment that meets the needs of the individuals within it. Some ways to achieve thermal comfort include (Khelifi, 2023):

1. Controlling temperature: The temperature of the environment should be maintained within a certain range for most people to feel comfortable. In extreme weather conditions, air conditioning or heating systems may be necessary.

2. Controlling humidity: The relative humidity of the environment should be maintained between 30-60% to prevent dryness or excess moisture in the air.

3. Controlling air movement: The flow of air can affect how comfortable a person feels. The air should be circulated effectively but not excessively, and drafts should be avoided.

4. Providing appropriate clothing: Clothing can significantly affect a person's comfort level. In colder environments, individuals should wear appropriate clothing to maintain warmth, while in warmer environments, lighter clothing should be worn.

5. Providing adequate ventilation: Proper ventilation can help to remove pollutants and excess moisture from the air, improving air quality and overall comfort.

6. Providing adequate lighting: Adequate lighting can help to create a comfortable environment by enhancing visibility and creating a sense of well-being.

By implementing these measures, individuals can achieve thermal comfort and create an environment that is conducive to productivity and overall well-being but in our case, we are going to focus on the first and fifth aspects by searching for some passive ways in term of Form, Envelope and Environment and apply them in our project.

2. Energy optimization on a building scale:

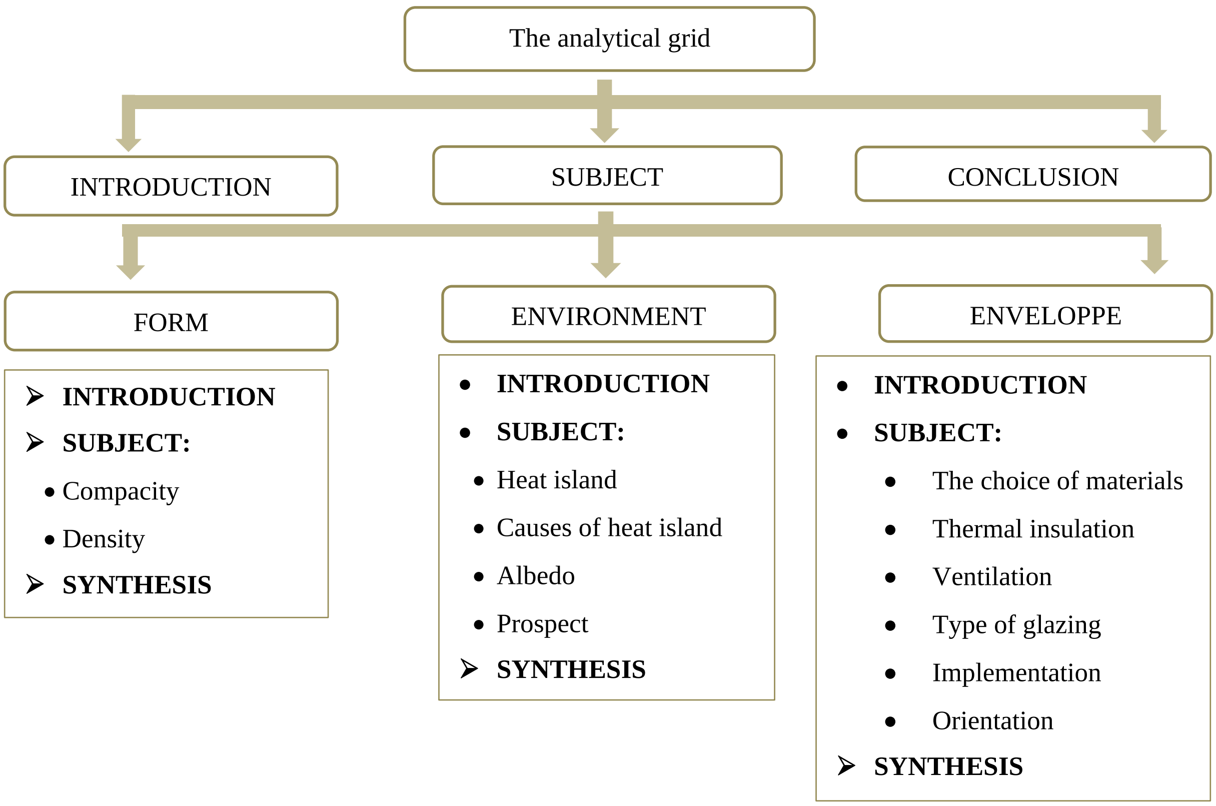
2.1 Introduction:

When we talk about energy optimization on an architectural scale, we have to think of an architectural design that meets all the criteria and climatic conditions to achieve thermal comfort with less use of heating and cooling in all seasons especially summer and winter.

In order to obtain the latter, we need a general study of the site of intervention and a good reading of the climatic data of the region concerned, this work facilitates our task and gives us a general idea of the needs of the region in order to obtain the desired comfort, from there we begin to think and create a strategy that allows us to choose the main elements of the architectural design (implantation, orientation, form of the building, construction materials, how to reduce thermal losses, how to ventilate the house naturally ..... etc.).

Each region is different from the others and each region has its climatic characteristics. It is necessary to take them into consideration to succeed in obtaining good results, because the needs and the criteria of the architectural design change from one region to another, i.e., a design in the NORTH is different from a design in the SOUTH, and in our case, we have chosen a region characterized by a hot and arid climate located in the south east of Algeria which is Ouargla.

Figure 2: Analysis chart (Author, 2023).



2.2 Envelope:

The envelope of a building is the visible part of any building, whether inside or outside the building. outside the building. In this sense, the envelope acts as an interface with the exterior. A Careful design of the building envelope is of paramount importance as it affects the energy performance of the building. It has an impact on the energy performance of the building throughout its lifetime.

2.2.1 Thermal inertia:

Thermal inertia can be defined as the ‘property of a material that expresses the degree of slowness with which its temperature reaches that of the environment’

A high thermal inertia is therefore also interesting in summer as in mid-season and in winter, it allows the storage of some of the solar heat that enters the building through the windows, to limit the heating demand in the evening.

- *Effusivity / diffusivity*

The notions of effusivity and diffusivity, which make it easier to interpret the role of thermal inertia thermal inertia. These concepts are calculated on the basis of the mass, thermal conductivity and mass heat of the materials making up the walls. They are defined as follows:

- *Thermal effusivity*

It is a measure of a material's ability to exchange thermal energy with its surroundings. It is defined as the square root of the product of the material's thermal conductivity and its volumetric heat capacity Thermal conductivity = heat flow rate × distance / (area × temperature gradient) (Buaer, 2021). It determines how a material feels to the touch, whether it feels warm or cool it can be measured by specialty sensors based on the interface temperature between two materials (Hakimian, 2020).

- *Thermal diffusivity*

It is the ratio of the thermal conductivity to the density and specific heat capacity of a material[1]. It measures how fast heat spreads through a material by conduction. It has the SI derived unit of m2/s (Karthik, 2021). Thermal diffusivity is often measured with the flash method, which involves heating a sample with a short pulse and analyzing the temperature change at a distance. Thermal diffusivity and thermal effusivity are related quantities; respectively a ratio versus a product of a material's fundamental transport and storage properties.

Material	Thermal conductivity	Density	Specific heat	Diffusivity	Effusivity
	λ ($W \cdot m^{-1} \cdot K^{-1}$)	ρ ($kg \cdot m^{-3}$)	Cp, ($J \cdot kg^{-1} \cdot K^{-1}$)	α, ($m^2 \cdot s^{-1}$)	β, ($J m^{-2} K^{-1} s^{-0.5}$)
Brick (outer)	0.77	1,750	1,000	4.40E-07	1,161
Brick (inner)	0.56	1,750	1,000	3.20E-07	990
Concrete block (heavy)	1.75	2,300	1,000	7.61E-07	2,006
Concrete block (light)	0.20	600	1,000	3.33E-07	346
Mineral wool (quilt)	0.042	12	1,030	3.40E-06	23
Plaster (dense)	0.57	1,300	1,000	4.38E-07	861
Plaster (light)	0.18	600	1,000	3.00E-07	329
Plasterboard	0.21	700	1,000	3.00E-07	383
Steel	50	7,800	450	1.42E-05	13,248
Wood	0.13	500	1,000	2.60E-07	255

Table 2: Example thermal properties of materials (Tim Dweyer, 2012)

Building materials properties are the characteristics of materials that affect their performance and suitability for various applications. Some of the common properties of building materials are:

- **Physical properties:** These include properties such as density, porosity, durability, hardness, specific weight, specific gravity, fire resistance, etc. They describe how a material behaves under different physical conditions such as temperature, pressure, moisture, etc (Unknown, TestBook, 2023).
- **Mechanical properties:** These include properties such as strength, compressive, tensile, bending, impact, hardness, plasticity, elasticity, and abrasion resistance. They describe how a material resists various forces and deformations that may be applied to it. (Harmathy, 2016)
- **Chemical properties:** These include properties such as corrosion resistance, chemical stability, reactivity, pH value, etc. They describe how a material interacts with different chemical agents and environments that may affect its quality and durability.

- **Thermal properties:** These include properties such as thermal conductivity, diffusivity, effusivity, specific heat capacity, thermal expansion coefficient, etc. They describe how a material transfers or stores heat energy and changes its dimensions with temperature. (Vicky, 2021)

Building materials properties are important for architects and engineers to select and design appropriate materials for various construction projects. They also help to evaluate the performance and service life of materials under different environmental conditions and loading scenarios.

2.2.2 The choice of materials:

The first few centimeters of material in contact with the environment are the most important in terms of inertia. It is with these first centimeters that effective heat exchange can take place to be created.

The right selection of materials can be made for a construction activity only when material properties are fully understood. Some of the most important properties of building materials such as:

- *Thermal conductivity*

It is the measure of a material's ability to conduct heat or move heat from one location to another without the movement of the material itself. It is commonly denoted by k, λ, or κ, it is measured in watts per meter kelvin (W/mK) (Ramza, 2018).

Thermal conductivity depends on factors such as temperature, chemical phase, thermal anisotropy, electrical conductivity, magnetic field, gaseous phases, and isotopic purity.

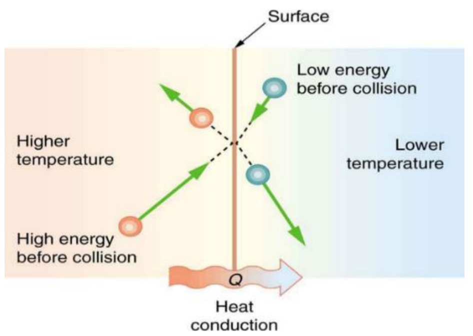


Figure 4: Heat conduction occurs through any material, represented here by a rectangular bar, whether window glass or walrus blubber. (OpenStax College Physics, 2018)

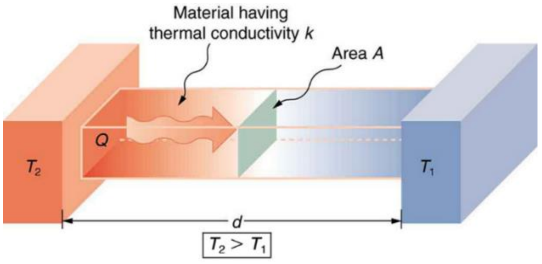


Figure 3: The molecules in two bodies at different temperatures have different average kinetic energies (OpenStax College Physics, 2018)

According to some studies made by some Architect researchers we conclude:

Figure 5: Synthesis of material studies (Richard Philippe Wafe, 2010)

Indicator	Researcher	Etude	Result
Materials	Bicini et al. 2009.	A comparative study between the indoor temperatures of an adobe house and a concrete block house concrete block house as a function of the outdoor temperature	Sound insulation: walls built of adobe offer adobe walls offer better sound insulation than than brick or concrete walls. In terms of thermal insulation: It is noticeable that the interior temperatures in the adobe house in the winter period varying between 13co despite the outside temperatures varying between 0-5co in parallel in the concrete house the temperatures vary between 5co . In the summer period it is noticed that the temperatures in the adobe house varying between 24.5c0 (stable) despite the outside temperature between 35 and 44°C and on the other hand in the concrete house the temperatures vary between 33 and 35co . **Synthesis:** Adobe has a particular capacity to regulate the temperature inside a house, i.e. the temperature inside the earthen house the house built with earth remains relatively Cool
	Minke 2006	A study on the ability of adobe to regulate indoor humidity. (this involved placing the adobe in a room with a humidity of 95% for six months).	Adobe does not lose its stability because its equilibrium moisture content is around 5-7% of its weight). 7 % of its weight). The relative humidity inside remains almost constant at 50%, with variations of 5 to 10% from of 5-10%, in a house built with adobe, despite variations in the humidity of the outside air. **Synthesis:** Adobe has the ability to regulate indoor humidity better than any other building material. building material.

2.2.3. Thermal insulation:

Thermal insulation is the process of reducing heat transfer between objects or spaces that are in thermal contact or exposed to radiative heat sources, it can be achieved by using materials or methods that have low thermal conductivity, high thermal resistance, or high reflectivity.

Thermal insulation can help to improve energy efficiency, comfort, safety, and environmental protection by minimizing heat losses or gains in buildings, pipes, vehicles, appliances, etc. (Connor, Thermal Engineering , 2019)

Some types of thermal insulation are:

- *Mineral insulation*

Those materials are made from natural inorganic materials.

- *Synthetic insulation:*

The majority of those materials are coming from fossil resources.

- *Animal and vegetable-based insulation:*

Animal and vegetable-based insulating is produced from plant or animal materials.

- *The different Technics of insulation:*

According to Louisa Parazynski and Flora Pinot we have three technics which are:

Table 3: Synthesis of insulation technics (Author, 2023)

Technic	Descriptions
Insulation from the inside	(This technique can be used for walls, roofs and floors). insulation boards are laid directly on the inside of the areas to be insulated, the advantage of this the advantage of this technique is that it is easy to implement and reduces the time of the works, on the other hand it reduces the surface area of the rooms.
Insulation from the outside	(This technique can be used for walls, roofs and attics). The insulation is applied directly to the facade, or to the roof structure but on the outside, the advantage of this the advantage of this technique is that it is very efficient and avoids thermal bridges, but it remains one of the most expensive solutions.
Insulation of the walls in their thickness	this technique integrates the insulation directly into the walls, thus avoiding the risk of thermal bridges. This solution can be used in new construction, this solution can be used in new construction, but it is also interesting in the case of renovation. The advantage of this technique is that it the advantage of this technique is that it saves time, reduces thermal bridges and facilitates installation.

Table 4:Insulation study (Benoudjafer, 2012)

Indicator	Researcher	Study	Result
Insulation	D. Medjelekh 2009	Effect of insulation thickness (Three thicknesses of insulation, 3, 5 and 7 cm, were checked in the case of a solid concrete wall with insulation placed on the outer side of its mass. The total thickness of the wall is kept constant (30 cm) and each time the thickness of the insulation is increased, the thickness of the thermal mass is decreased by the same amount).	The 7 cm thick insulation gives an improvement in thermal performance with lower temperatures from midnight to noon and from 8 pm to 10 pm than either the 3 cm or 5 cm thick insulation. The 5 cm insulation also gives lower temperatures than the other two from 13:00 to 19:00. The 3 cm insulation gives the highest temperatures during the whole day. **Summary:** The ideal thickness of insulation is 5 cm, since the interior temperature is not very sensitive at this thickness. The 7 cm thickness gives the best performance at night, and that is the moment when ventilation is ensured.

2.2.4 Natural ventilation:

According to Nick Connor, natural ventilation is the process of supplying and removing air from a space or a building without using mechanical systems, such as fans or air conditioners, it relies on natural forces, such as wind and buoyancy, to create air movement and pressure differences that drive the air exchange, it can provide fresh air, thermal comfort, and indoor air quality benefits, as well as reduce energy consumption and costs.

There are two main types of natural ventilation:

- Wind-driven ventilation: This type of natural ventilation uses the pressure differences created by the wind around the building to induce air flow through openings, such as windows, doors, vents, or louvers[12]. The wind-driven ventilation can be enhanced by using features such as wind towers, wing walls, or atria that capture and direct the wind.
- Buoyancy-driven ventilation: This type of natural ventilation uses the temperature differences between the inside and the outside of the building to create density differences that cause air movement[12]. The warmer air inside the building tends to rise and escape through high-level openings, while cooler air from outside enters through low-level openings. This is also known as the stack effect.

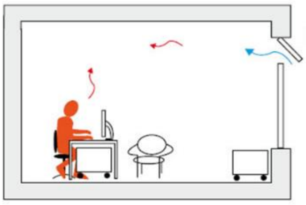
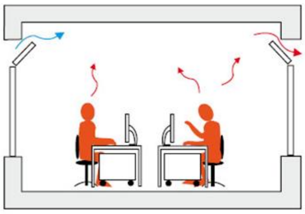
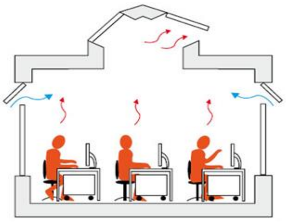
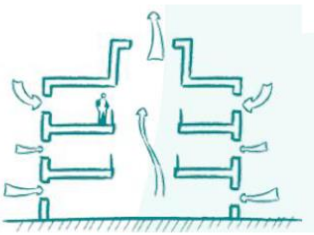
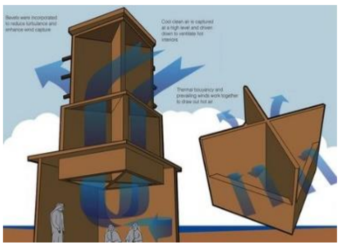
Natural ventilation can be designed and controlled by using various strategies and devices, (Connor, Thermal Engineering , 2019) such as:

1. Opening windows manually or automatically according to weather conditions, occupant preferences, or indoor air quality sensors.
2. Using operable shading devices, such as blinds, curtains, or shutters, to regulate solar heat gain and glare.
3. Using thermal mass, such as concrete floors or walls, to store and release heat and moderate indoor temperature fluctuations.
4. Using natural cooling techniques, such as night flushing or evaporative cooling, to lower indoor temperatures and enhance comfort.
5. Using passive design principles, such as building orientation, shape, layout, and envelope, to optimize natural ventilation potential and performance.

- *Types of Natural Ventilation*

There are basically two kinds of Natural Ventilation that happen naturally in buildings. First is wind-based ventilation (also introduced as cross ventilation), and the second is Buoyancy operated (also known as stack-effect) ventilation. Nevertheless, choosing the best method to design and operate a ventilation system is based on various issues. Both the effectiveness and design considerations include some different parameters, which are explained in the table below:

Table 5: Synthesis of ventilation types (Author, 2023)

Type	Illustration	Description
Single sided ventilation		In this case, only one side is free and clear for ventilation. to ventilate, but the other side is partitioned side are partitioned and without openings.
Cross ventilation		Windows in two or more façades can create cross-ventilation in the room. The ventilation is powered primarily by wind, which creates differences in air pressure on the facades in which the vents are located.
Stack ventilation		Stack ventilation occurs when there is a height difference between windows – i.e., between façade and roof windows. This type of ventilation is primarily driven by warm air rising to the top, whereby it creates a pressure difference which drives the ventilation.
Ventilation by courtyard		The role of these low-pressure patios, which are essential in the natural cross ventilation system, is to generate a continuous flow of air inside the buildings, including between the rooms and corridors.
Ventilation by a windcatcher		the temperature and pressure directing the air inside buildings in which the airspeed and its direction are essential elements to control the airflow. Originally, the windcatcher was one of the traditional Persian architectural elements used to ventilate buildings with cool air during the summer period. It was built as a tall tower containing slots facing wind direction to catch the air and direct it down to cool the building.

2.2.5 Glazing:

Glazing is referred to the panels that are fixed into the aluminium or other types of frames to curtain wall construction. Commonly, there are various techniques which can be used in the construction or placement of glazing panels; glaze panels might be glass or other materials. These methods glazing panel construction will be discussed in the following sections.

According to Robe Sabo glazing methods are provided as follows:

Single Glazed Windows:

Also called single pane windows, these windows only have one sheet of glass inside the frame. If you have an older home, chances are you have single glazed windows because those were the only types widely available when these houses were built.

Double Glazed Windows:

Double glazed windows have two panes of glass that have a space between them. In order to create insulation, argon gas—which is a nontoxic, odourless gas—is used to fill the space between the two panes of glass. As a result, double glazed windows are more energy efficient and they can help reduce any noise in your neighbourhood from disrupting the peace in your home.

Triple Glazed Windows:

If you live in an extremely cold climate, triple glazed windows, which are three panes of glass with argon gas in between them, are a good choice. These windows are the most energy efficient variety, but they are also the most expensive—costing $550 to $3,550 per window—and the heaviest. However, the upfront costs that you spend on these types of windows may be offset by the amount you save on energy bills later. In addition, triple glazed windows are the most effective at noise reduction, making your home feel snugger and more comfortable as you avoid disruptive sounds from the outside world.

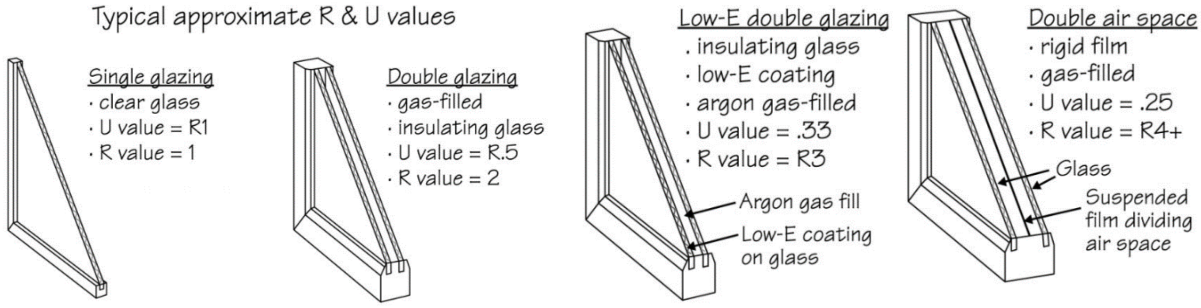


Figure 6: Types of glazing (Tom Feiza, 2020)

2.2.6 Implementation:

Implementation is the execution or practice of a plan, a method or any design, idea, model, specification, standard or policy for doing something. As such, implementation is the action that must follow any preliminary thinking for something to actually happen (Moussa, 2019).

Before building any construction, it is necessary to have a perfect knowledge of the location and the natural potentials of the site in order to benefit from the maximum of:

- Solar energy.

- Anticipate the optimal orientation.

- Anticipate possible solar protection.

The layout consists of marking out all the geometric layouts on the ground, such as:

- ✓ Earthworks to be undertaken (excavation for large-scale spoil).
- ✓ Delimitation of gullies and trenches
- ✓ Position of the foundations,
- ✓ Passage of pipes and manholes
- ✓ Layout of facade walls, gables etc.

2.2.7 Orientation:

Orientation is simply what compass direction the building faces. Does it face directly south? 80° east-northeast?

Along with massing, orientation can be the most important step in providing a building with passive thermal and visual comfort.

Orientation is measured by the azimuth angle of a surface relative to true north. Successful orientation rotates the building to minimize energy loads and maximize free energy from the sun and wind.

Successful orientation can also take advantage of other site conditions, such as rainwater harvesting driven by prevailing winds. It can even help the building contribute to the health and vitality of the surrounding social, and economic communities, by orienting courtyards or other social spaces to connect to street life.

2.3 Form (Shape)

"Our eyes are made to see shapes in the light; shadows and light reveal shapes; cubes, cones, spheres, cylinders or pyramids are the great primary shapes that light reveals well the light reveals well; the image is clear and tangible to us, without ambiguity. That is why they are beautiful forms, the most beautiful forms. Everyone agrees in this, the child, the savage and the metaphysician. (Corbusier)

2.3.1 Compactness:

Studies on the compactness of buildings generally deal with the overall form, but rarely, if ever, with the influence of architectural elements such as recesses or projections which contribute to the plan and the volume of the building.

Balconies, which can be considered as added elements, do not fall into this category since they do not modify the heated volume of the building and have very little influence on the thermal balance if they do not create a thermal bridge (Architecte, 2017)

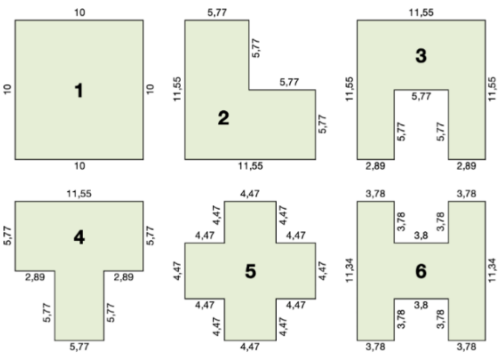


Figure 8: Compactness of squire shapes (J-M Pupille, 2017)

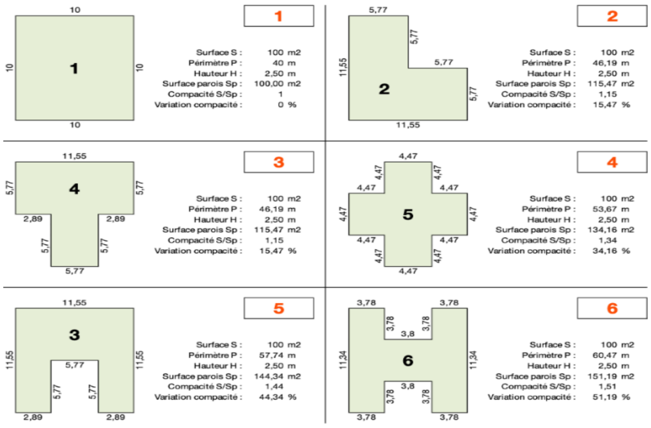


Figure 7: Determination of the compactness coefficient as a function of the shape (J-M Pupille, 2017)

Indicator	Researcher	Study
Compactness	Unité de Recherche Appliquée en Energies Renouvelables, Ghardaïa – Algérie 15, 16 et 17 Octobre 2012	The compactness of the architecture shows that the energy performance deteriorates as the surface area of the external facades increases, thus a decrease in energy performance for form 02 of 7.81% and for form 03 (even less compact) a decrease of about 13% compared to form 01 (the most compact). The compactness which is often not taken into account during the design and even during the design and even during thermal studies, whereas our study shows our study shows without ambiguity the important role of compactness for energy management.

Table 6: Synthesis of study case Ghardaia (Author, 2023)

Results:

- **For the first case:** The heating and cooling energy requirements in the heating and cooling energy requirement (EU) of the building is found to be in the order of 9180 (KWh/an) for heating and 11060 (KWh/an) .
- **For the second case:** The simulation gave the heating and cooling energy requirements for the 2nd case of 10290 (KWh/an) energy requirements of 10290 (KWh/an) for heating and 11530 (KWh) for cooling for the second case and 11530 (KWh/an) .
- **For the third case:** The simulation gave for the 3rd case: 11710 (KWh/an) for heating 11160 (KWh/an) for air conditioning A total annual requirement of 22870 (KWh).

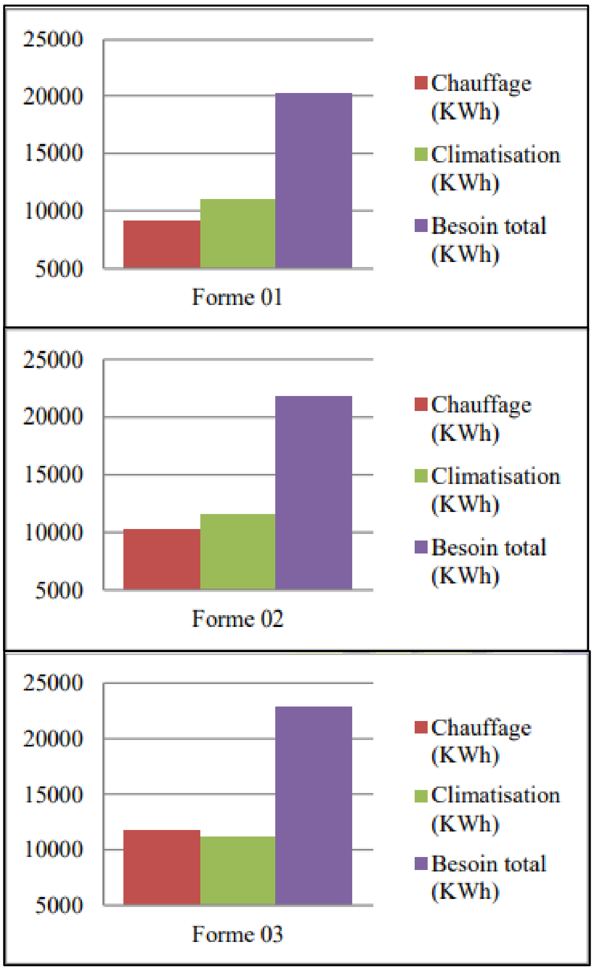


Figure 9: Graphs (A.Borsas, 2012)

2.3.2 Density:

Density in architecture is a term that refers to the amount of built space or population in a given area. It can be measured in different ways and at different scales, depending on the purpose and context of the analysis.

The definition of density in relation to build environment can have different meanings or different quantification according to the method of analysis and spatial indices taken into account. There is no universal standard formula, only some of the formulas are being used more as opposed to others. (Unknown, Densit

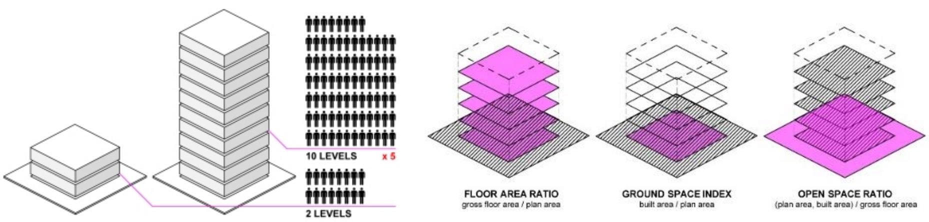


Figure 10: Population and Building density.

Table 7: Synthesis of study cases (Lefebvre Megane, 2013)

<table>
<tr><th>Indicator</th><th>Cases</th><th>Synthesis</th></tr>
<tr><td rowspan="4">Density</td><td>• Agglomeration centre (intermediate housing).
• land area: 0.51 ha
• Dwellings: 68
• Number of units/ha: 133
• Building density: 1.1
• Number of floors: R+3</td><td rowspan="4">-Density does not correspond to specific urban forms
- High density is not synonymous with a high height
- More than height, it is the compactness and continuity of to be related to the density of the with density
- Dense individualised housing can have high densities</td></tr>
<tr><td>• Town centre (grouped individual housing)
• land area: 1.8 ha
• Dwellings: 118
• Number of dwellings/ha: 65
• Building density: 0.63.
• Number of floors: R+2</td></tr>
<tr><td>• Large complex (collective housing)
• Land area: 10 ha
• Dwellings: 573
• Number of units/ha: 58
• Building density: 0.41
• Number of floors: R+5</td></tr>
<tr><td>• Suburban (individual housing)
• Land area: 3.5 ha
• Dwellings: 38
• Number of dwellings/ha: 11
• Building density: 0.12
• Number of floors: R+1</td></tr>
</table>

Plant’s density:

According to AHMED OUAMER, F. (2007), vegetation density refers to the horizontal distribution of all green urban facilities (vegetation parks, tree gardens) and their relationship to the total surface of the calculation perimeter.

The distribution of vegetation in the urban layout has an impact on the temperature balance and the relative humidity of the air.

The numerical value of the vegetation density is a function of all the vegetation arrangements and is expressed by the following equation by AHMED OUAMER, F. (2007): PD = Av / Ap

Av: total area of the green development.

Ae: total area of the calculation perimeter

2.4 Environment

2.4.1 Introduction:

The environment is the set of elements (biotic or abiotic) that surround an individual or a species, some of which contribute directly to its needs, or as a species, some of which contribute directly to meeting its needs, or as the set of natural (physical, chemical, biological) and cultural (sociological) conditions likely to affect living organisms and human activities.

2.4.2 Heat Island:

Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. These pockets of heat are referred to as "heat islands." Heat islands can form under a variety of conditions, including during the day or night, in small or large cities, in suburban areas, in northern or southern climates, and in any season.

Causes of heat island: According to Simmons, M.T., B. Gardiner, S. Wind Hager, and J. Tinsley. 2008 heat island might be a result of:

- **Reduced Natural Landscapes in Urban Areas**. Trees, vegetation, and water bodies tend to cool the air by providing shade, transpiring water from plant leaves, and evaporating surface water, respectively. Hard, dry surfaces in urban areas – such as roofs, sidewalks, roads, buildings, and parking lots – provide less shade and moisture than natural landscapes and therefore contribute to higher temperatures.

- **Urban Material Properties.** Conventional human-made materials used in urban environments such as pavements or roofing tend to reflect less solar energy, and absorb and emit more of the sun's heat compared to trees, vegetation, and other.

- natural surfaces. Often, heat islands build throughout the day and become more pronounced after sunset due to the slow release of heat from urban materials.
- **Urban Geometry.** The dimensions and spacing of buildings within a city influence wind flow and urban materials' ability to absorb and release solar energy.

In heavily developed areas, surfaces and structures obstructed by neighbouring buildings become large thermal masses that cannot release their heat readily. Cities with many narrow streets and tall buildings become urban canyons, which can block natural wind flow that would bring cooling effects.

- **Heat Generated from Human Activities**. Vehicles, air-conditioning units, buildings, and industrial facilities all emit heat into the urban environment. These sources of human-generated, or anthropogenic, waste heat can contribute to heat island effects.
- **Weather and Geography**. Calm and clear weather conditions result in more severe heat islands by maximizing the amount of solar energy reaching urban surfaces and minimizing the amount of heat that can be carried away. Conversely, strong winds and cloud cover suppress heat island formation.

2.4.3 Albedo:

Albedo is a term that describes how much light is reflected by a surface or a body. It is measured on a scale from 0 to 1, where 0 means no reflection and 1 means total reflection. Albedo can vary depending on the colour, texture, angle, and wavelength of the surface or body and the light source. (Rafferty, 2023)

2.4.4 Prospect:

Several researches consider the H/L ratio, as the basic structural unit of an urban entity. urban entity, the table below shows the different definitions of prospect (H/L ratio):

Table 8: Different definitions of prospect (Author, 2023)

Researchers	Definitions
Givoni (1998)	The ratio between the average height of a space and its smallest width the ratio between the average height of the space and its smallest width allows to evaluate the smallest distance between facades that may be exposed or not to solar radiation.
ALITOUDERT, F. (1999)	H/L ratio can be observed with a relatively high-density if the buildings are staggered. This same ratio can be presented in a simplified form of a rectangular profile. The H/L ratio expresses the ratio between the average height of the space and its width.
SANTAMOURIS, M. (2001)	H/L ratio can change the initial wind flow. Facades can channel the wind, slow it down the wind, slowing it down and causing vortex movements at the foot of the building.

3.Passive parameters in an arid climate

3.1 The climate in Algeria:

In Algeria, the largest African country, there are three types of climates: the mild Mediterranean climate of the coast (zone 1 on the map), the transitional climate of the northern hills and mountains (zone 2), which is a little more continental and moderately rainy, and finally, the desert climate of the vast area occupied by the Sahara (zone 3).

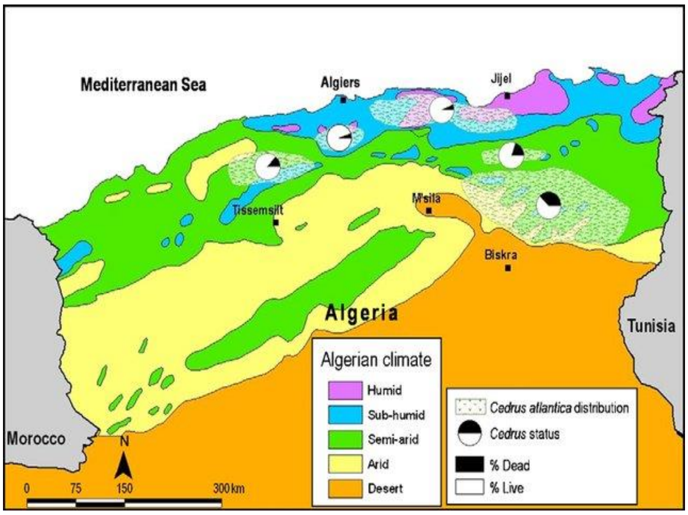


Figure 11: different climate zones by Dominique Bachelet

Table 9: Climate types and characteristics in Algeria (Belkacem Berghout: 2012)

Zones	climate	Characteristics
The Tell	Mediterranean	• Hot and dry summer. • Mild and wet winter. • High precipitation. • Sunshine and dryness in the summer period.
The Plains	Continental	• A large annual temperature range (over 20°C)1. • Cold winter. • Hot and dry summers. • Annual precipitation exceeds 500mm.
The Sahara	Semi-arid	• Hot and dry summer. • Cold winter (during the night) • drought for most of the year the year. • Insufficient precipitation. • Sunshine throughout the year
	Arid	• Hot and dry summer. • Cold winter (during the night). • Permanent dryness and aridity throughout the year. • A great lack of water. • Low humidity. • Sunshine throughout the year

3.2 Hot & Dry climate:

Hot climates are characterised by mean annual temperatures between 20 and 35°C and fall into two main categories according to humidity, which has a significant effect on the proportion of direct or diffuse solar radiation:

- Dry, for a relative humidity below 55% (dry tropical, desert, hot altitude climates).
- Humid, for a relative humidity above 55% (equatorial, tropical monsoon, tropical humid, Mediterranean climates).

3.2.1 construction materials:

The materials surrounding the occupants of a building are of paramount importance for protection against heat and cold.

Careful consideration must be given to the choice of wall and roof materials and their thicknesses in relation to their physical properties, such as thermal conductivity, resistivity and transmission, and optical reflectivity.

Table 10: Sythesis of building materials used in arid clilate (Author, 2023)

	Adobe	**Pisé (masonry)**	**CEB**
Definition	Adobe is one of the oldest building materials. This brick made of clay, water and sun-dried straw is still one of the most widely used building materials in the world.	Pisé is a building system that has been used for centuries. It is made of earth and is widely used throughout the world.	Compressed Earth Bricks (or C.E.B.) allow a modern use of raw earth and a rapidity of the construction. used for the purpose of giving inertia to the habitat
Components and proportions	-55 to 75% sand. -10 to 28% silt. -15 to 18% clay. -0 to 3% organic matter.	20% gravel. -40% sand. -15% silt -25% clay.	30% - 40% clay. -20% - 30% sand. -4% - 8% Cement.
Characteristics Physical	-clay soil sandy soil with a good proportion of sand. Dimensions40*20*10cm	Soil texture sandy or sandy-gravelly gravelly texture. A silty or sandy-clay soil also suitable.	-Soil texture: sandy-clay. -Dimensions: 290 x 140 x 85 mm.

Characteristics Thermal	-Insulation Thermal insulation:0 to 4W/mC°. -Mass density: 1200 à 17000kg/m³. -Conductivityλ:0.650 /m.K	-Capacity heat capacity: 510 Wh/m³°C. -Mass density: 1800 Kg/m3 -Conductivity λ: 0.8W/m.K.	-Thermal conductivity (λ): 11w/m°C. -Density (ρ): 2000 kg/m3 -Heat capacity by volume: 3000 kJ/m3. °C.
Characteristics Mechanical	-Density: 1.4 to 1.8 T/m3. -Strength in compression Strength: 0 to 5 MPA. -Durability: Low.	-Density: 1.7 to 1.9 T/m3. -Resistance in Compression strength: 20 to 80 KG/cm2.	-Density: 2000 kg/m3 -Compressive strength: 78bars.
Advantages	Raw material readily and locally available. Low-cost production equipment.	Solid, self-supporting self-supporting wall. -Very good sound insulation.	-Very good hygrothermal regulation inertia and regulation and humidity regulation.
Disadvantages	-Consumes a lot of water. -Drying time drying time depending on climate. -Low resistance to water	Very sensitive to rain, moisture and the freeze-thaw mechanism.	-Stabilised bricks not resistant to water. -Industrialization difficult

3.2.2 The openings:

In arid areas, a difficulty is found in combining the three functions of the ordinary window: light, ventilation and view. If windows are used to provide air movement inside, they must be very small, which reduces the amount of light in the room. If windows are used to provide indoor air movement, they must be very small, which reduces the amount of light in the room. Increase the size to allow sufficient light and an outside view allows in warm air as well as strong offensive glare. glare. Therefore, it is necessary to add elements to satisfy all three the three functions of the window.

There are many different reasons to want to control the amount of sunlight that is admitted into a building. In warm, sunny climates excess solar gain may result in high cooling energy consumption, in order to avoid this, we need to use some elements shown in the figure below:

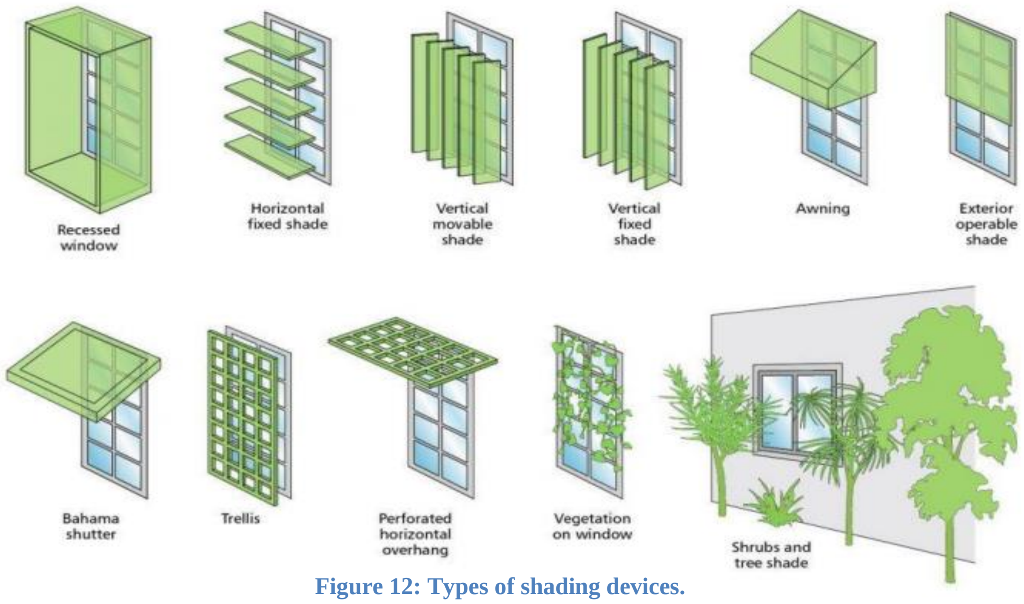
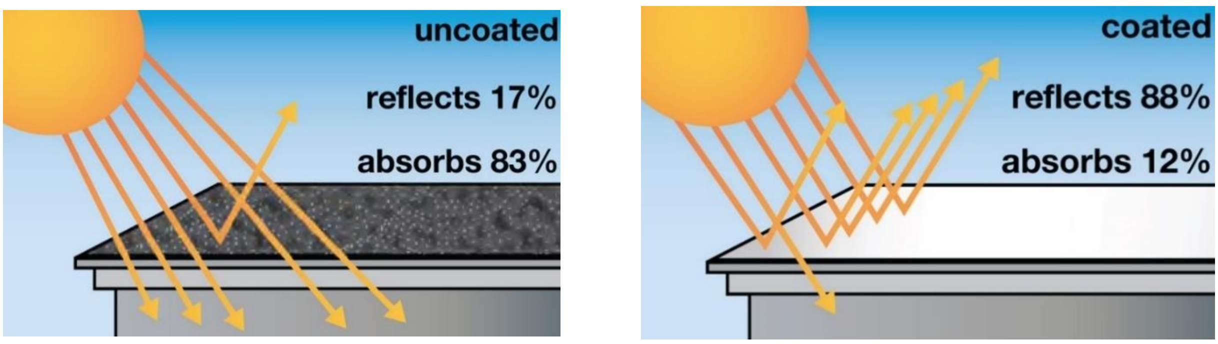


Figure 12: Types of shading devices.

3.2.3 The rooftop:

The indoor environment is affected by thermal loads that come through the building envelope exposed to the sun, wherein a large amount of heat is transferred into buildings of large envelopes. Painting exterior building envelopes with light-coloured coatings reduce the transferred heat remarkably thanks to the high reflectivity of these coatings against solar rays, as shown in the figure bellow:

Figure 13: Difference between coated and uncoated rooftop.



3.2.4 The courtyard (patio):

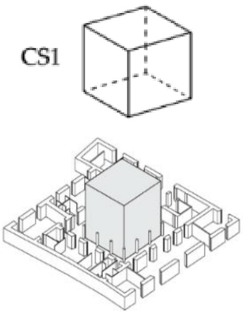
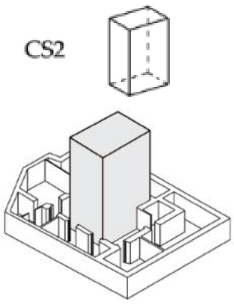
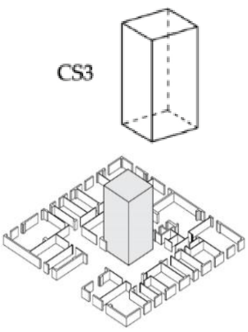
According to Hassan Fathy the patio is an important element to ensure the fresh air in any construction especially in the hot and dry climate, by definition the patio is a courtyard lined with porticoes or arcades or just cells and spaces. The great difference in temperature between night and day is an important climatic on which the patio depends for its function. Due to the sun's rays of the sun, the warm air rises upwards, because its density is reduced (called convection) and resolves the position of the cooler air, which in turn warms up and so on. warms up and so on. There is a continuous heat source that generates a constant motion.

- *Study case:*

In order to assess the influence of this geometric factor on the cooling energy demand of the

building indoors, we need to rely on a study 'Unravelling the impact of courtyard geometry on cooling energy consumption in buildings' (Diz-Mellado, 2023), where the researcher has analysed three dwellings with an interior courtyard:

Table 11: Synthesis of the three cases (Author, 2023)

Cases	Geometrical parameters	Results
	Length: 9 m Width: 9 m Height: 8,5 m Area: 81 m² AR = H/W = 0.95	The simulation has been performed for this case with the lowest energy saving results, with the lowest AR (8%). Cooling demand simulation results shows between 24-26(kWh/m²)
	Length: 5,6 m Width: 4 m Height: 8,5 m Area: 22,4 m² AR = H/W = 1,50-2,12	The simulation has been performed for this case with the medium energy saving results, with the medium AR (11%). Cooling demand simulation results shows between 27-33(kWh/m²)
	Length: 7,3 m Width: 6,6 m Height: 14 m Area: 48,2 m² AR = H/W = 1,92-2,12	The simulation has been performed for this case with the highest energy saving results, with the highest AR (18%). Cooling demand simulation results shows between 17-21(kWh/m²)

- *The influence of the courtyard's geometry:*

The results show an increase in TG (indoor temperature- courtyard temperature) of almost 4°C between the selected cases.

The simulations performed, taking into account the courtyard geometry itself and the shading it generates (Simulation B), indicate energy savings of 7-17% compared to simulation, which does not take into account the shading generally by the courtyard geometry.

The energy saving increase by an additional 4% when the monitored courtyard temperatures are introduced in (simulation C)

Depending on the geometry of the case studies used, energy consumption between different case studies can be reduced by up to 10%. This result establishes a direct correlation between courtyard geometry and the TG and the percentage of energy savings produced. The higher the AR, the higher the TG, and the greater the energy savings in the building due to the courtyard. This effect, which depends on parameters such as the level or orientation of the rooms adjacent to the courtyard, is analysed below in detail.

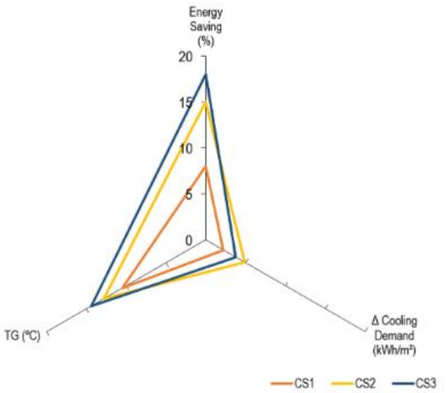


Figure 14: Comparison of results as a function of courtyard geometry (Eduardo Diz-Mellado, 2023)

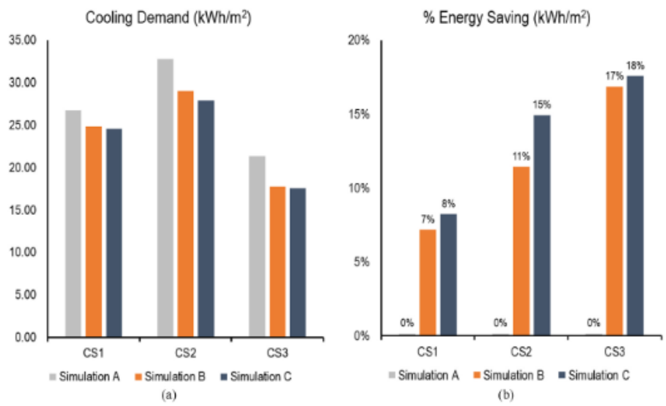


Figure 15: Simulation results of colling demand and energy savings (Eduardo Diz-Mellado, 2023)

The influence of the courtyard's geometry:

For an analysis of the influence of orientation and perimeter verandas on the courtyards of the case studies, only CS1 and CS2 are considered, as CS3 has no perimeter verandas.

3.2.5 The wind catcher:

A windcatcher is a traditional architectural element that originated in Iran, and is used to create cross ventilation and passive cooling in buildings (Parham Kheirkhah Sangdeh, 2022). it comes in various designs: unidirectional, bidirectional, and multidirectional. They work by directing cool wind that is circulating at higher levels downwards through vertical openings with oblique sides (Stouhi, 2021).

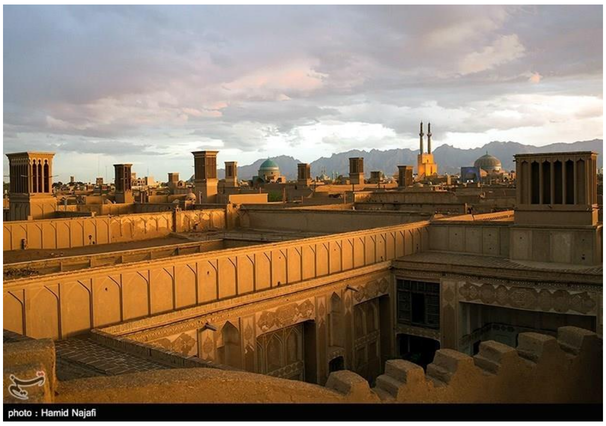


Figure 16: Iran Wind catchers (Hamid Najafi, 2017)

- *Function of a Malqaf*

The malqaf is a shaft rising high above the building with uni-directional opening facing the prevailing wind. It traps the wind from high above the building where it is cooler and stronger, and channels it down into the interior of the building. The malqaf thus dispenses with the need for ordinary windows to ensure ventilation and air-movement in addition to enhancing indoor environmental quality. The malqaf is also useful when filters are integrated within the shaft; in reducing the sand and dust so prevalent winds of hot arid regions.

- *Types of wind catchers:*

Beyond the evident typology in Muslim-Arab architecture and the guiding architectural principles, their buildings were shaped by a conceptual framework, which developed an understanding of conscious responses to environmental, urban and societal conditions of existence. Traditional buildings are the true expression of the architecture that provides comfortable living conditions in all different climates. In hot arid regions, in specific, the forms of these traditional buildings have been shaped according to the available natural sources of energy, which help reduce humidity and create natural ventilation.

Table 12: Synthesis of wind catcher types (Author, 2023)

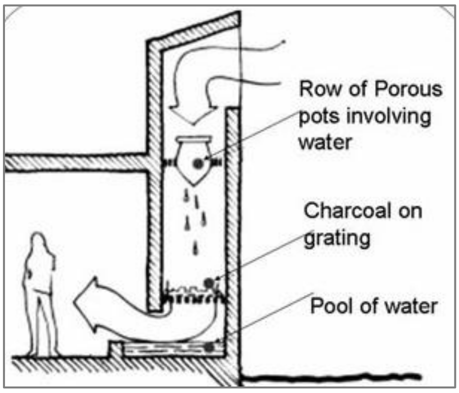
<table>
<tr><th>Type</th><th>Illustration</th><th>Description</th></tr>
<tr><td>Unidirectional Windcatcher</td><td>

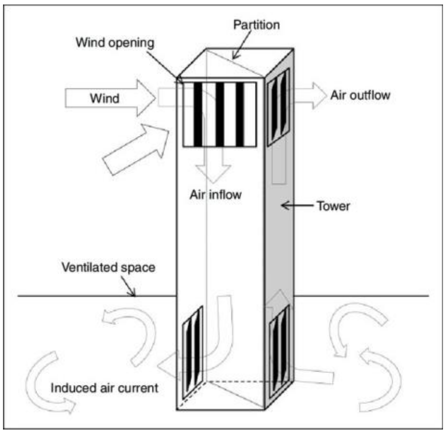
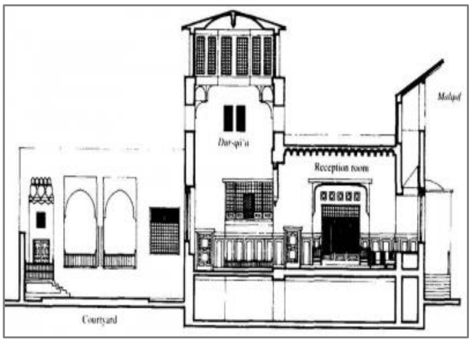
Figure 17: traditional unidirectional windcatcher (Abbas Hassan, 2015)</td><td>A unidirectional windcatcher is a type of windcatcher that has only one opening facing the direction of the prevailing wind, it is designed to catch the cool breeze and direct it downwards into the building and it is suitable for regions where the wind direction is relatively constant.</td></tr>
<tr><td>Bidirectional Windcatcher</td><td>

Figure 18: Traditional bi-directional wind-catcher basic principle. (Radwan Kassir, 2015)</td><td>A bidirectional windcatcher is a type of windcatcher that has two openings facing opposite directions, it is designed to catch the cool breeze from either direction and direct it downwards into the building and is suitable for regions where the wind direction changes frequently.</td></tr>
<tr><td>Multidirectional Windcatcher</td><td>
Figure 19: multidirectional windcatcher (Hassan Fathy, 1986)</td><td>A multidirectional windcatcher is a type of windcatcher that has four or more openings facing different directions[12]. It is designed to catch the cool breeze from any direction and direct it downwards into the building and it is suitable for regions where the wind direction varies widely.</td></tr>
</table>

Study case:

The urban peak load of energy consumption in the meantime is used to satisfy air conditioning demands alone. Therefore, the objective of the research is to develop a viable passive alternative to active cooling by exploring the potentials and design parameters of windcatchers as solution for passive cooling and natural ventilation during the summer season for low-rise housing (Attia, 2009):

Table 13: windcatcher case study synthesis (Author, 2023)

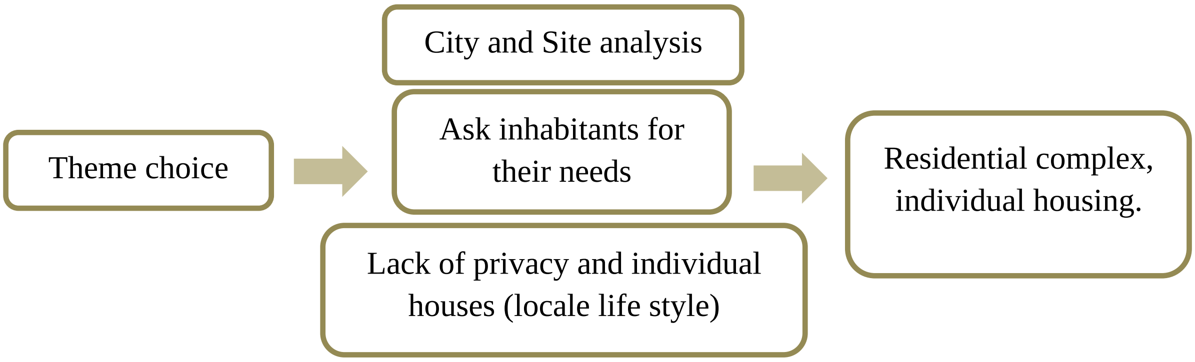
Study	Researcher	Methodology	Results
Designing the Malqaf for Summer Cooling in Low-Rise Housing.	Shady Attia, André De Herde (22-24/06/2009)	This study investigated, both theoretically and experimentally, the interaction between parameters considered to be important in achieving natural ventilation, passive cooling and indoor environmental quality. The research has been carried out in two parts. The first part consisted of an analysis of existing malqaf houses, necessary to identify the main design parameters and traditional design settings. The second part compromised the flow visualisation in wind tunnel for a model that resembles the traditional buildings in Egypt. Each part was started with a literature review on the specific subject	The experimental results carried out in the smoke tunnel visualised the flow patterns inside the test model. Also, we have measured the velocity, not taking in account internal resistances such as filters. The measurements were based on influence of design parameters on the prototypical model. The air velocity profile at test section was measured and presented. It is important to mention that the results are not representing the full-scale experience.

4.Thematic research

4.1 The theme choice

The theme is chosen from the analysis of the city, focusing on vocations and gaps in the intervention site in Ouargla, here is a representative diagram of theme:

Figure 20: Theme choice schema (Author, 2023)



4.2 Definition of housing:

Housing, or more generally, living spaces, refers to the construction and assigned usage of houses or buildings individually or collectively, it is a basic human need, and it plays a critical role in shaping the quality of life for individuals, families, and communities (Oxford, 1989) to ensure that members of society have a place to live, whether it is a home or some kind of physical structure for dwelling, lodging or shelter and it includes a range of options from apartments and houses to temporary shelters and emergency accommodations (Wright, 1983).

4.3 Brief history of housing:

The history of housing is a long and complex one, involving different types of dwellings, and influences from various cultures, climates, and socio-economic factors, so here is what we found according to synthetised in the table below:

Table 14: Types of habitats (Author, 2023)

Type	Definition
Nomadic habitat	At the beginning of prehistory, man was nomadic and moved according to the seasons, so he had no need to settle permanently somewhere for that he made a quick shelter to protect against bad weather and wild animals.
Sedentary Habitat	About 12k years ago man became sedentary he invented breeding and agriculture and to do this, man needed a durable shelter.
Rural habitat	These include areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units. The houses are found in forest, farmland or rangeland areas. Developed open spaces, such as parks, golf courses, developed campgrounds and ball fields are included here
Urban habitat	These are the most developed areas in the landscape. It includes areas characterized as low density residential, medium density developed, and urban and industrial areas. They include a high number of land-cover types, including areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-100 percent of total cover

According to Jimmy Kagan the current style, which in this case would be 21st century architecture and design. It's evolutionary, meaning it changes and grows as we do, constantly adapting to what's new, intriguing, and trending in the world of home design. now adays we have three famous typologies: individual, collective and semi-collective.

Table 15: housing typologies (Author, 2023)

Typologies	Definition
Collective Housing	It is a building or groups of buildings that include individual dwellings, where each unit is inhabited by a family, independent from the rest. Their use is mainly residential and there are common areas, such as the entrance and a common garden or a garage. At the end of the 19th century and during the first half of the 20th century, the growth of cities and socioeconomic and cultural changes promoted the development of collective housing, which responded to the great demand for housing in urban areas. There are several types of collective housing projects: Residence, Lofts, Flat-Blocks, Duplex... (Housing, 2021)
Semi-Collective Housing	Intermediate or semi-collective housing is an intermediate urban form between the individual house and the collective building (flats). It is mainly characterized by a grouping of superimposed dwellings with characteristics similar to individual housing: individual access to the dwellings and private outdoor spaces for each dwelling. (Mialet, 2006)
Individual Housing	The term "individual housing" is used to describe a single-family dwelling, i.e., one in which only one family resides; it is also called a "single-family house". In contrast to collective housing with several dwellings in the same building, individual housing corresponds to a building with only one dwelling and a specific entrance. There are two types of individual housing: Pure individual or diffuse individual and grouped individual. (Ooreka, 2023)

4.4 Housing in hot and dry climate:

According to the Department of Energy (DOE), housing in hot and dry climates should have high-performance ducts that are located fully within conditioned space, ducts in sealed attics, or a "high-performance attic" that adds insulation to the roof deck of a normally vented attic1. These strategies can help reduce cooling loads and improve energy efficiency.

Building a new house in a hot dry climate in quite different then building a house in a cold climate therefore in order to design a house in such a climate we need to follow the next steps:

1. The building orientation is the most basic and prominent element to consider while designing, it should help in minimizing sun exposure during summer and provide warmth during winter, it is recommended to orientate our building in north-south path and avoid west orientation.
2. The material choice and thickness of walls which should have low-conductivity and a high resistance value, it is recommended to use locale materials (sun-dried bricks, masonry, …).
3. The openings (windows) as much as it is important to provide ventilation it is also necessary to keep the size of the windows small and minimal in number as to reduce heat, the optimum window area for the eastern and western building facades varies depending on the location. For example, in Bushehr (Iran), it is 30-50%; in Tabriz (Iran), it is 40-70%, respectively (Shaeri, 2019).
4. Roofs suffer most because it is the first surface facing the sky which means it has the most direct contact with the sun receiving the solar radiation throughout the year that effects the ambient temperature, it is recommended to coat the roof with w alight colour. (Ganapathy)
5. Plants and vegetation act as a cooling element in the regions of the hot and dry climate, that is why vegetation plays a key role in designing (bougainvillea, palms, Dodona...Etc.).
6. Colour is also an important aspect where it is better to white walls in the exterior envelope as they reflect heat, given their high reflection ratio. (Ganapathy)

In order to understand the impact of the different settings of the building (such as: orientation, walls, windows, WWR, etc) we tried to make some hypothesis and simulated them in the module using 'Design Builder' as a program of simulation, following the next simulation.

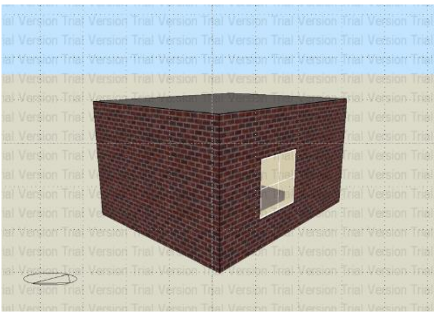


Figure 21: Module of simulation on DesignBuilder (Author, 2023).

Simulation:

1.Module:

Our module is a cube of (6*6) m², with a window in the north side and a door in the south side.

2. The table of parameters:

Inputs	Hypothesis							
Orientation	0°	45°	90°	180°	135°	225°	270°	315°
Building materials	Burned brick wall U=1.526(w/m²-k)			Masonry wall U=0.980(w/m²-k)			Aerated brick wall U=0.690 (w/m²-k)	
Glazing ratio (WWR)	10%			20%			30%	
Glazing types	Sgl LoE (e2=.4) Clr 3mm			Sgl LoE (e2=.2) Clr 6mm			Dbl LoE (e2=.1) Clr 3mm/13mm Air	
Local Shading	No shading			1.0m Overhang			1.5m Overhang	
Heating Set-back temperature	20			22			24	
Cooling Set-back temperature	28°C			29°C			30°C	

Results:

1. *Sensitivity Analysis Report:* Sensitivity analysis identifies how uncertainty in an output relates to uncertainty in the input parameters. This analysis identifies which input variables influence the simulation results the most.

The report consists of following sections:

1) Input Variables: Details of all simulation input with their distribution curves

2) Outputs (KPIs): Details of the outputs analyzed.

3) Analysis Information: Analysis summary, details about input samples and output uncertainty.

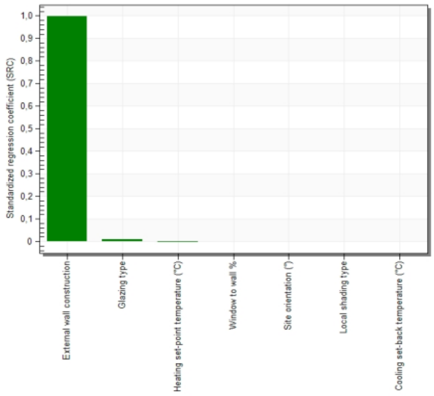
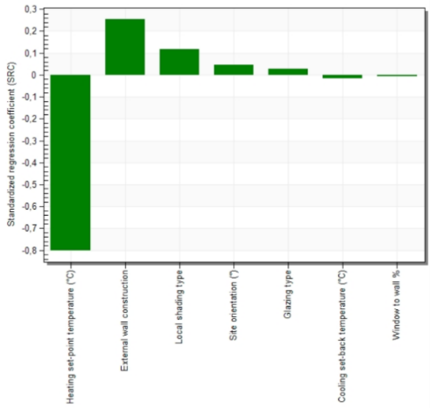
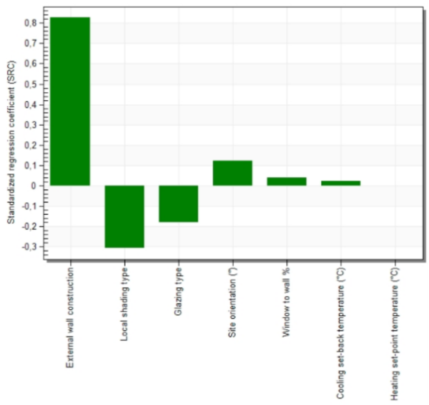
4) Sensitivity Analysis Results: Graphs and statistical details identifying most influential parameters for each output.

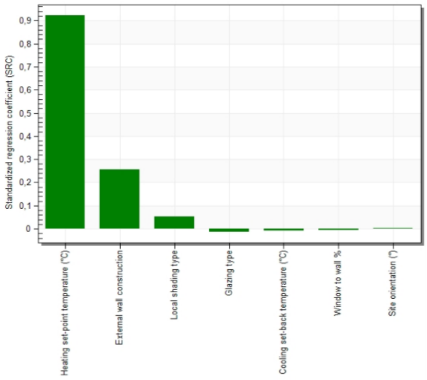
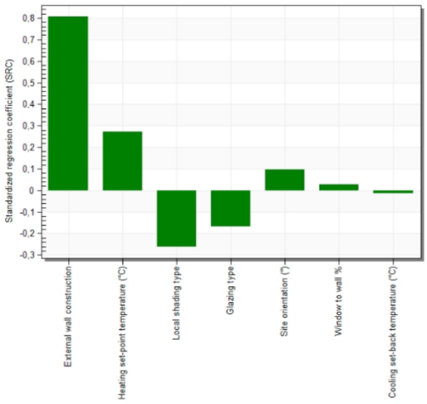
Summary of the influential factors for each output:

- **Embedded CO2** is most strongly *influenced by External wall construction*. The input and output are directly related. Increasing External wall construction leads to increase in Embedded CO2. Glazing type, Heating set-point temperature, Window to wall %, Site orientation, Local shading type and Cooling set-back temperature do not have a notable influence on Embedded CO2, therefore, these inputs can be ignored in further analysis of Embedded CO2 for this model.
- **Discomfort ASHRAE 55 Adaptive 80% Acceptability** is most strongly *influenced by Heating set-point temperature, however there is an inverse relationship*. Increasing Heating set-point temperature leads to a decrease in Discomfort ASHRAE 55 Adaptive 80% Acceptability. Discomfort ASHRAE 55 Adaptive 80% Acceptability is also strongly influenced by External wall construction. Discomfort ASHRAE 55 Adaptive 80% Acceptability is also moderately influenced by Local shading type. Site orientation, glazing type, Cooling set-back temperature and Window to wall % do not have a notable influence on Discomfort ASHRAE 55 Adaptive 80% Acceptability, therefore, these inputs can be ignored in further analysis of Discomfort ASHRAE 55 Adaptive 80% Acceptability for this model.
- **Cooling (Electric)** is most strongly *influenced by External wall construction*. The input and output are directly related. Increasing External wall construction leads to increase in Cooling (Electric). Cooling (Electric) is also strongly influenced by Local shading type. Cooling (Electric) is also moderately influenced by Glazing type and Site orientation. Window to wall %, Cooling set-back temperature and Heating set-point temperature do not have a notable influence on Cooling (Electric), therefore, these inputs can be ignored in further analysis of Cooling (Electric) for this model.
- **Heating (Gas)** is most strongly influenced by Heating set-point temperature. The input and output are directly related. Increasing Heating set-point temperature leads to increase in Heating (Gas). Heating (Gas) is also strongly influenced by External wall construction. Local shading type, glazing type, Cooling set-back temperature, Window to wall % and Site orientation do not have a notable influence on Heating (Gas), therefore, these inputs can be ignored in further analysis of Heating (Gas) for this model.
- **LCA (Simple)** is most strongly influenced by External wall construction. The input and output are directly related. Increasing External wall construction leads to increase in LCA (Simple). LCA (Simple) is also strongly influenced by Heating set-point temperature and Local shading type. LCA (Simple) is also moderately influenced by Glazing type and Site orientation. Window to wall % and Cooling set-back temperature do not have a notable influence on LCA (Simple), therefore, these inputs can be ignored in further analysis of LCA (Simple) for this model.

Result Interpretation

Table 16: Synthesis of simulation results Design Builder (Author, 2023)

<table>
<tr><th>Output</th><th>Results</th><th>Diagram</th></tr>
<tr><td>CO2 (Embedded CO2)</td><td>For the output: 'CO2 (Embedded CO2)', the 'adjusted R-squared' value of '0,9998' is high, suggesting that most of the key sensitive input variables have been identified. Only a few input variables might be left that can improve the results. The current results can be usefully considered to identify most and least sensitive input variables.</td><td>
</td></tr>
<tr><td>Discomfort (Discomfort ASHRAE 55 Adaptive 80% Acceptability)</td><td>For the output: 'Discomfort (Discomfort ASHRAE 55 Adaptive 80% Acceptability)', the 'adjusted R-squared' value of '0,7455' is not very high, suggesting that the current input variables partially explain the uncertainty in the output. Some more input variables need to be identified to improve the results. Alternatively, some of the current input variables are insignificant and can be removed. The current results can be still be used to screen out less sensitive input variables.</td><td>
</td></tr>
<tr><td>Cooling (Cooling (Electric)</td><td>For the output: 'Cooling (Cooling (Electric))', the 'adjusted R-squared' value of '0,8184' is not very high, suggesting that the current input variables partially explain the uncertainty in the output. Some more input variables need to be identified to improve the results. Alternatively, some of the current input variables are insignificant and can be removed. The current results can be still be used to screen out less sensitive input variables.</td><td>
</td></tr>
</table>

Output	Results	Diagram
Heating (Heating (Gas)	For the output: 'Heating (Heating (Gas))', the 'adjusted R-squared' value of '0,8946' is high, suggesting that most of the key sensitive input variables have been identified. Only a few input variables might be left that can improve the results. The current results can be usefully considered to identify most and least sensitive input variables.	
LCA (LCA Simple)	For the output: 'LCA (LCA (Simple))', the 'adjusted R-squared' value of '0,8111' is not very high, suggesting that the current input variables partially explain the uncertainty in the output. Some more input variables need to be identified to improve the results. Alternatively, some of the current input variables are insignificant and can be removed. The current results can be still be used to screen out less sensitive input variables.	

By putting the simulation results running 500 scenarios on excel we have the next table:

Table 17: energetic class B (Author, 2023)

Iteration	Embeddec	Discomfor	Cooling (El	IPE	Heating (G	Heating se	Window tc	Glazing ty	Local shad	Site orient	Cooling se	External wall construction
447	3 590 573	116 000	2 346 860	80 096	56 010	18	20	Dbl LoE (e	1.0m Over	180	30	Masonry block wall 1
9	3 590 573	196 000	2 326 906	80 439	86 253	18	20	Dbl LoE (e	1.0m Over	0	32	Masonry block wall 1
310	3 590 573	196 000	2 326 906	80 439	86 253	18	20	Dbl LoE (e	1.0m Over	0	30	Masonry block wall 1
420	3 590 573	196 000	2 332 236	80 630	86 671	18	30	Dbl LoE (e	No shading	0	32	Masonry block wall 1
483	3 590 573	117 000	2 392 258	81 814	62 162	18	20	Sgl LoE (e2	1.5m Over	180	30	Masonry block wall 1
0	3 567 264	116 000	2 404 104	82 196	61 787	18	20	Sgl LoE (e2	1.5m Over	180	32	Masonry block wall 1
59	3 590 573	98 000	2 412 769	82 213	53 618	18	10	Sgl LoE (e2	1.0m Over	180	34	Masonry block wall 1
227	3 590 573	98 000	2 412 769	82 213	53 618	18	20	Sgl LoE (e2	1.0m Over	180	32	Masonry block wall 1
426	3 567 264	212 000	2 377 615	82 527	98 189	18	20	Sgl LoE (e2	1.0m Over	0	30	Masonry block wall 1
455	3 567 264	97 000	2 425 941	82 624	52 793	18	30	Sgl LoE (e2	1.0m Over	180	32	Masonry block wall 1
121	3 590 573	159 000	2 424 509	83 360	76 280	18	30	Dbl LoE (e	1.5m Over	90	34	Masonry block wall 1
451	3 590 573	120 000	2 432 541	83 362	68 314	18	10	Dbl LoE (e	1.0m Over	135	32	Masonry block wall 1
430	3 590 573	180 000	2 424 455	83 490	80 252	18	20	Dbl LoE (e	1.5m Over	270	34	Masonry block wall 1
211	3 590 573	171 000	2 435 337	83 642	73 918	18	20	Dbl LoE (e	1.0m Over	225	30	Masonry block wall 1
458	3 590 573	213 000	2 416 974	83 732	94 990	18	20	Dbl LoE (e	1.0m Over	315	32	Masonry block wall 1
296	5 123 062	135 000	2 449 562	83 834	65 452	18	10	Dbl LoE (e	1.5m Over	180	32	Brick aerated wall 2
200	3 590 573	222 000	2 421 874	83 935	96 187	18	30	Dbl LoE (e	1.0m Over	45	34	Masonry block wall 1
112	3 590 573	74 000	2 481 840	84 019	38 744	18	10	Dbl LoE (e	No shading	180	34	Masonry block wall 1
19	5 123 062	119 000	2 463 718	84 074	58 491	18	20	Dbl LoE (e	1.0m Over	180	34	Brick aerated wall 2
487	5 123 062	119 000	2 463 718	84 074	58 491	18	20	Dbl LoE (e	1.0m Over	180	32	Brick aerated wall 2
131	5 123 062	200 000	2 449 653	84 495	85 199	18	10	Dbl LoE (e	1.5m Over	0	30	Brick aerated wall 2
62	5 123 062	201 000	2 449 925	84 509	85 340	18	20	Dbl LoE (e	1.0m Over	0	30	Brick aerated wall 2
411	5 123 062	201 000	2 449 925	84 509	85 340	18	10	Dbl LoE (e	1.0m Over	0	32	Brick aerated wall 2
380	3 590 573	39 000	2 328 521	85 127	225 298	20	30	Dbl LoE (e	1.5m Over	0	34	Masonry block wall 1
139	3 590 573	173 000	2 477 104	85 274	81 127	18	30	Sgl LoE (e2	1.5m Over	225	34	Masonry block wall 1
260	3 590 573	148 000	2 490 460	85 626	78 306	18	10	Sgl LoE (e2	1.5m Over	90	34	Masonry block wall 1
268	5 123 062	119 000	2 507 268	85 721	64 370	18	30	Sgl LoE (e2	1.5m Over	180	30	Brick aerated wall 2
172	3 590 573	105 000	2 505 477	85 764	67 442	18	30	Sgl LoE (e2	1.0m Over	135	34	Masonry block wall 1
324	3 590 573	105 000	2 505 477	85 764	67 442	18	20	Sgl LoE (e2	1.0m Over	135	32	Masonry block wall 1
37	3 590 573	215 000	2 469 918	85 776	103 372	18	20	Sgl LoE (e2	1.5m Over	315	34	Masonry block wall 1
188	3 590 573	18 000	2 415 981	85 856	159 700	20	10	Sgl LoE (e2	1.0m Over	180	32	Masonry block wall 1
318	3 590 573	18 000	2 415 981	85 856	159 700	20	10	Sgl LoE (e2	1.0m Over	180	30	Masonry block wall 1
450	3 590 573	18 000	2 415 981	85 856	159 700	20	20	Sgl LoE (e2	1.0m Over	180	30	Masonry block wall 1
336	5 099 752	117 000	2 517 555	86 046	63 825	18	30	Sgl LoE (e2	1.5m Over	180	32	Brick aerated wall 2
473	5 099 752	117 000	2 517 555	86 046	63 825	18	20	Sgl LoE (e2	1.5m Over	180	30	Brick aerated wall 2
418	3 590 573	162 000	2 508 179	86 092	74 582	18	30	Sgl LoE (e2	1.0m Over	225	34	Masonry block wall 1
13	3 567 264	150 000	2 505 634	86 167	79 373	18	10	Sgl LoE (e2	1.5m Over	90	34	Masonry block wall 1

Table 18: energetic class B (Author, 2023)

351	3 590 573	45 000	2 478 318	91 093	254 458	20	20	Sgl LoE (e2	1.0m Over	315	30	Masonry block wall 1
419	3 590 573	46 000	2 478 354	91 192	257 415	20	30	Sgl LoE (e2	1.5m Over	45	30	Masonry block wall 1
21	3 590 573	16 000	2 584 767	91 329	155 110	20	20	Dbl LoE (e	No shadin	135	30	Masonry block wall 1
397	3 590 573	16 000	2 584 767	91 329	155 110	20	20	Dbl LoE (e	No shadin	135	30	Masonry block wall 1
11	5 123 062	37 000	2 496 477	91 445	246 860	20	30	Sgl LoE (e2	No shadin	0	30	Brick aerated wall 2
166	3 590 573	46 000	2 485 843	91 455	257 808	20	30	Sgl LoE (e2	1.0m Over	45	34	Masonry block wall 1
475	3 590 573	46 000	2 485 843	91 455	257 808	20	10	Sgl LoE (e2	1.0m Over	45	32	Masonry block wall 1
75	3 567 264	13 000	2 628 698	91 491	116 045	20	30	Sgl LoE (e2	No shadin	180	34	Masonry block wall 1
474	3 567 264	13 000	2 628 698	91 491	116 045	20	30	Sgl LoE (e2	No shadin	180	34	Masonry block wall 1
493	3 567 264	13 000	2 628 698	91 491	116 045	20	10	Sgl LoE (e2	No shadin	180	30	Masonry block wall 1
10	5 099 752	39 000	2 499 535	91 626	249 232	20	20	Sgl LoE (e2	1.5m Over	0	34	Brick aerated wall 2
124	5 099 752	39 000	2 499 535	91 626	249 232	20	10	Sgl LoE (e2	1.5m Over	0	32	Brick aerated wall 2
176	5 123 062	22 000	2 556 784	91 713	194 592	20	30	Dbl LoE (e	1.0m Over	135	34	Brick aerated wall 2
157	5 099 752	40 000	2 501 434	91 784	252 082	20	10	Sgl LoE (e2	No shadin	0	30	Brick aerated wall 2
403	5 099 752	40 000	2 501 434	91 784	252 082	20	20	Sgl LoE (e2	No shadin	0	34	Brick aerated wall 2
109	3 590 573	163 000	2 677 036	91 826	77 739	18	30	Sgl LoE (e2	No shadin	270	32	Masonry block wall 1
302	5 123 062	90 000	2 697 691	91 863	58 190	18	30	Dbl LoE (e	No shadin	135	32	Brick aerated wall 2
491	5 123 062	90 000	2 697 691	91 863	58 190	18	20	Dbl LoE (e	No shadin	135	34	Brick aerated wall 2
402	3 590 573	71 000	2 703 977	91 869	52 095	18	20	Sgl LoE (e2	No shadin	135	34	Masonry block wall 1
216	3 590 573	27 000	2 586 619	92 015	173 828	20	30	Dbl LoE (e	No shadin	225	32	Masonry block wall 1
352	5 123 062	148 000	2 697 148	92 033	63 853	18	10	Dbl LoE (e	No shadin	225	32	Brick aerated wall 2
271	3 567 264	50 000	2 498 367	92 044	262 962	20	30	Sgl LoE (e2	1.0m Over	45	30	Masonry block wall 1
277	5 123 062	35 000	2 544 944	92 170	220 143	20	20	Dbl LoE (e	1.5m Over	270	32	Brick aerated wall 2
486	3 590 573	22 000	2 581 446	92 327	188 350	20	30	Dbl LoE (e	No shadin	90	30	Masonry block wall 1
354	5 123 062	34 000	2 559 205	92 424	213 506	20	10	Dbl LoE (e	1.0m Over	225	30	Brick aerated wall 2
234	5 099 752	232 000	2 666 217	92 445	107 139	18	30	Sgl LoE (e2	No shadin	315	32	Brick aerated wall 2
446	3 590 573	32 000	2 573 801	92 523	201 887	20	10	Dbl LoE (e	No shadin	270	30	Masonry block wall 1
238	3 567 264	167 000	2 699 860	92 610	78 452	18	10	Sgl LoE (e2	No shadin	270	34	Masonry block wall 1
363	3 567 264	71 000	2 731 755	92 763	51 130	18	20	Sgl LoE (e2	No shadin	135	32	Masonry block wall 1
464	3 567 264	117 000	2 713 112	92 836	71 953	18	30	Sgl LoE (e2	No shadin	90	30	Masonry block wall 1
114	3 590 573	8 000	2 404 804	92 925	382 960	22	10	Sgl LoE (e2	1.5m Over	180	32	Masonry block wall 1

Synthesis:

As we can see the best scenario is number 447 where we have:

Inputs	Best Option
Orientation	North-South
Building Materials	Masonry block wall
Glazing ratio (WWR)	20%
Glazing types	Dbl LoE (e2=.1) Clr 3mm/13mm Air
Local Shading	1.0m Overhang
Heating Set-back temperature	18°C

6. Cases study:

In order to understand better and know more about *'how to design a building in a hot dry climate?'* we need to analyse and study some cases that were made by grand architects, in our research we will base on two cases:

2. **1st Case:** Akil Sami House, Giza, Egypt
3. **2nd Case:** Tafilelt Kaser, Ghardaia, Algeria

Following the next chart:

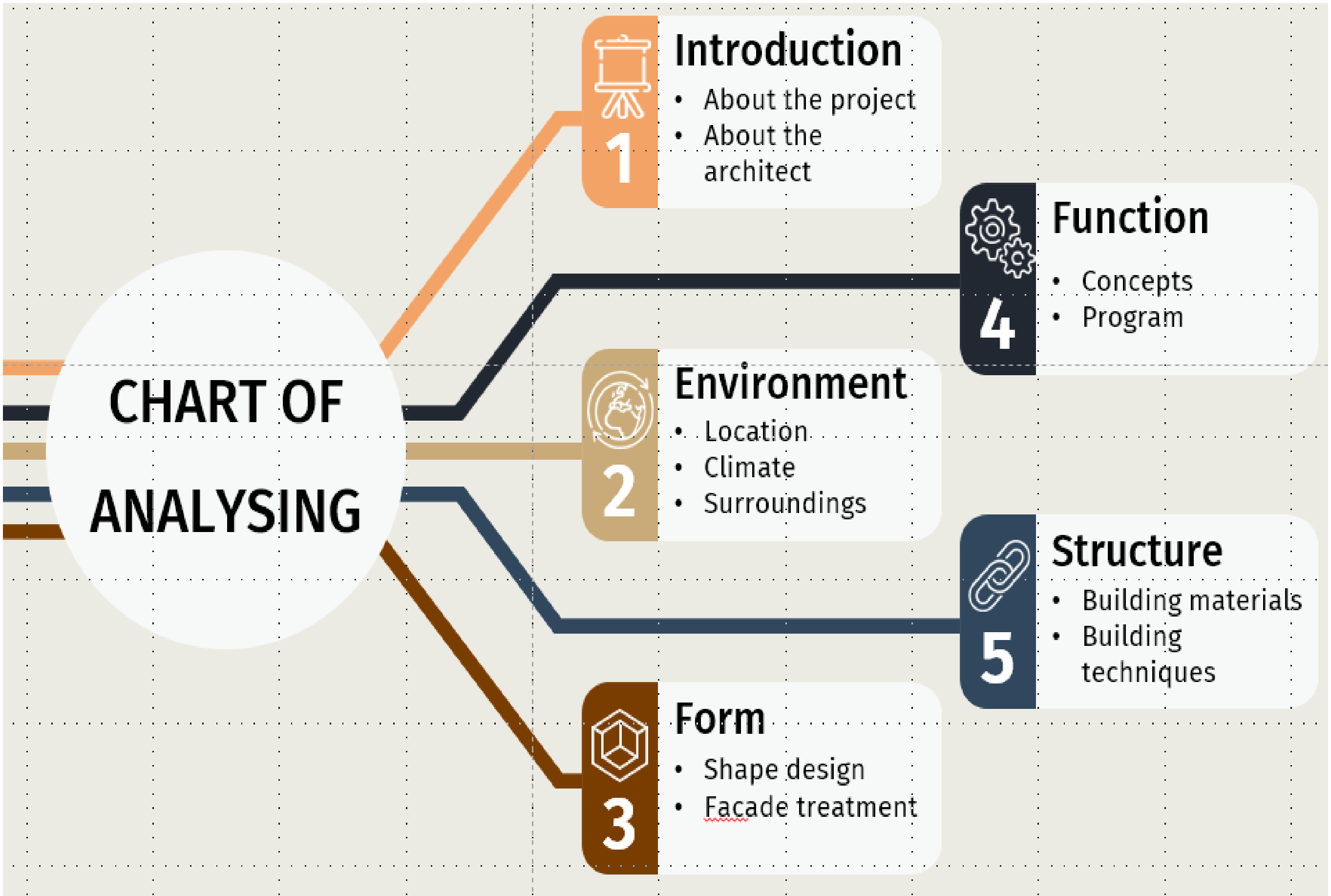


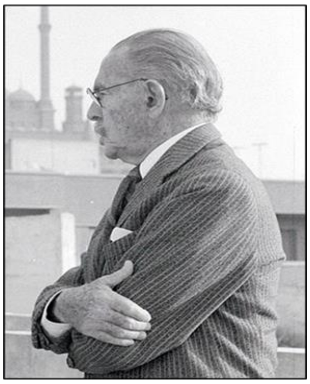
Figure 22: Chart of analysing (Author,

5.1 1st case study: Akil Sami House, Giza, Egypt

ABOUT THE ARCHITECT AND THE PROJECT

Hassan Fathy was a famous Egyptian architect who pioneered appropriate technology for building in Egypt, especially by working to reestablish the use of adobe and traditional mud construction. (Bertini, 2020)

This house, and several others that followed it in the same area, were built in local limestone because of a governmental ban on the use of mud-brick following the construction of the high dam, as well as unsatisfactory test results for the structural strength of the soil in this area, first confirmed in the Fouad Riad project.

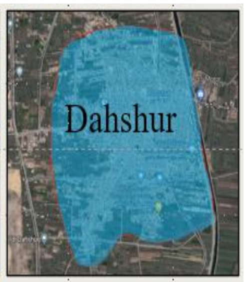


AKIL SAMI HOUSE

Location	Dahshur, Egypt
Architect	Hassan Fethy
Date	1978
Building type	Residential

CLIMATE

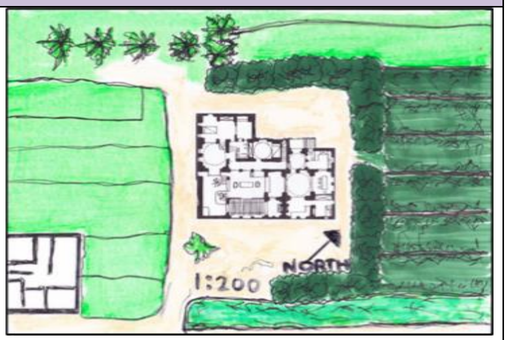
The given location is in the northern hemisphere. Summer begins at the end of June and ends in September. The months of summer are: June, July, August, September. The climate here is hot and arid “desert" During the year, there is virtually no rainfall in Dahshur.The driest month is April, with 0 mm of rain. The greatest amount of precipitation occurs in January, with an average of 4 mm, August is the warmest month of the year.



	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	13.4 °C (56.1) °F	14.9 °C (58.9) °F	18.2 °C (64.7) °F	21.8 °C (71.2) °F	25.8 °C (78.4) °F	28.3 °C (83) °F	29.5 °C (85.1) °F	29.6 °C (85.3) °F	27.6 °C (81.7) °F	24.1 °C (75.5) °F	19.5 °C (67) °F	15.1 °C (59.1) °F
Min. Temperature °C (°F)	7.8 °C (46) °F	8.7 °C (47.7) °F	11.1 °C (51.9) °F	13.9 °C (57) °F	17.6 °C (63.7) °F	20.2 °C (68.3) °F	21.6 °C (70.9) °F	22.1 °C (71.7) °F	20.5 °C (69) °F	17.9 °C (64.3) °F	13.7 °C (56.7) °F	9.7 °C (49.4) °F
Max. Temperature °C (°F)	19.1 °C (66.4) °F	21.1 °C (70) °F	25.1 °C (77.1) °F	29.2 °C (84.5) °F	33.3 °C (91.9) °F	35.9 °C (96.7) °F	37 °C (98.6) °F	36.8 °C (98.2) °F	34.5 °C (94.2) °F	30.4 °C (86.8) °F	25.5 °C (77.9) °F	20.8 °C (69.4) °F
Precipitation / Rainfall mm (in)	4 (0)	4 (0)	2 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0)	2 (0)
Humidity(%)	53%	46%	40%	35%	34%	37%	42%	44%	46%	50%	52%	55%
Rainy days (d)	1	1	0	0	0	0	0	0	0	0	0	0
avg. Sun hours (hours)	8.0	9.0	10.2	11.2	12.0	12.3	11.8	11.2	10.5	9.8	8.8	8.1

SURROUNDING ENVIRONMENT

The building is located in a rural area, it is surrounded by a natural environment (trees and palms).
The positioning of the building is also important in his design, where he placed the Sami house facing north-east (in the plans), so that the courtyard would get sunlight most of the day and the bedroom would avoid getting hit by the hot morning sun.



SHAPE OF THE BUILDING

The building has a cubic shape with some subtractions in different levels with 4 different sized cupolas.

The architect opted for traditionally arched shaped windows, completed with the detailing of the stained-glass windows. In the figure, the difference in heights is visible, as well as the cupola and the wooden detailing of the pergola.

Fathy admired the ancient Egyptian architecture, more precisely the Pharaonic architecture. This type of architecture uses the "physique of the ideal man", factoring the number pi (3.14…) and the number phi (1.61…) the golden number (Rastorfer 1985). Fathy used this method in planning his rooms, height of walls, doors and depth of squinch zones.

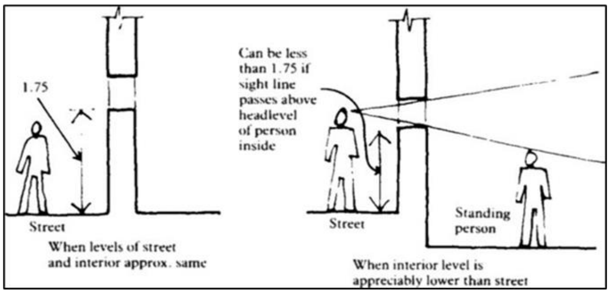


Figure 24:Traditional islamic window height in arabic cities (Hakim, 1986)

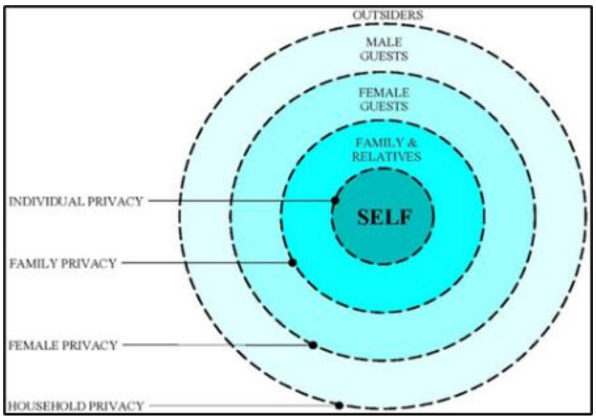
Figure 23: Akil sami house window and pergola open source

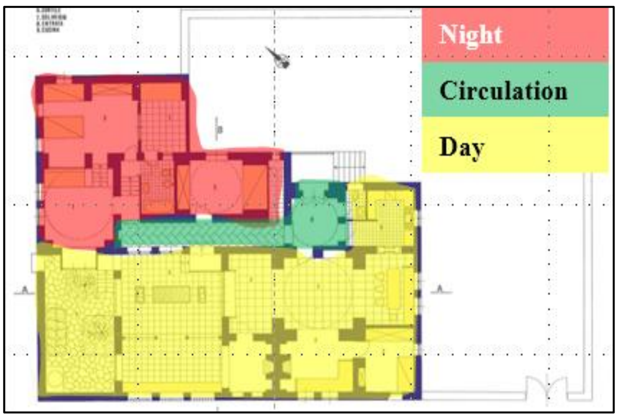
FUNCTION AND ACTIVITIES

Hassan Fathy Divided the Private and Public areas of the house by using the circulation spaces as a buffer.

Privacy is a very important aspect of Islamic culture, so he creates areas that are traditionally open to guests and areas that are closed. Inside the architect created lots of different levels, including the pergola.

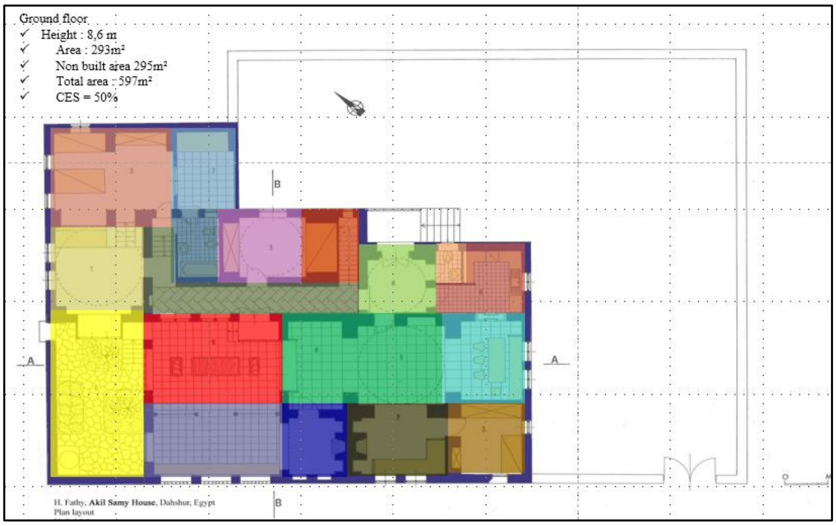
These levels interact with each other but still divide up the room in to smaller, more defined spaces. Also visible is the high ceilings. This gives the rooms a more vertical oriented dimension.

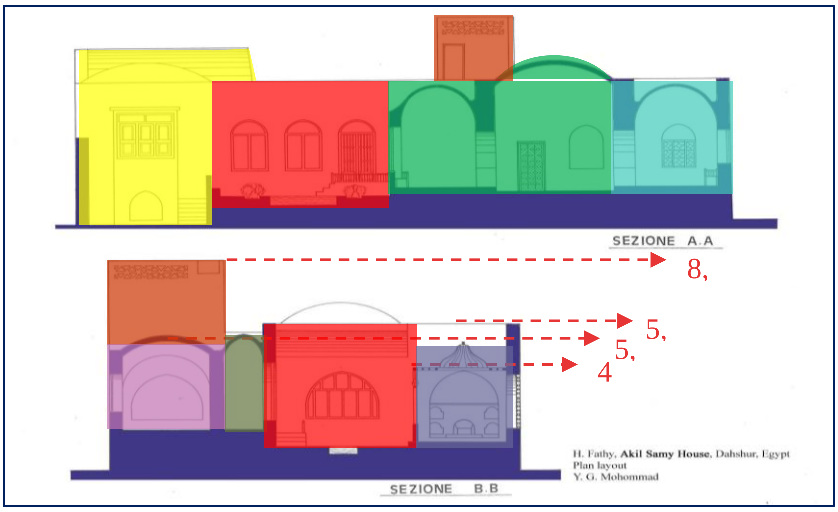




THE QUANTITATIVE PROGRAM:

Space	Area
Entrance	10 m²
Interior courtyard	27,5 m²
Kitchen	9,83 m²
Dinning	13 m²
Guest bedroom	9,56 m²
Hallway	14 m²
Drawing room	12 m²
Guest room	7,8 m²
Office	10,5m²
Wind catcher	8,7 m²
Pergola	15,36 m²
Courtyard	23,4 m²
Bedroom	20 m²
Toilette	6 m²
Lodge	15,15 m²
Garden	26,8 m²
Sunbath	9 m²
Guest toilet	1,7 m²



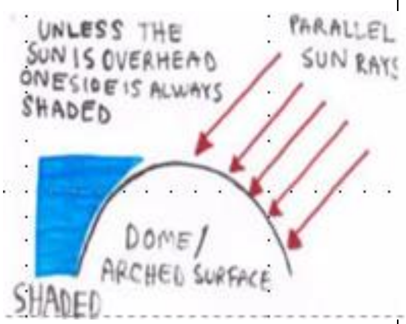
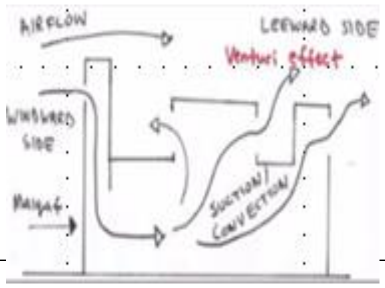
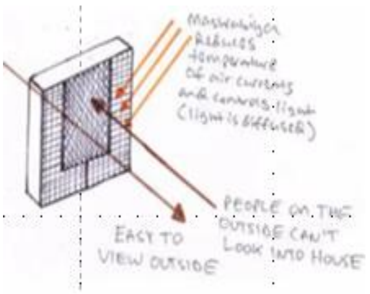
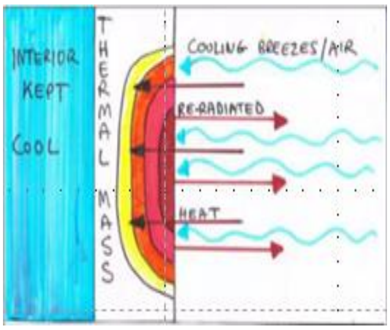


STRUCTURE AND BUILDING TECHNICS:

The Akil Sami House is a perfect example of Fathy's work, but here he used local limestone instead of local mud-brick. Because of a governmental ban and the questionable strength of the soil he wasn't able to use mud-brick.

The architect applied many technics and use different architectural elements which are explained in the table below:

Table 19: Architectural elements in Akil Sami house for thermal comfort (Author, 2023)

Element	Illustration	Explanation
Curved surfaces		Hassan Fathy makes use of many curved surfaces such as arches, vaults and domes these elements increase the speed of airflow due to low pressure also limits the amount of heat absorption due to the larger surface area.
Wind catcher and		Hassan Fathy uses this element in order to ensure the low-pressure difference/suction and the Bernoulli effect to channel and accelerate air movement in the internal space.
Screened-wall (Mashrabiya)		It is an Islamic traditional screen wooden latticework, serves many purposes but one of most important is the ability to impede the view of those outside whilst still allowing those in the interior to view the outside and it effectively controls the temperature of air currents.
Thick walls		Fathy uses thermal mass to prevent solar radiation from penetrating into the interior spaces, the heat does not reach the inner side of the wall when the temperature drops at night the cool breezes can then draw the heat out into the night sky.

5.2 2nd case study: ksar tafilelt, Gihardaia, Algeria

ABOUT THE ARCHITECT AND THE PROJECT

AHMED NOUH The president of AMIDEL foundation, a pharmacist, inspired by locale architecture and modern minimalist architecture as well as the environment.

The Sustainable City of Ksar of Tafilelt of Beni-Isguen story was known to the local people since its inception. It has been rewarded last Monday in Marrakech, Morocco, by the 1st Sustainable City Prize, following an online vote called "Internet's users Favourite City", the Algerian Press Service (APS) reported on Wednesday citing officials of the Amidoul Foundation, initiator of the Ksar.

The Ksar of Tafilelt, which was regarded as a very human experience in the northern edge of the Sahara and an eco-city in the desert, had more than 600 votes of the built environment professionals of the world, for having combined architecture, sustainable development, preservation of the environment and local lifestyle, said Moussa Amara, the Project Manager of the Ksar of Tafilelt. (Farolco, 2016)

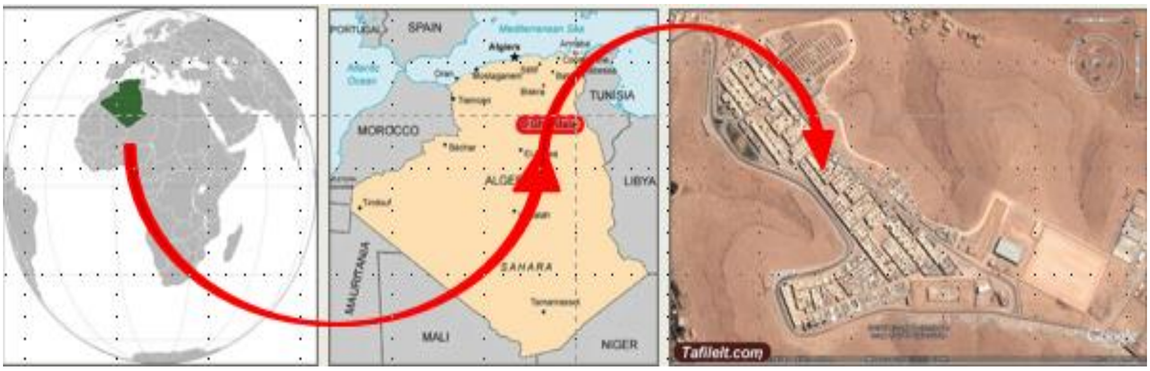
KSAR TAFILELT	
Location	Ghardaia, Algeria
Architect	AMIDEL
Date	1997
Building type	Residential

CLIMATE

The city is located within the Sahara Desert in northern-central Algeria. Ghardaïa Province is divided into 13 communes or municipalities, which includes the Ghardaïa municipality. It is bordered by Ouargla and El Bayadh Wilayas, the ksar is located in the east side of the city. Ghardaïa has a hot desert climate, with extremely hot summers and mild winters.

The region is marked by large temperature differences between day and night, and summer and winter ranging from lows of 5 °C to highs of 46 °C.

The prevailing winds of summer are extremely hot, extremely dry and strong, while winter winds are warm and dry. Sandstorms generally occur from March to May.



SURROUNDING ENVIRONMENT

In term of accessibility, we have two types

The ksar of Tafilelt located on a plateau overlooking the valley is exposed to all directions of the wind, the orientation north to south (about 600 x 200 m), often exposed to winds from all directions, makes the air temperatures air temperatures cooler by about 2.5 to 4°C in winter and 2 to 3°C in summer, compared to the valley.

The ksar of Tafilelt is organised according to a rectilinear road system, with a profile that is less narrow (4.50 m) than the streets of the old ksour for modern requirements (the car).

The houses occupying the whole of the plot are as close as possible to each other which reduces the amount of the surfaces exposed to the sun, except for the main façade and terrace.

A compact urban organisation has been produced compact urban organisation.

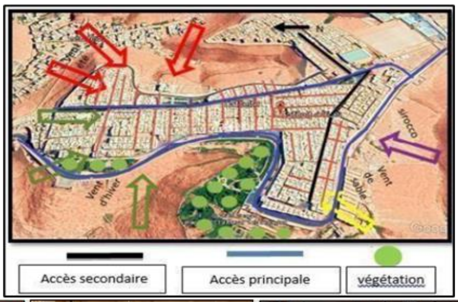
The introversion of the houses, through their organisation around a courtyard, enormously reduces the areas exposed to the outside world.

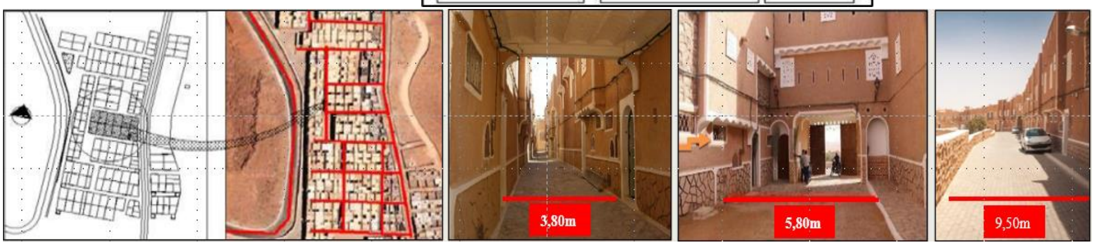
The streets are oriented in two main directions (East-West and North-South) and classified into three categories:

The primary roads, with an average width of 9.50 m, serve the ksar with the exterior, they have a prospect (H/L) of 0.89;

The secondary or junction roads with an average width of 5.80 m connect the primary roads with those primary roads with the service roads, have a prospect of 1.45;

Tertiary or service roads are relatively narrower, varying between 3.60 and 3.80 m for prospects of 2.35 to 2.22m.





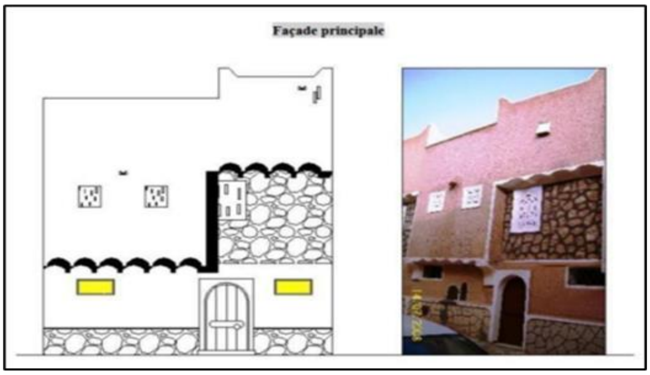
SHAPE OF THE BUILDING

The importance of the shape concerns the distribution and quantity of the walls in contact with the outside.

To limit fluctuations in indoor comfort due to external phenomena (sun, wind, etc.), it is a good idea to seek a maximum amount of indoor space for a maximum of (sun, wind...), it is a rule to seek a maximum of interior space for a minimum of exterior

The rectangular shape of the houses in Tuscany is a good example of this. The rectangular shape of the Tafilelt houses with the neighbouring houses, allows a minimum of heat loss in winter and a minimum of in winter and a minimum of gain in summer.

- Asymmetrical façade
- Small openings in wood (à l'échelle humain)
- Simple geometrical patterns for decorations
- Colours: white and sand colours



FUNCTION AND ACTIVITIES

The Tafilalt project aims to restore some of the ancestral customs based on faith and "self-reliance" that have enabled oases in general and those of the Mzab in particular to survive in a hostile environment, and to build what is now known worldwide as a Millennium Architecture worthy of the name "sustainable development".

Ksar Nouvelle Tafilelt : "la cité Tafilelt Tajdite" - 870 housing units - Ville Beni-Isguen - Ghardaïa-Algeria, it is based on:

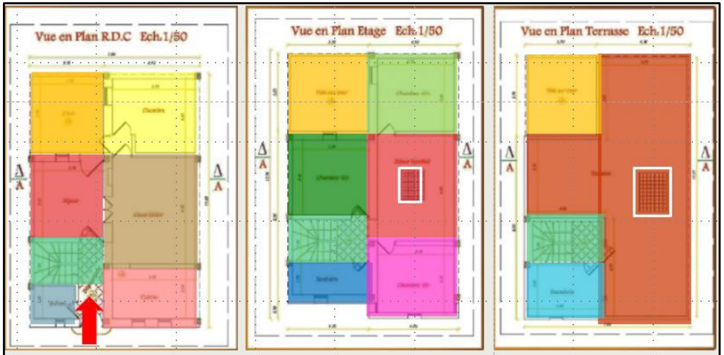
● The contribution of traditional social institutions.

● The proposal of a rational housing environment.

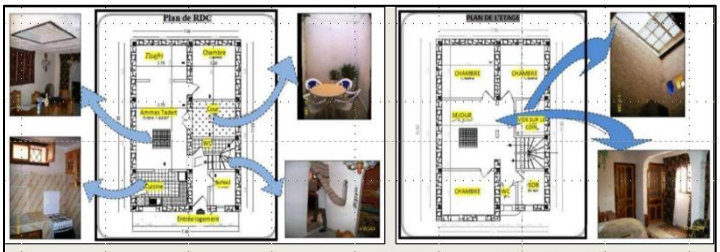
● The involvement of man - especially in his cultural dimension - in the implementation of his home.

● The conscious interpretation of the ancient architectural heritage.

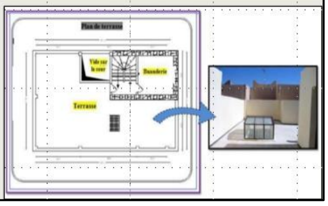
THE QUANTITATIVE PROGRAM:



Ground floor | 1st level | Terrace



- The house is a rectangle of 8m in depth and 12m in length .
- Total area = 96m²
- Privacy and differentiation between humid and dry areas in the building



Space	Area
Entrance	2,4 m²
Stair case	6,78 m²
Kitchen	9 m²
Guest room	19 m²
Bedroom parents 1	13,50 m²
Courtyard ouast eddar	12,20 m²
Tizefri	11 m²
Toilette	3 m²
Bathroom	5,60 m²
Bedroom 2	12m²
Bedroom 3	12m²
Bedroom 4	12 m²
Laundry room	8,5 m²
Terrace	26 m²
Shbek	2,7 m²

STRUCTURE AND BUILDING TECHNICS:

- Construction method: load-bearing walls.
- The foundation is made of local stone, mortar (sand cement) with a thickness of 40cm using a peripheral chain and reinforced concrete corner and edge stiffeners.
- For the partitions: breeze blocks or clay bricks of varying thickness.
- *Plastering:* Interior: Platter, except wet rooms.
- Exterior: Bastard mortar (lime+cement+sand).
- *Flooring:* Voutain in plaster.
- Compression slab in BA 5cm.
- Underfloor plaster: cement for damp areas.
- Hollow body in agglo concrete (hourdis).
- Reinforced concrete joist.
- Sanitary plumbing: PVC piping d-110 and -60mm.

GENERAL SYNTHESIS

After analyzing both cases, we understood that in order to build in a hot dry climate first we need to:

1. Look for a better orientation like architects did in their designs by understanding the sun path and the amount of solar heat in the area.
2. Using thick walls and material is really important and it can reduce the temperature from the exterior to the interior area.
3. The architect took use of light colour basically a white envelope we all know that white has a better reflection of solar radiations.
4. Windcatcher and mashrabiya these are really good elements to provide a good air ventilation.

And here are some strategies followed by some recommendation:

Figure 25: Strategies and recommendations (Author, 2023)

STRATEGIES	ACTIONS / RECOMMANDATIONS
1. Increase vegetation in the surrounding environment	• Plant different types of desertic plants like : Palms, Bougainvillea, Dodonea and Moringa
2. Take use of a nested urban layout	• Create mechanical roads with 9m in width and a prospect of 0,9 • Create pavements of 3m of depth and a prospect of 2,3
3. Eco-system preservation in the area	• Sand dunes form for the urban layout • chose the north-south orientation • Take use of quadrangular shape for buildings
4. Ensure privacy in the area	• Take use of linear hierarchical roads system (tree based) Create of less mechanical roads inside the plot
5. Respect social concepts of living in the house	• Hierarchical spaces system (public, semi-public and private) : entrance, courtyard, circulation, Livingroom, kitchen and finally bedrooms
6. Guaranty a natural lightning and warmth	• Make sure to put kitchen in north or north east, Livingroom and bedrooms in south or south west .
7. Make sur to have a passive acoustic comfort	• Differentiate between day/night spaces for ex: Livingroom, kitchen, sports room, playroom in the ground floor in the other hand bedrooms need calm so put them in the 1st level
8. Facilitate sanitation operation	• Differentiate between dry and humid areas in the house , kitchen, laundry, bathroom(humid) then bedrooms, Livingroom (dry)
9. Provide a natural ventilation and fresh air	• Take use of different architectural elements such as the patio with a fountain or a terrace and windcatcher
10. Respect the environment and economical stage of the city	• Take use of locale materials , bricks, BTC, wood, limestone and plaster to avoid the costs of transportation , also use thick walls (40-45cm) and load-bearing walls structure

3RD CHAPTER:

THROUGH THE PROJECT

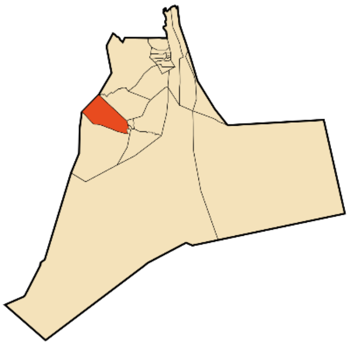
1. Analysis of the city:

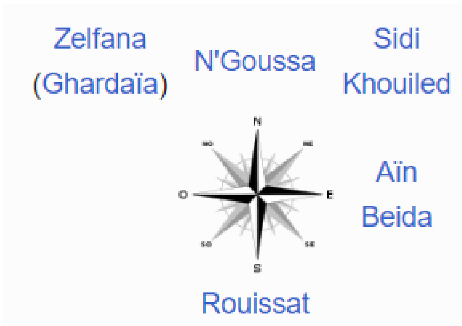
1.1 Geographical situation:

The study area is the Ouargla region with an area of 136.32 km2. It is limited to the north by OumErraneb, to the east by the ergs Touil and Arifdji, to the south by the dunes of Sedrata and to the west by the eastern slope of the M'Zab ridge in southern Algeria. (Mohamed, 2013)

1.2 Borders:

Ouargla is located in the north-east of Algeria more precisely in the northern part of the Algerian Sahara, it is located 190km east of Ghardaïa, 160km southwest of Touggourt, 388km south of Biskra, 800km from Algiers and 618km from Constantine.





1.3 Accessibility:

We can access the city by many routes shown in the figure bellow:

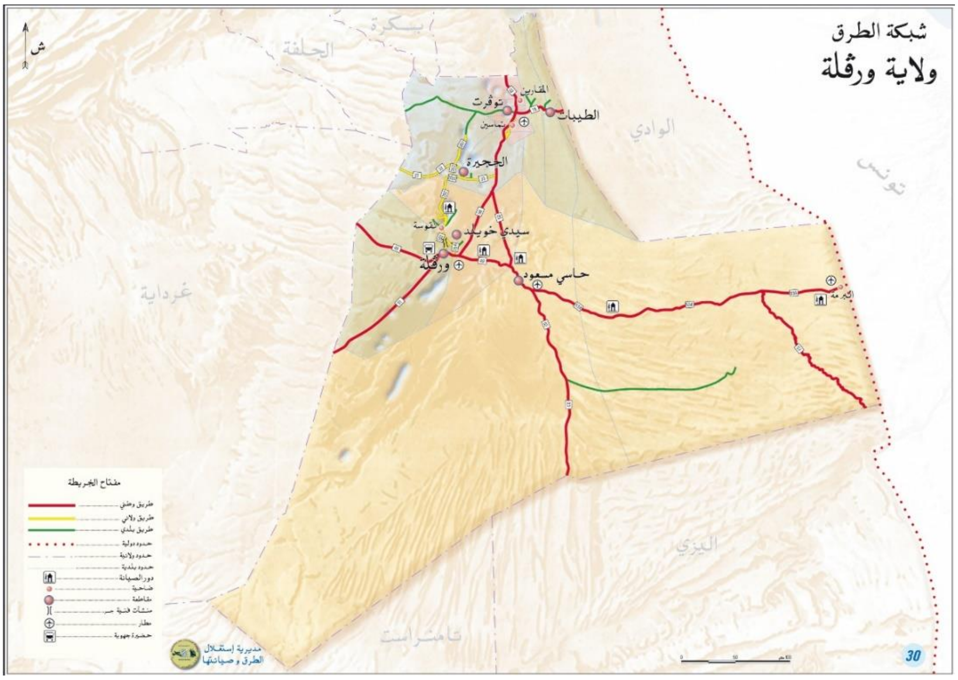


Figure 26: Ouargla roads map on mpt.gov.dz (Atlas of streets, 2023)

1.4 Geomorphological characteristics:

The geomorphology of Ouargla is influenced by the interactions of climate, hydrology, geology, and human activities. Some of the geomorphological features of Ouargla include:

Table 20: geomorphological features (Author, 2023)

Sebkha	A flat-bottomed depression usually floodable, or salty soils limit vegetation, Vast basins of saline soils, residues of ancient lakes dried up thousands of years ago.	
Palm grove	Huge expanse of agricultural plots mainly intended for the cultivation of palm trees; it extends to the sabkha.	
Shott	A large endorheic Salt Lake that stays dry for much of the year but receives some water in the winter.	

The longitudinal profile of the valley has a general slope directed from the South-West to the North-East and of approximately 1‰.

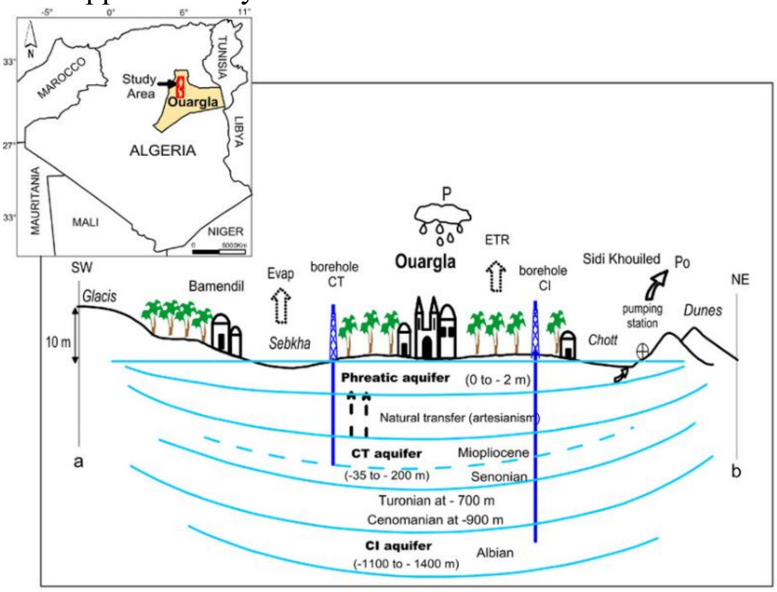
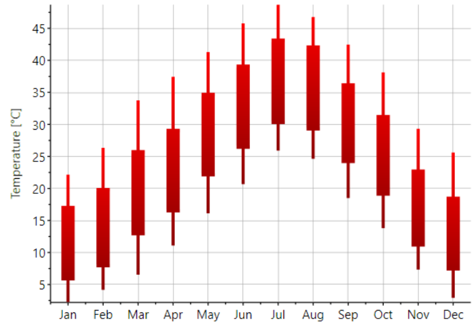
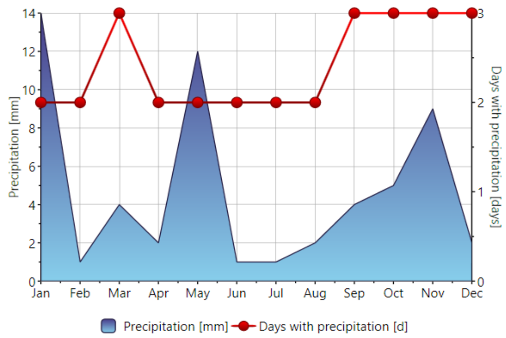
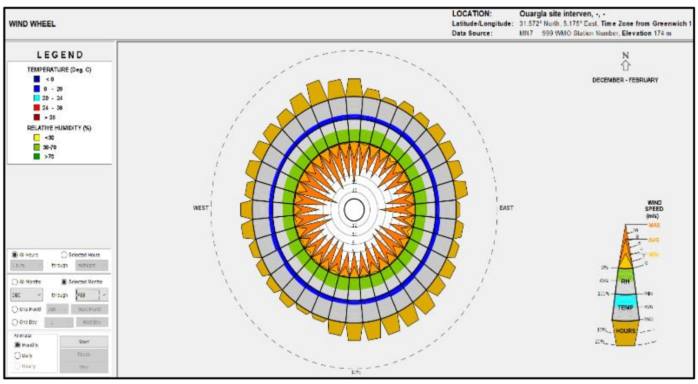


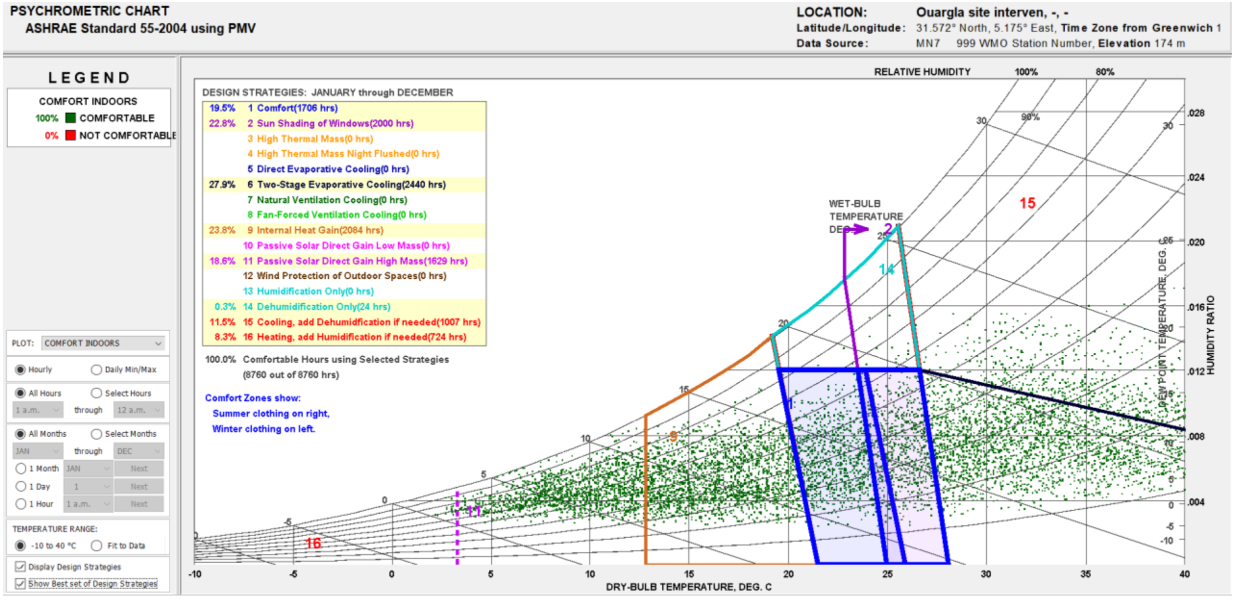
Table 21: Cross-section diagram (Belhadj Hamdi-Aissa, 2018)

1.5 Climatic analysis:

Table 22: Climatic data of Ouargla using meteonorm (Author, 2023)

ANNUAL TEMPERATURE	
-Annual temperature equal to 24°C it is in the comfort zone. -The hottest month is July the average temperature 35°C. -The coolest month is Januarys the average temperature 11°C.	
HUMIDITY	
-The average annual humidity is 45%. -The wettest month December with a percentage of 64%. -The least humid month is July with a percentage of 28%.	
PRECIPITATION	
-The average annual precipitation is only 65 millimetres -The driest months are June, July, and August, when no precipitation occurs. -The wettest month is April, with an average of 15 millimetres.	
WINDS	
-Winds in Ouargla are generally moderate, with an average speed of 9km/h. -The windiest month is May, with an average speed of 18km/h. -The calmest month is October, with an average speed of 7km/h.	

GIVONI DIAGRAM
The comfort zone includes the months March and April and October, comfort is ensured naturally without recommendations. The zone of underheating this zone includes the months December and January and fever or temperature does not exceed 6C during the night, in this period comfort and ensure by a Passive or Active heating system. The area of overheating it is read important it includes the months May and June and July and August and September, comfort and ensure by protection against solar rays.



GENERAL SYNTHESIS

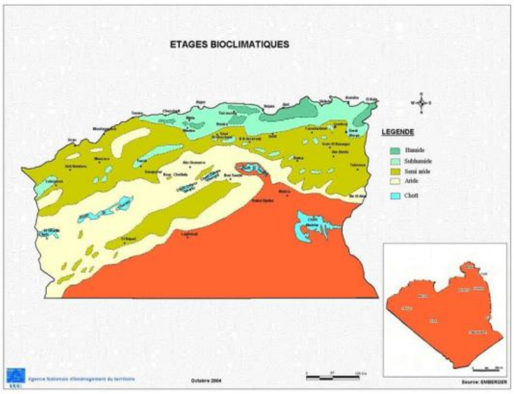


Figure 27: Classification du climat en Algérie (Benazza Mounia, 2017)

Index value	Type of climate
0 < IDM < 5	Hyper aride
5 < IDM < 10	Aride
10 < IDM < 20	Semi-aride
20 < IDM < 30	Sub-humide
30 < IDM < 55	Humide

$$\frac{p}{t} + 10 = \frac{1{,}1}{27} + 10 =$$

$$10{,}04\ IDM$$

Table 23: Index value and type of climate (Author, 2023)

The climate analysis norms allow to deduce that the city is in the Saharan bioclimatic stage with an arid climate is characterized by a hot and dry climate and rainfall is low and irregular at less than 200 mm per year.

2. Diachronic reading

2.1 Territorial reading

2.1.1 Implementation:

In the case of our study area "Ouargla basin", the urban sprawl observed since independence is related to population growth.

The city manages its urban growth through urban sprawl, however, this phenomenon of sprawl does not necessarily result in the transformation of rural municipalities into urban municipalities, because the habitat of a municipality can expand without increasing its population.

In the 19th century, the town was known for being on a caravan route to the south, and a starting point for exploring the southern Sahara.

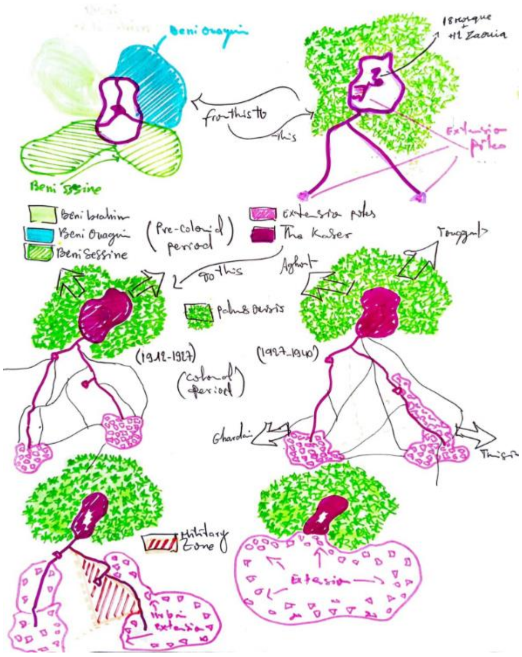


Figure 28: city evolution sketches (Author, 2023)

The reason why the kasr didn't get effected by the colonisation is because it was secured by locale citizens who did not accept to change their lifestyle with a strong resistance so the French military went to settle in the southern side of the kser, then creating a military zone. *(Tourist guide, 2023).*

Commune	Taux d'urbanisation en		
	1998 *	2008 *	2015**
Ouargla	93,55 %	93,46 %	98,47%
Ain El Beida	68,02 %	67,75 %	-
N'goussa	0 %	35,39 %	68,00%
Rouissat	90,68 %	92,27 %	92,27%
Sidi Khouiled	0 %	74,33 %	-
Hassi Ben Abdellah	0 %	0 %	0 %

Table 24: Taux d'urbanisation (Chaouch, 2018)

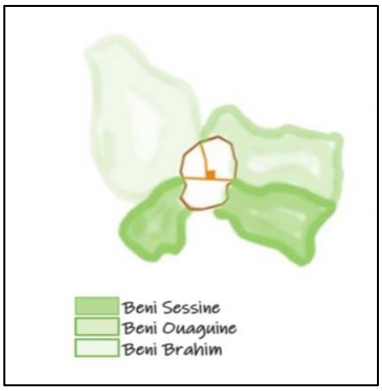
2.1.2 Genesis of the city:

The diachronic reading of the city allowed us to know the stages of the city's development over time. The city of Ouargla has seen three periods of urbanization:

a)- The precolonial period (IX century):

According to Ibn Khaldun the town was founded by *Banu Warglan* who, accompanied by sections of the Maghrawa and Banu Ifran, left the Tlemcen region and founded Ouargla. These Berbers of Ouarghla then embraced Ibadi doctrines, which later made the town an attractive refuge for the citizens of Tahert.

- In the 11th century, Banu Hilal, an Arab tribe living between Nile and Red Sea, settled in Tunisia, Tripolitania (western Libya) and Constantinois (eastern Algeria) which was Ouargla party.
- In the 19th century, the town was known for being on a caravan route to the south, and a starting point for exploring the southern Sahara. (Britannica, 2022).



- The city had a cellular shape surrounded by a fortress wall with 7 gates, and a very dense structure of the urban layout.
- It covers 30-hectare intramural inhabited by a population estimated at 10,000 people occupying 2,400 dwellings.

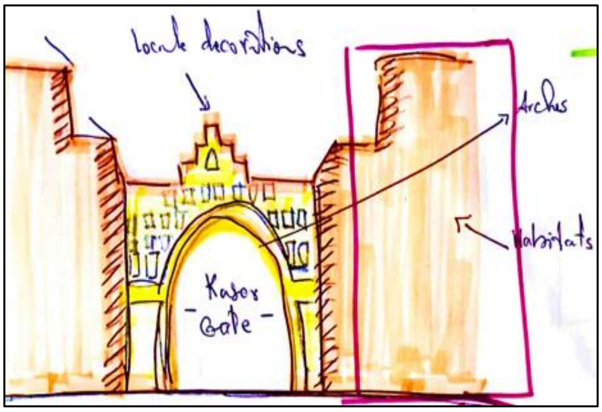
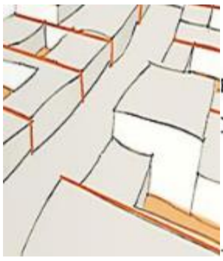
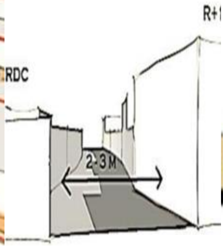
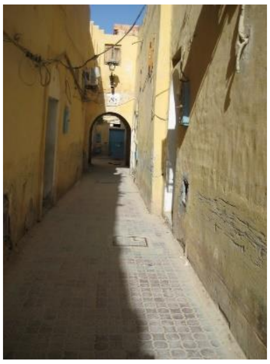
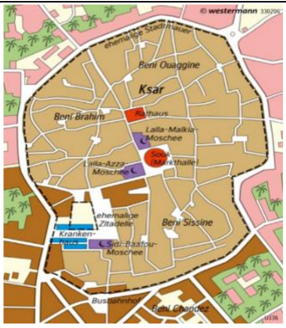
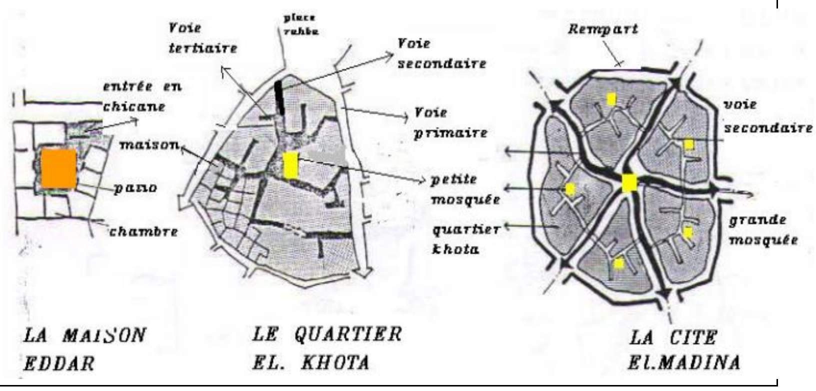
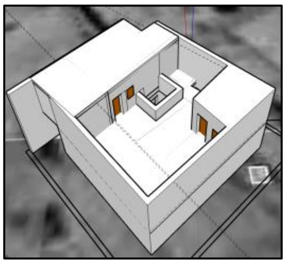
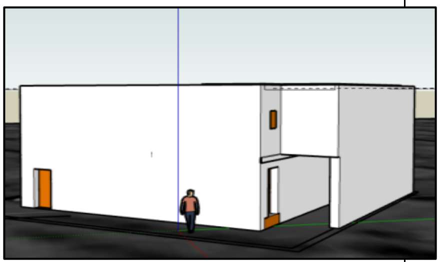
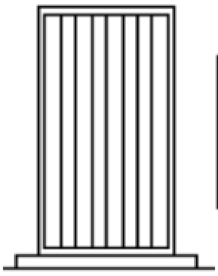
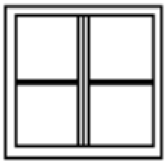


Figure 29: the ksar gate (Author, 2023)

Table 25: The characteristics of the city in the pre-colonial period (Author, 2023)

ENVIRONMENT	**Prospect:** A narrow passage with pedestrian ways.	  
	Breezeway: Existence of many breezeways separated in different positions inside the kaser area.	  
	Urban compactness: -Cellular shape -Nested urban layout -Compact	  
	Vegetation: Existence of palms grove, used as a barrier against sandstorms to protect the city.	 
FORM	**Geometry:** The city has a circular shape, cellular layout with rectangular and square plan for the buildings.	

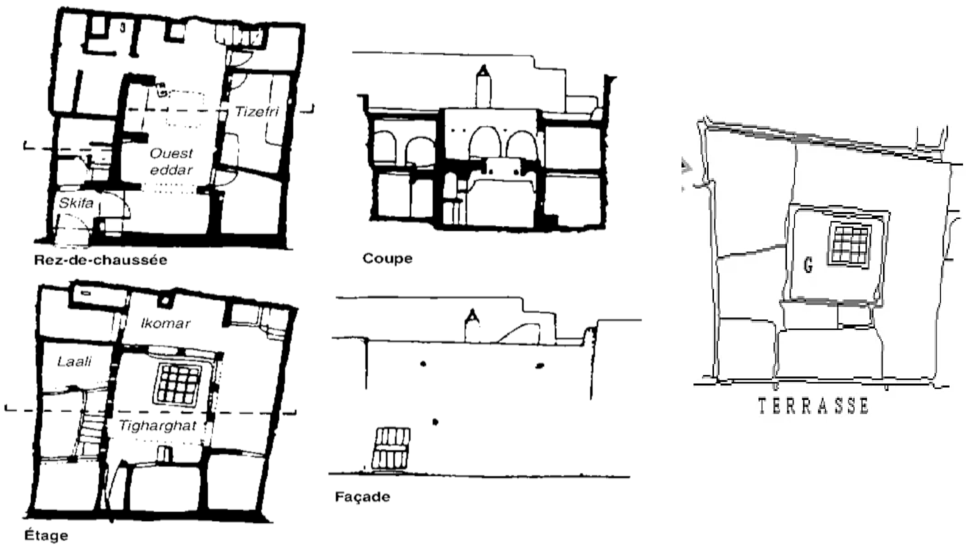
FORM	**Courtyard (patio):** To ensure the thermal and visual comfort as well as the ventilation and to clean the area.	 
	Compactness: Less compacted	 
ENVELOP	**Decoration:** -Geometrical elements are made with plaster. -The wall of the facade is smooth in appearance and light in colour.	
	Openings: -Main entrance door in wood with a rectangular shape with a single leaf. -Window of a square shape with two shutters.	  
	Building materials: load-bearing wall of stone and Timchemt (local materials) floors in the form of vaults with trunks of palm trees with vaulted floor covering the gallery of arcades.	 

a)-1 Case study:

House with Shbek or courtyard:

Remains of open central spaces were found nearly 6,000 years ago in Mesopotamia, they can also be found in Pharaonic Egypt, as in the Indus Valley and as far away as China. One can reasonably think of polygenesis, i.e., separate inventions independent of each other. (Abdulac, 2011). As for our case study these houses are characterized by the following aspects:

- **Environment:** Surrounded by traditional urban layout with one free façade through the street.
- **Form:** Squared plan with a patio that has an opened roof.
- **Envelop:** Main entrance door in wood with a rectangular shape with a single leaf. Window of a square shape with two shutters. Timchemt + adobe + rocks.



b)- The colonial period (1830-1962):

During the colonial period, the ramparts and ditches that surrounded it were replaced by a ring road, The new city inherited from the city of the French civil and military administration of the 1930s, is built according to a triangular layout. It brings together a number of administrations. This new city was intended to accommodate French officers and civil servants, after 1940, the city continued to expand and become denser, the most important operation being the construction of the (Cité Sélice) intended to accommodate French civilians. Then the settlement of sedentary nomads appears, they are divided according to tribal affiliations: in the north Said Otba, in the south-west Mekhedma and in the south-east Beni Thour.

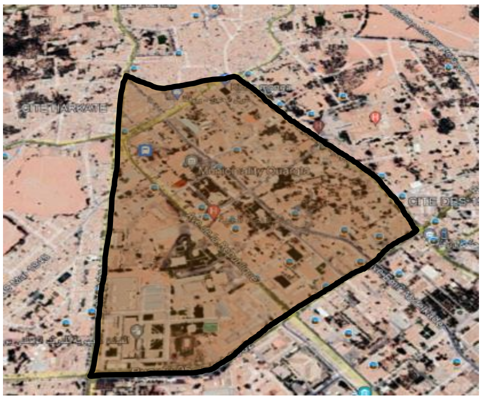
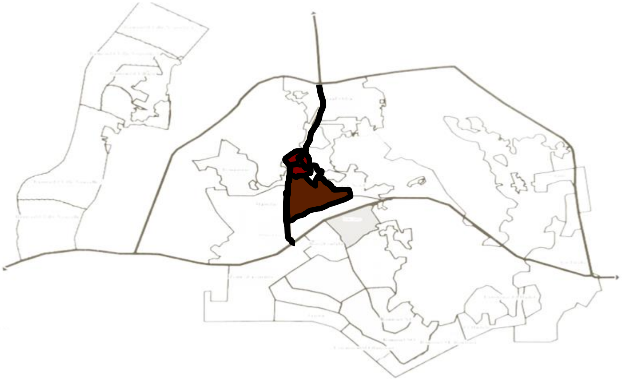
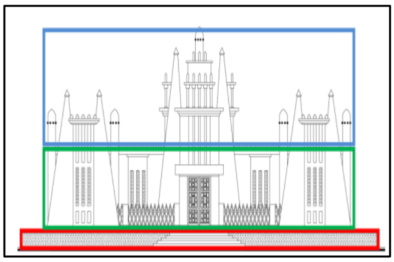
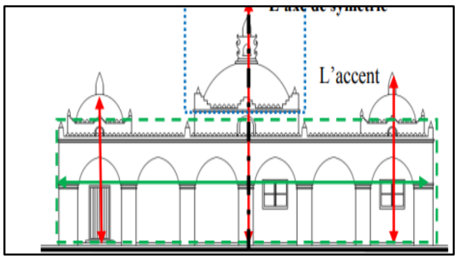
 

Table 26:The characteristics of the city in the colonial period (Author, 2023)

ENVIRONMEN	**-Prospect:** Large passage **-Urban compactness:** new structure of plan layout less dense		
FORM	We observe the use of **regular shapes**: square and rectangle **Sudanic and Moorish styles** **Elements:** cupolas		
ENVELOP	**Building materials**: timchemt (locale plaster), stones and palm wood.		

b)-1 Case study:

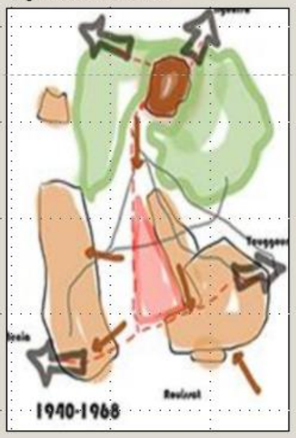
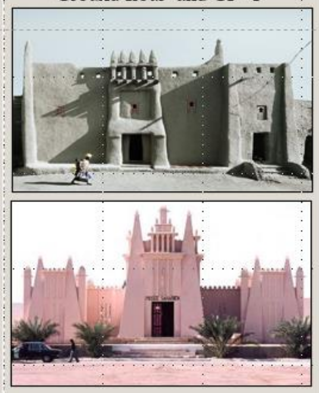
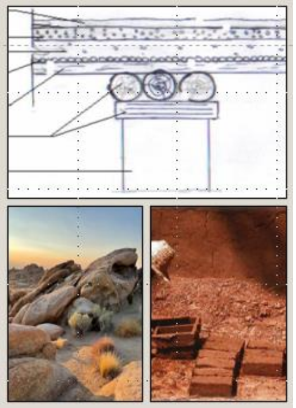
The Saharian museum:

The museum currently the Municipal Museum is located in downtown Ouargla opposite the military hospital on the Boulevard de la Republic axis.

It was inaugurated in 1938 by the General Nieger accompanied by Colonel Cabriolet.

It was built within the city news from Ouargla and there was a collection of photos from all the regions of the great desert.

Table 27: Synthesis of the city's architectural characteristics (Author, 2023)

Urban plan	Environment	Architectural style	Building materials
• Introduction of new urban layout by the colonizer	• Expansion of palm grove to protect the town	• Buildings with Sudanic and moorish style • Building size : between Ground flour and GF+1	• Building materials : timchent , rocks , clay (adobe) , sand rose and palm wood .
			

c)- The post-colonial period (1966-1962):

After independence, the public authorities built collective housing estates.

The city in full expansion, overflows from all sides, and joins the peripheral ksour: Rouissat in the south, Chott, Adjaja or Sidi Khouiled in the east, and Boumendil in the west and to the south, a new administrative district is being developed.

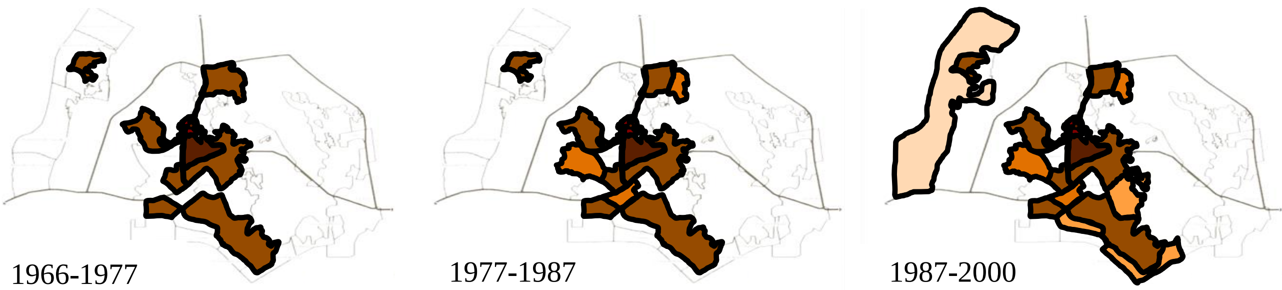


Table 28: The characteristics of the city in the post-colonial period (Author, 2023)

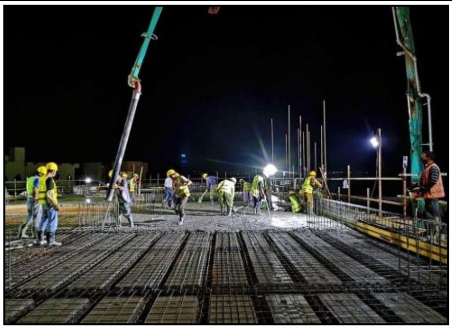
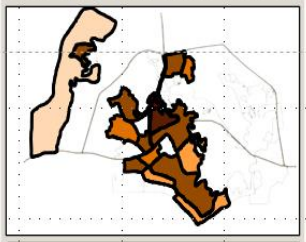
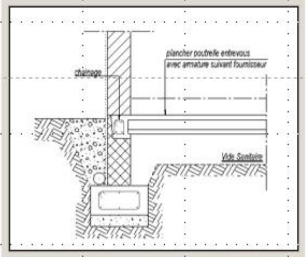
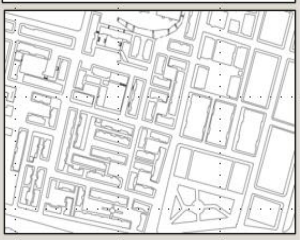
ENVIRONMEN	Prospect: Large passage Urban compactness: new structure of plan layout less dense, regular layout well structured		
FORM	We observe the use of regular shapes: square and rectangle Height: GF+4		
ENVELOP	Building materials: Timchemt (locale plaster), reinforced concrete and BTS, steel		

Table 29: Synthesis of the city's architectural characteristics (Author, 2023)

Urban plan	Environment	Architectural style	Building materials
• Introduction of new urban layout , regular and less compacted	• Expansion of palm grove to protect the town	• Buildings with no style • Building size : between Ground flour and GF+4	• Building materials :concrete and steel also timchent
			
			

Building typologies in Ouargla:

From the figure bellow we observe the high existence of individual habitat and less existence of collective habitat which means that people are more into this type (locale lifestyle).

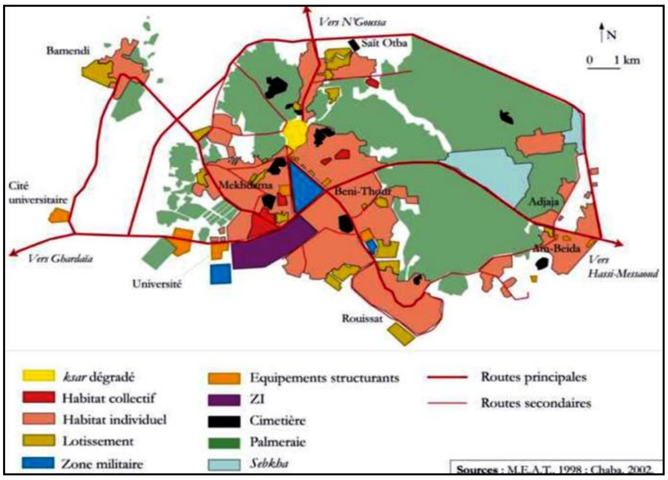
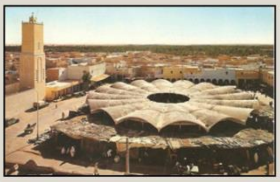
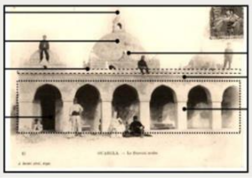
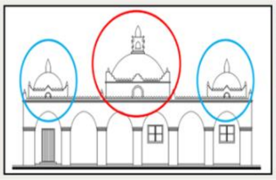
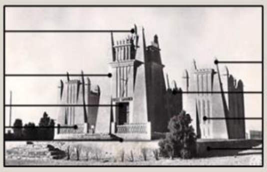
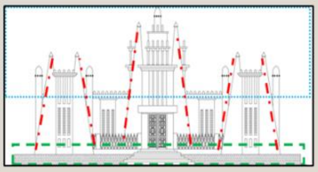
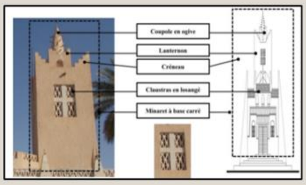
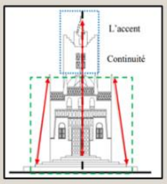
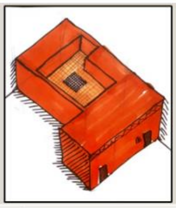
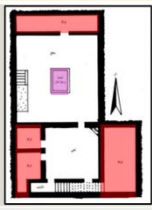
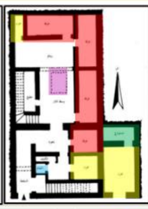
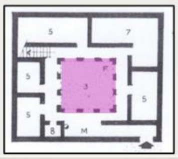
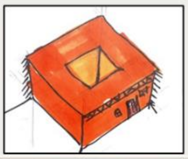
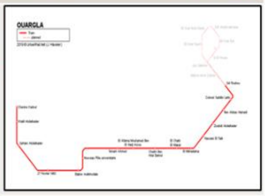


Table 30: Synthesis of building typologies (Author, 2023)

Types		Comments	Illustration			
Culture	Souk	• Located in the centre of the kasr , used for sand rose , gold and slaves trade • A squared shape with a circular shape of market covered				
Culture	Dar El Kadi	• Dar El Kadi is located in the southern part of the Ksar of Ouargla, has a point of Control • The facades of neo-Moorish style buildings + coupolas • Articulation with the outside through a gallery of pointed arcades.				
Culture	Museum	• Wooden entrance door decorated with geometric ornamentation. • The building is in the neo-Sudanese style. • an assembly of squares and rectangles sculpted on the main door .				
Types		**Comments**	**Illustration**			
Religion	Masjid	• Lalla A'azza Mosque, or the Ibadi Mosque, is a historical mosque located in the Ksar of Ouargla in Algeria. The history of the mosque backs to 600 years ago, in the 15th century AD. • Quadrangular form				
Religion	Graveyard	• Located close from mosques • Different irregular shapes				
Religion	Church	• The facades of neo-Moorish style buildings • consisting of a single level, enclosed by two uprights vertical • The church is the second religious building after the one built within the Ksar in 1930				

Types		Comments	Illustration
Habitat	Habitat with shbek	• **Form :** rectangular • **Size:** 3 floors With an Entry into a chicane • contains 8 rooms (4 in ground floor and 4 in the first floor) A shbek in the first floor to light the ground floor A terrace in the last floor • **Façade** with less openings	   
	Habitat with patio	• **Form :** squared • **Size :** ground floor +1 • With an Entry into a chicane • **Façade** with less openings	   
	Flats	• **Form :** rectangular • **Size :** 1 floor with Two bedrooms A kitchen A bathroom • **Façade** with much openings	  

Types		Comments	Illustration
Transport	Bus station	• Located in front of the tram station • Has a regular shape • Distant from the centre	  
	Tram station	• The path starts from the east part to the west part of the city • Regular shape	  
	Airport	• Located in the south east part of the city • Due to radiation reasons it is distant from residential areas	  

Types		Comments	Illustration
Education	Schools	• Located between residential areas	   
	University	• The Université de Ouargla is a university located in Ouargla, Algeria. • The university covers 88 hectares has 6 libraries and 26 research laboratories	  
	Youth center	• Youth activities and sport	   

GENERAL SYNTHESIS

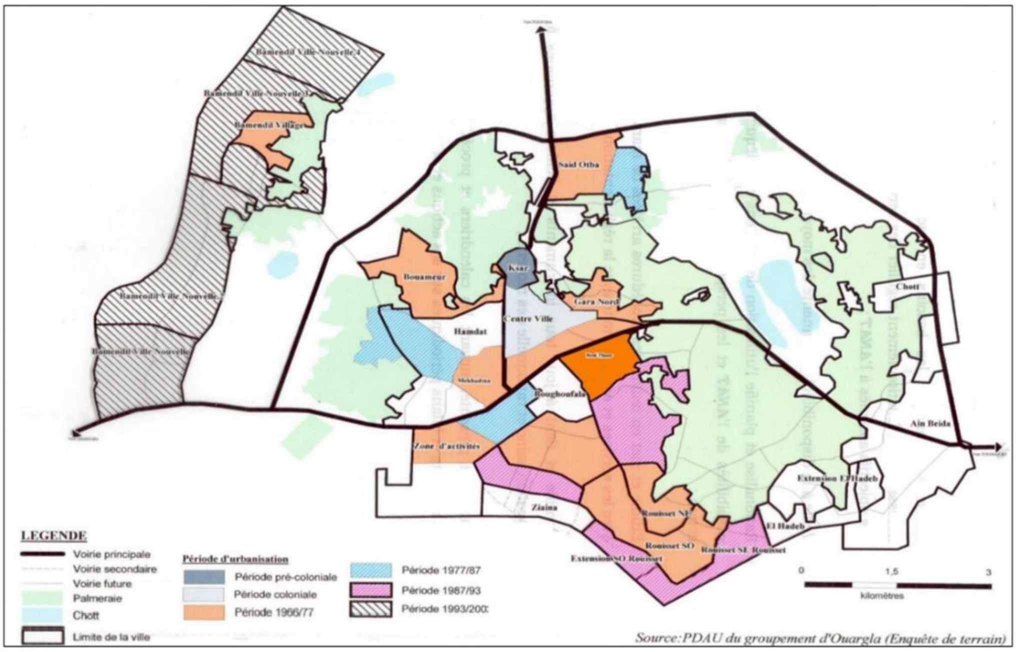


Figure 30: Pdau du groupement Ouargla (2007)

- ***9th century:***

Banu hilal and banu ouarglan made an internal expansion with a locale style of building where we find houses with patio or shbek and a terrace which is used in summer nights mostly and some souks and mosques in addition these buildings were made from locale construction materials such as Timchemt, adobe, clay and palm wood.

- ***year 1830:***

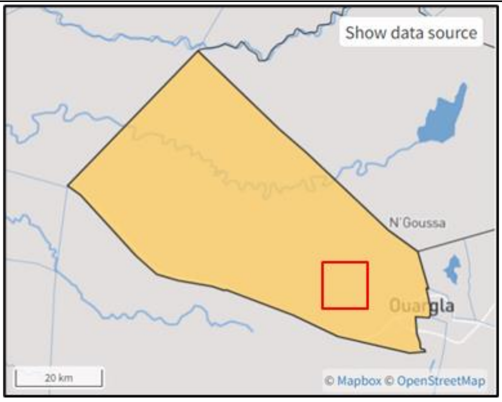
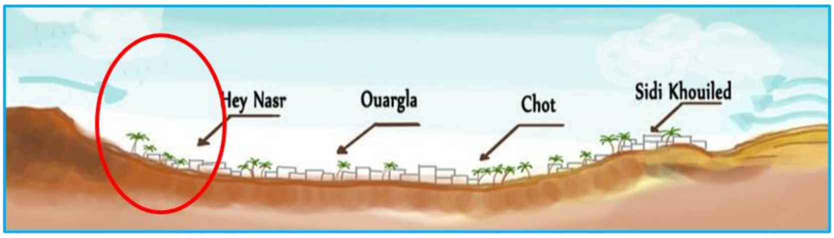
With the arrive of French colonization we can observe an external expansion in the south side of the Ouarglan ksar, the colonize built some cities of collective housing for the settlers the building were mostly made with glass, metal and concrete.

- ***From 1962 till 2007:***

The expansion goes in all directions of the ksar, due to the demography and the need of housing we see most of the buildings are collective by using modern building materials and that's what causes a high energy consumption as well as this style isn't accurate with the locale lifestyle which is basically individual housing.

3. Synchronic reading

a) motivations of the site choice:

1. The site is located in an urban expansion side of the city (east).	
2. Existence of transport and different equipment (university, schools, hospital), easy access to the site.	
3. Better temperature then the city center with a difference of 2°c to 4°c.	
4. The population in Ouargla for 2022 is 149 795 and that shows that we need housing to occupy the inhabitants.	(Settlements table below)

Settlements

All urban and semi-urban settlements in the Ouargla Province.

Name	Status	Commune	Population Census 1998-06-25	Population Census 2008-04-14
Aïn Beida	Urban Settlement	Aïn Beida	9,862	12,899
Bamendil	Semi-Urban Settlement	Ouargla	...	6,753
Benaceur	Urban Settlement	Benaceur	...	9,737
Blidet Amor	Urban Settlement	Blidet Amor	9,168	10,753
Chott Kasba	Semi-Urban Settlement	Aïn Beida	...	5,786
El Allia	Semi-Urban Settlement	El Allia	...	4,729
El Bour	Semi-Urban Settlement	N'Goussa	...	3,075
El Hadeb	Semi-Urban Settlement	Rouissat	...	4,318
El Hadjira	Urban Settlement	El Hadjira	...	9,000
Goug	Semi-Urban Settlement	Blidet Amor	...	3,690
Hassi Ben Abdellah	Semi-Urban Settlement	Hassi Ben Abdellah	...	4,810
Hassi Messaoud	Urban Settlement	Hassi Messaoud	37,539	44,478
Hay Alnasr	Urban Settlement	Ouargla	...	8,012
Megarine	Urban Settlement	Megarine	8,559	10,813

b) introduction of the intervention site:

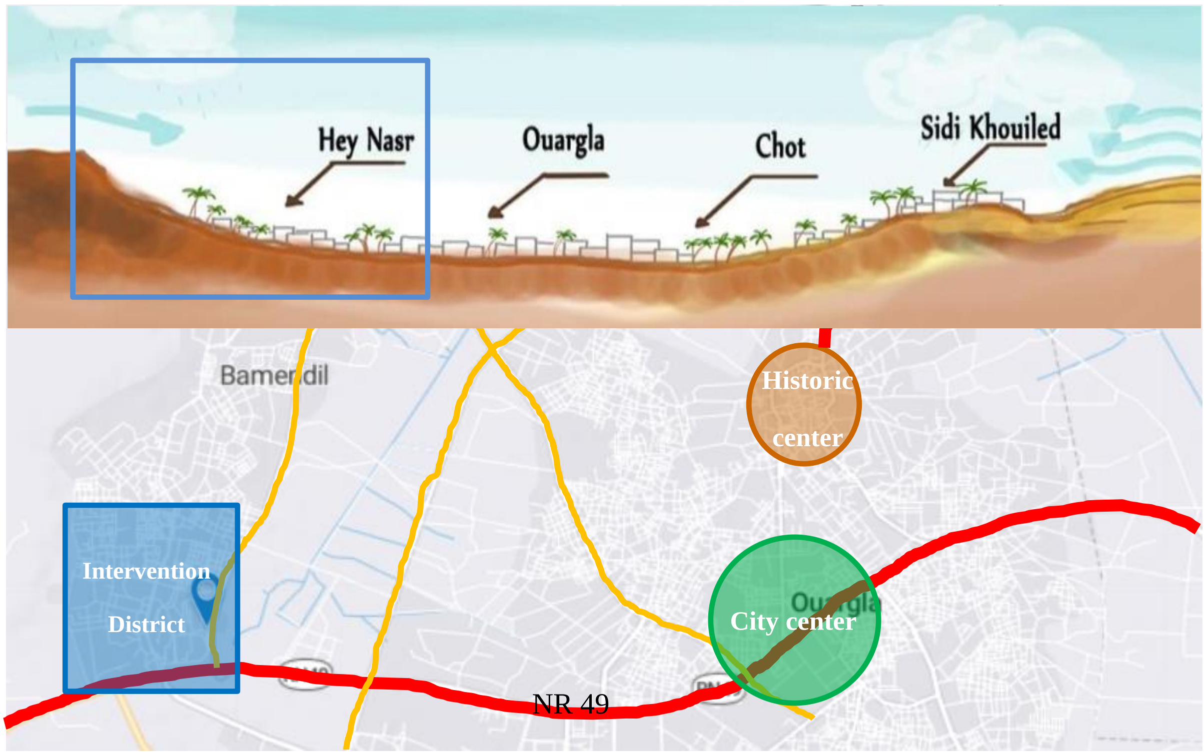


Figure 31: Intervention site on map (Author, 2023)

THE TERRAIN ACCESSIBILITY	
Our site is located in the east side of the city, Latitude/Longitude: 31.572° North, 5.175° East. The terrain is located exactly in hay nacre, in the north we can access to the site through the national road number 29 (in blue) then follow the tram line (in red) till the Aisha Mosque and turn left (in yellow) finally go all the way straight.	
THE BORDERS	
North: Elementary school, Private clinic. **East:** Individual dwellings. **South:** Empty site. **West:** Collective housing.	

To fully understand our intervention site, we have broken down the urban layout that makes up the city into four systems: road system, parcel system, built system and system of public spaces according to the typo-morphological approach.

- *Road's system:*

we observe a regular road system with an easy relation between secondary and primary roads, in addition, existence of tramway which facilitate the transportation.

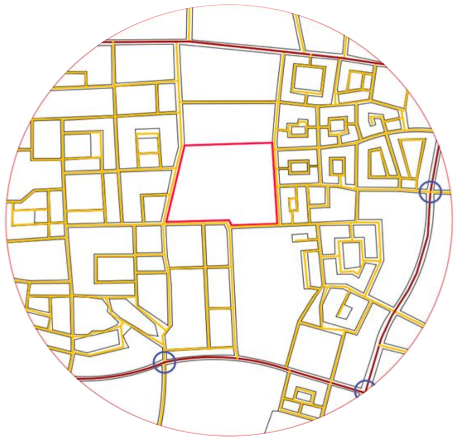
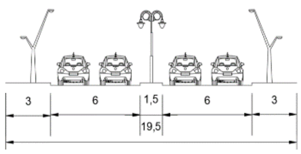
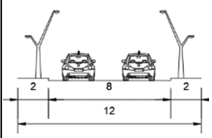
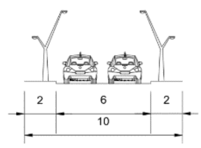
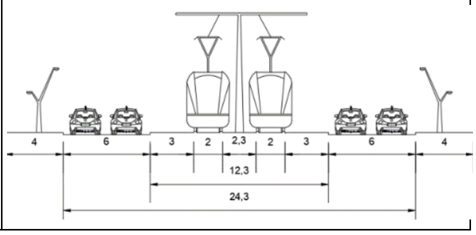


Table 31: Road's system different paths (Author, 2023)

Figure 32: map of the terrain (Author, 2023)

Primary path	Secondary path	Tertiary path	Tram line
			

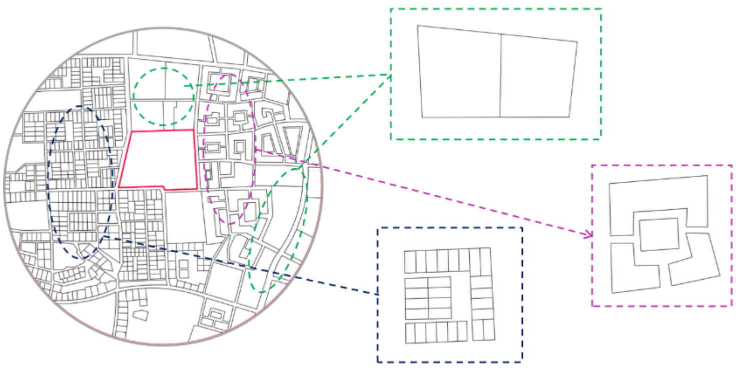
1. Looped system: it is characterized by two paths that lead from one point to the other, we observe the existence of three types:
   - Double exit system
   - Hierarchical system
   - Dead end system
2. Linear system: we observe a tree-based system which characterized by a double exit system where there is two paths lead from one point to the other.

- *Plot's system:*

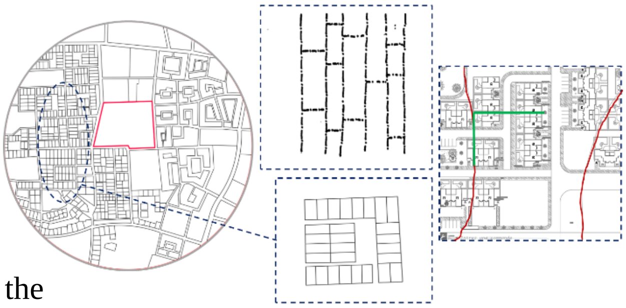
The urban layout is regular with Plots in different forms and areas:

Macro lot

Parcels: big and small area



1st type:

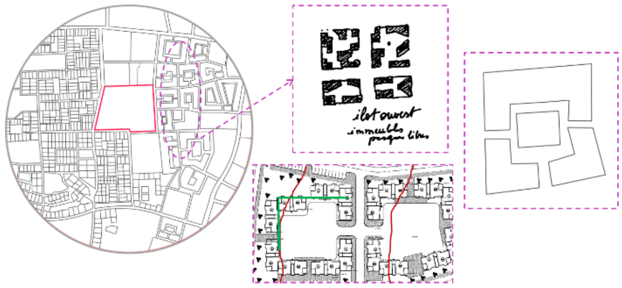


Typological aspect: Hierarchical plots, based on regular parcels shape

Geometrical aspect: The fundamental directions of the plot system is linked to the slope of the land, noting that it is perpendicular to the slope to facilitate the flow of run-off water

Dimensional aspect: 10m in depth and 21m in length

2nd type:

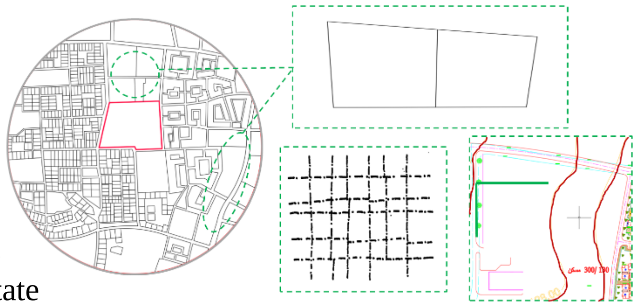


Typological aspect: a macro – lot (open plot)

Geometrical aspect: The fundamental directions of the lot is linked to the slope of the land, noting that it is perpendicular to the slope to facilitate the flow of run-off water

Dimensional aspect: 70m in depth and length

3rd type:



Typological aspect: Non-Hierarchical plots, based on regular parcels shape

Geometrical aspect: The fundamental directions of the plot system is linked to the slope of the land, noting that it is perpendicular to the slope to facilitate the flow of run-off water

Dimensional aspect: 90m in depth and 101m in length

- *Built system:*

On the east side of our intervention site we have collective housing, Size: GF+2-3

Style: simple, beige, red and white colours.

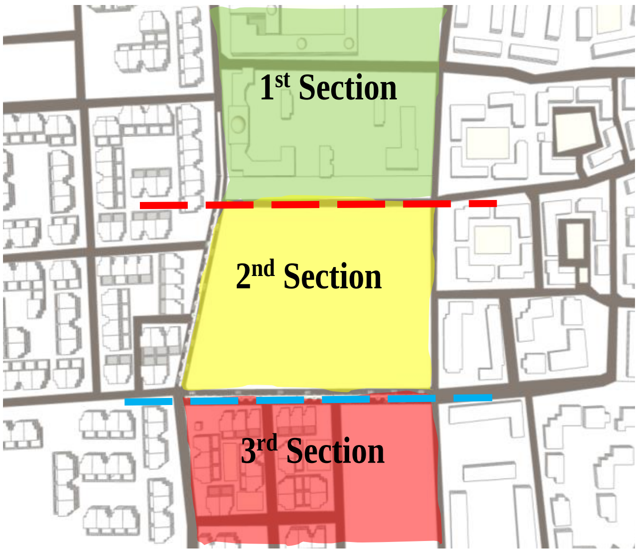
Some individual housing located in south and west side of the site, Size: GF+2-3

Style: simple, beige, red and white in general sand colours.

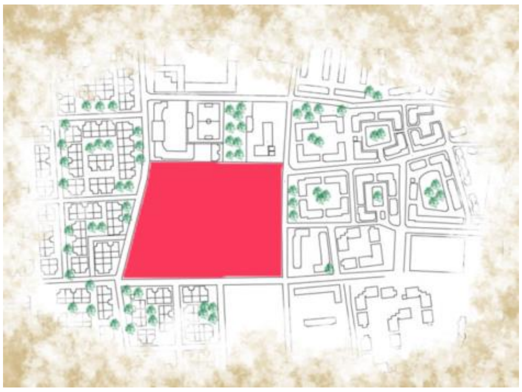
Aisha mosque in the west side we can use it as a bench mark for an easy arrive of visitors.

In the north side of the intervention site, we have a middle school, high school and a private clinic.

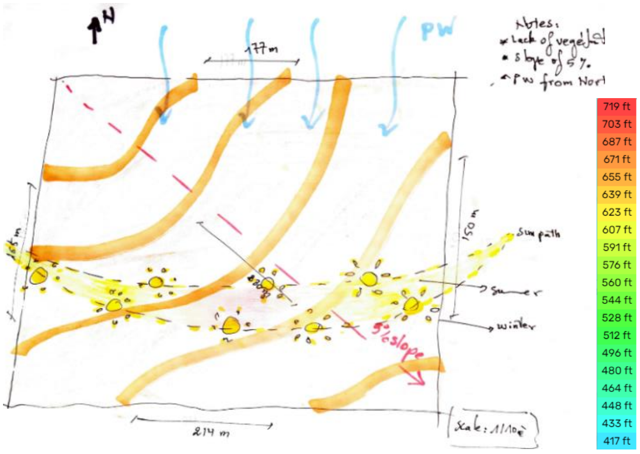
Sequential analysis:

1st section	1. Existence of transportation 2. The equipment is a source of noise 3. Existence of public light	Figure 33: sequential analysis schema by Author, 2023.
2nd section	1. Calm section 2. Not much noises or movement 3. Not much lights	
3rd section	1. Calm section as well 2. Just residential buildings 3. An average amount of noises	

Synthesis of urban analysis:

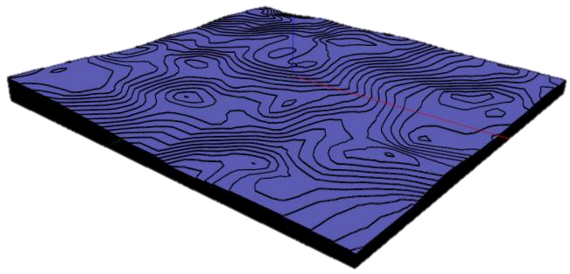


Vegetation: lack of vegetation in general



The climate is hot and dry and we have a big solar radiation range.

Buildings: the area is residential where we have individual and collective dwellings

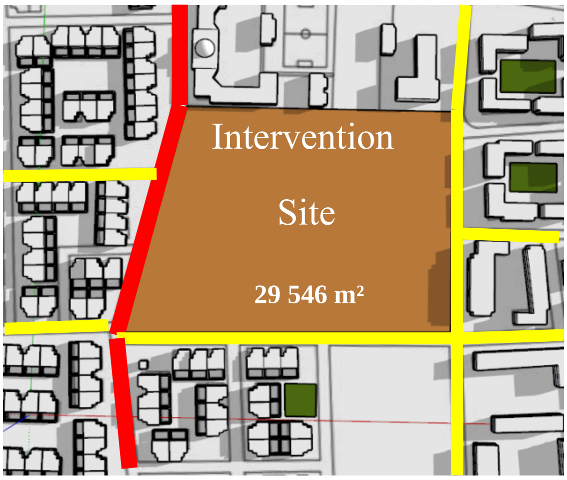


Topography:

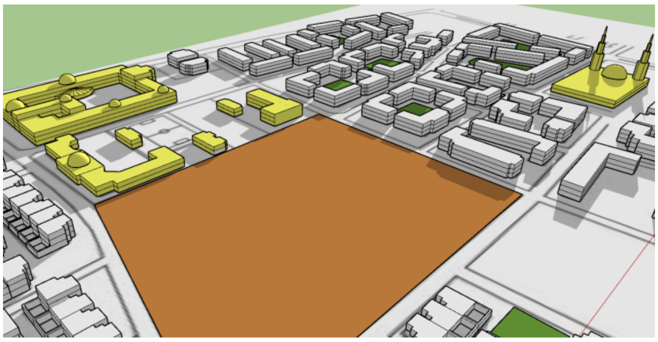
Minimum elevation: 381 ft

Maximum elevation: 837 ft

Our intervention site is located in 480ft which has a slope of between 3 up to 5 per cent



Accessibility: the plot can be accessed by three roads



Nearby places: schools middle and high, private clinic and a mosque

First of all, before starting our project we actually did many hypotheses of layout design one of them was creating a palm shape layout:

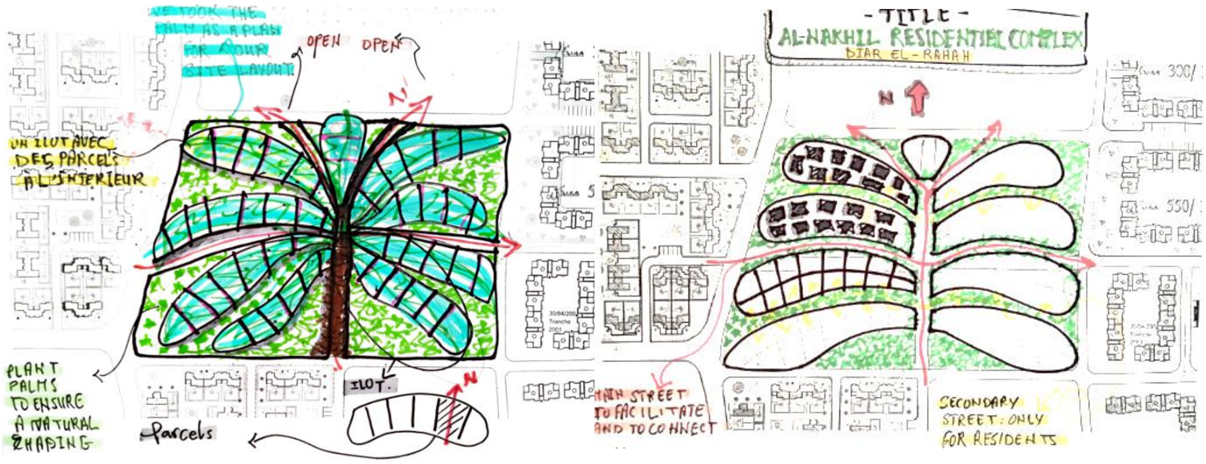


Figure 34: First hypothesis layout sketch by Author, 2023.

But this was not a good design as for it does not follow the layout of the surrounding environment there for, we tried to be more realistic and do the next following steps:

1. Environment:

The site analysis shows that our intervention site has a lack in green areas and vegetation so the first thing to make is creating green spaces following the concept of freshness island (ilot de fraicheur).

1- Green areas are divided into public and semi- public the public one is in the middle and the semi public is in between the houses as it is shown in the figure bellow.
2- Avoiding traffic circulations inside our area in order to have a clean and fresh air inside and encourage the pedestrian circulation.

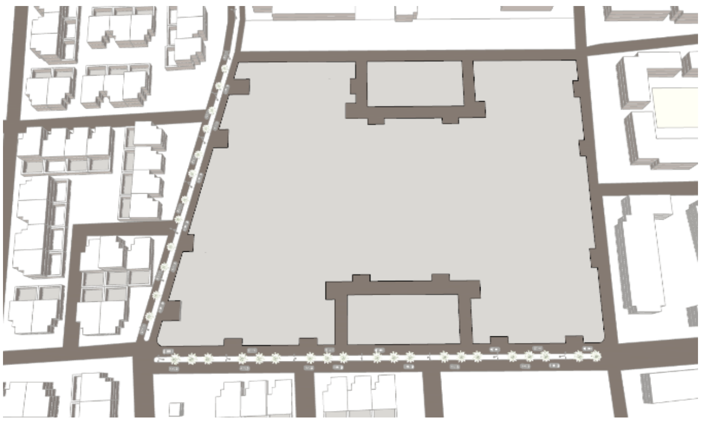


Figure 35: roads system in the plot by Author, 2023.

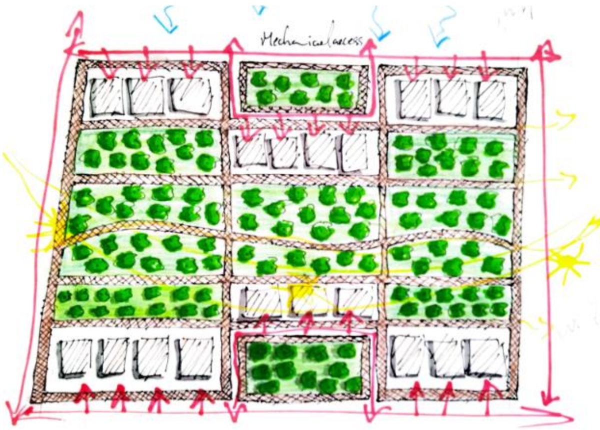


Figure 36: hypothesis sketch by Author, 2023.

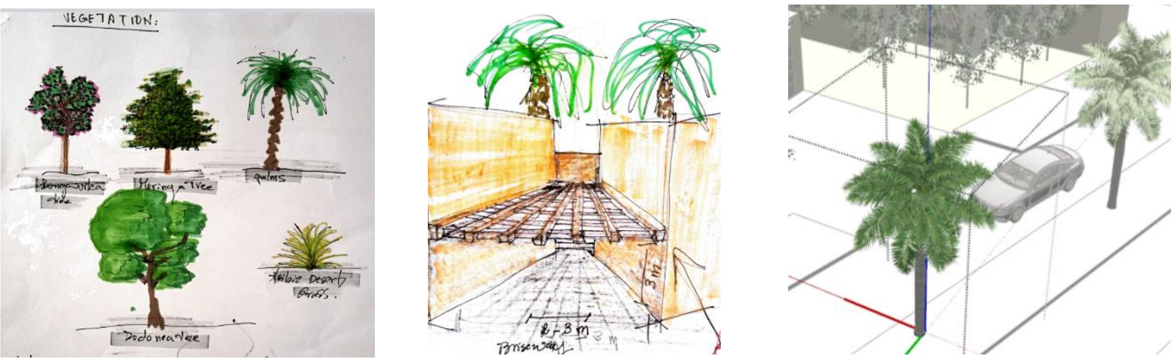
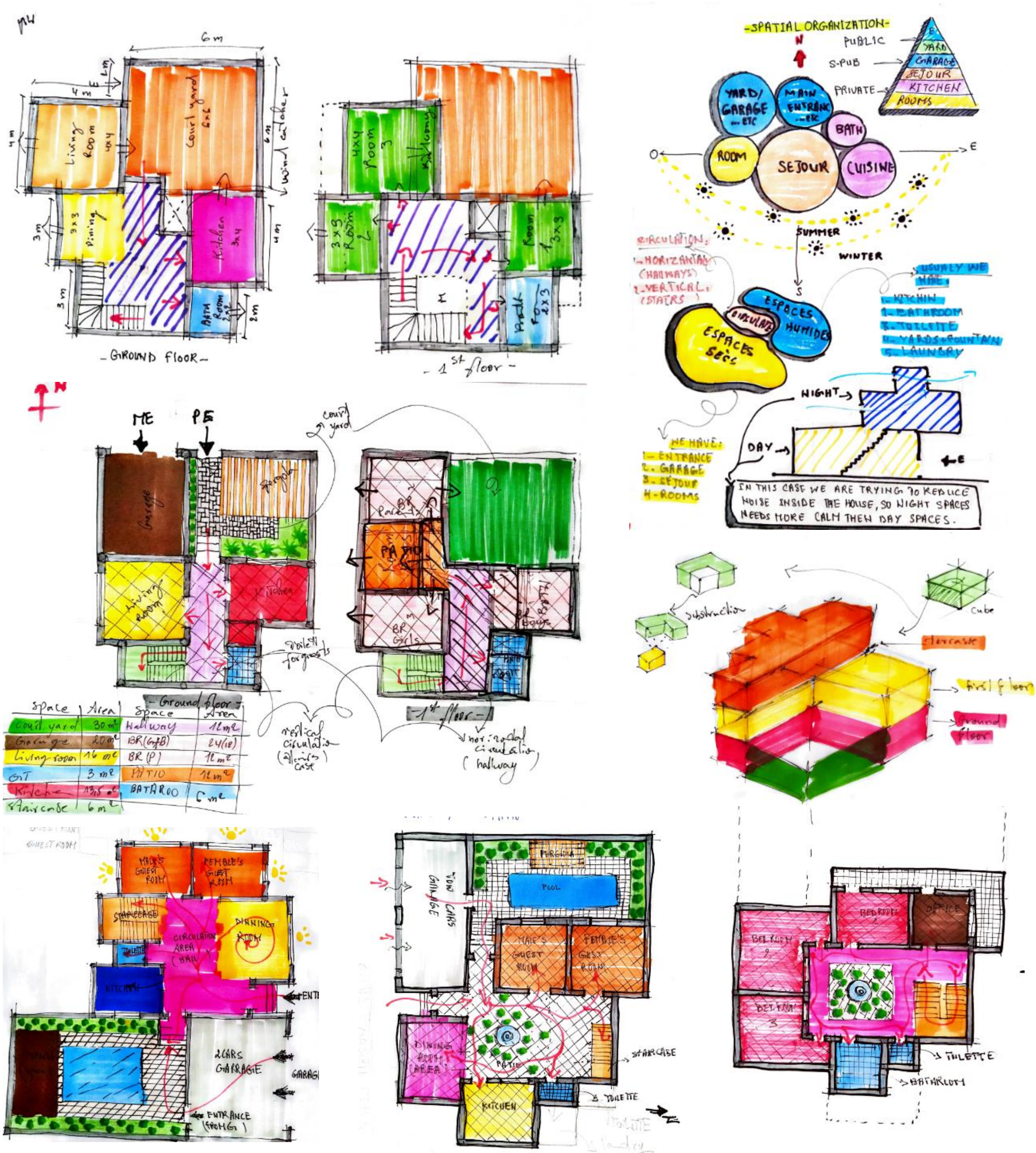


Figure 37: type of vegetation used by Author, 2023.

2. Form:

In term of form, we tried to create three types of houses after some trials:

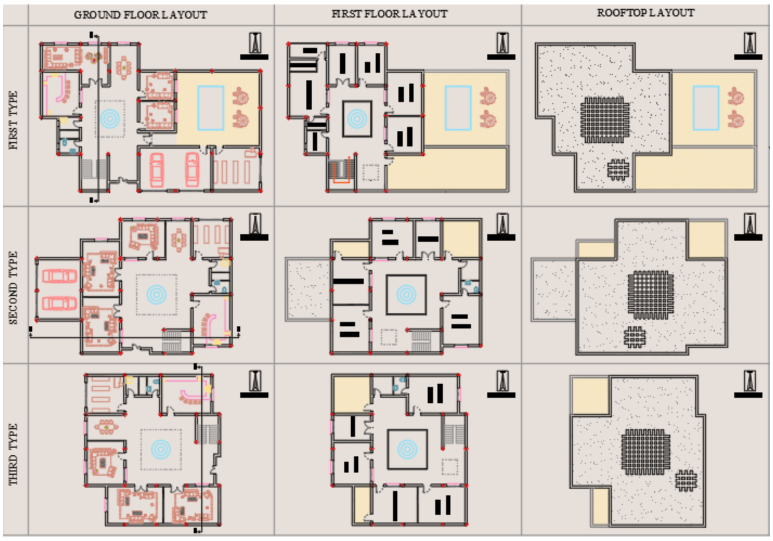


And we finally we had created the layout of all the three types:

1st type: a dwelling contains a courtyard (patio) and a backyard.

2nd and 3rd type contains only a courtyard (patio).

In overall the dwellings has a regular shape some additions and subtractions.



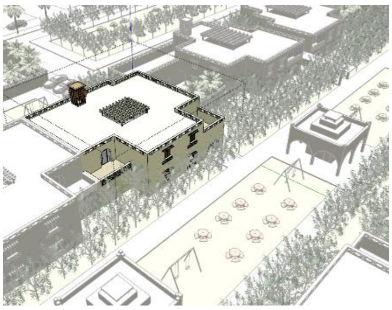
Zone	Area
Entrance	14m^2
Garage	43m^2
Living room	37m^2 room
Gust room (female)	18m^2
Guest room (male)	18m^2
Backyard	112m^2
Courtyard	68m^2
kitchen	30m^2
Dinning	20m^2
Toilette	5m^2
Laundry	8m^2
Staircase	13m^2
Parents bedroom	43m^2
Office room	19m^2
Doubled bedroom 1	23m^2
Doubled bedroom 2	27m^2
Single bedroom	19m^2
Bathroom	8m^2

Figure 38: layouts of the houses Author, 2023

3D views:

1st type

2nd type



3rd type

3. Envelope:

We followed Hassan Fathi and Le Corbusier in the way they treat the façade in a minimalistic way no decorations needed we just used some arcs; we did follow the less opening concept due to the need of privacy and the hot and dry climate.

We tried to add a light colour on our envelope called milky white to avoid the sun heat attraction and heat gains.

Talking about materials we used a mixed structure of masonry blocks and iron for the structure with concrete.

And here is the final result:

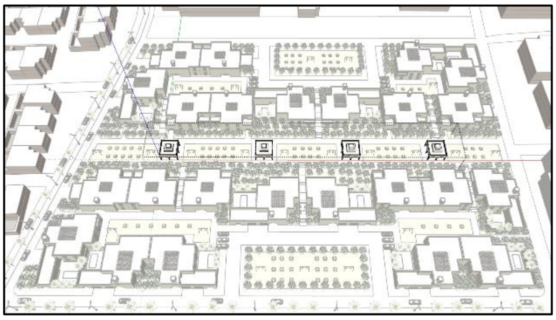
Step n°=01: realizing the green area which is divided into public and semipublic.

Step n°=02: adding the houses type one.

Step n°=02: adding the houses type two.

Step n°=02: adding the houses type three.

Step n°=03: adding some breezeways (passage couver) inspired from the Ouarglan ksar.



Step n°=04: adding some boutiques in the form of a souk inspired from the Ouarglan ksar.

CONCLUSION

In this thesis, I have examined the effects of the orientation, shading, glazing and construction materials on the thermal comfort of the house. I have argued that to ensure the thermal comfort of any building we have two ways: passive traditional and active by using some technologies can depending on how it is used and what factors influence its use. I have supported my argument with evidence from various sources, including scientific reviews, articles and experiments.

The main points of my thesis are:

- Comfort is an important need for human being to live and architects need to ensure it in the building.
- The thermal comfort can be ensured by some architectural elements such as the courtyard and the windcatcher which produce a natural ventilation.
- The thermal comfort can be ensured by using constructing buildings such us adobe and aerated brick that has a lower conductivity.
- Thermal comfort can be ensured by adding green areas and vegetation which produces shading in the space.

The importance of comfort in the building lies in its positive impacts on the occupants' health, well-being, satisfaction, and performance. Comfortable buildings can enhance the occupants' physical and mental health by reducing stress, fatigue, discomfort, and illness. Comfortable buildings can also improve the occupants' well-being and satisfaction by creating a pleasant and stimulating environment that meets their needs and expectations. Comfortable buildings can further increase the occupants' performance and productivity by supporting their concentration, creativity, communication, and collaboration. Therefore, comfort in the building is not only a desirable goal but also a necessary requirement for sustainable and human-centered design.

To conclude, this thesis has shown that comfort in general and thermal comfort specifically is that much important for human being to do their activities and that we have many ways as architects to ensure it. It has also highlighted the need for more research and education on this topic to help architects to understand well both ways passive and active willing to use a mix of both to have a better comfort.

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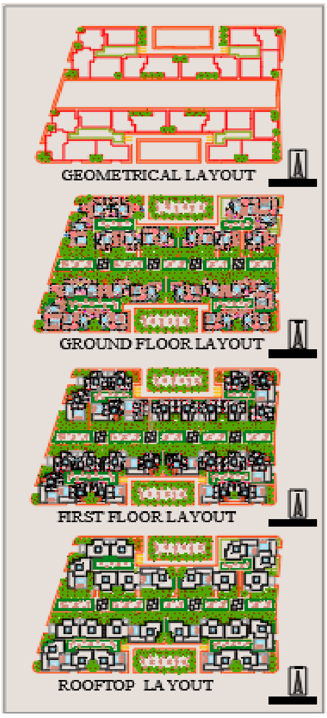
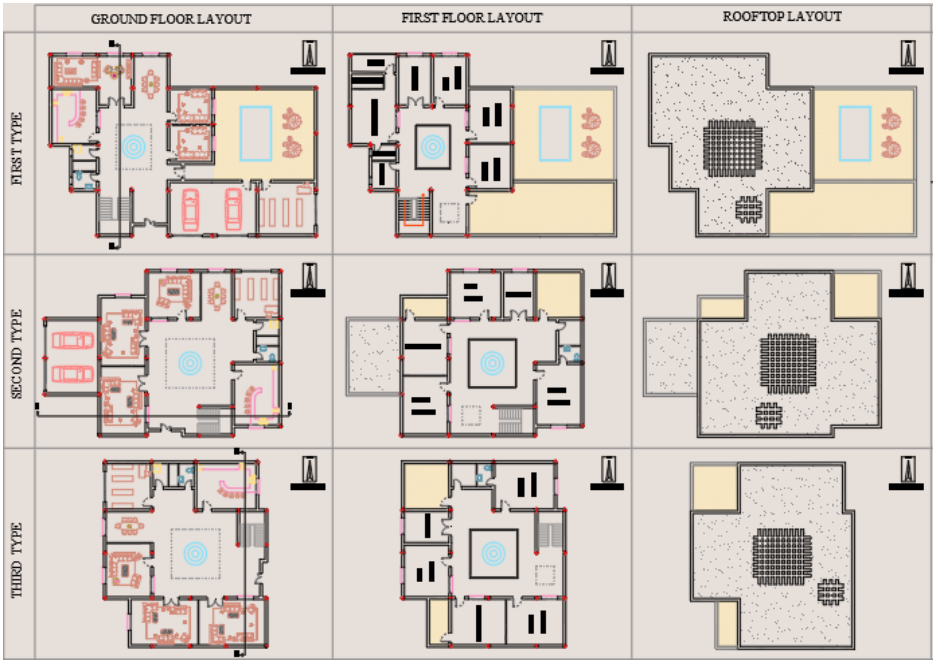
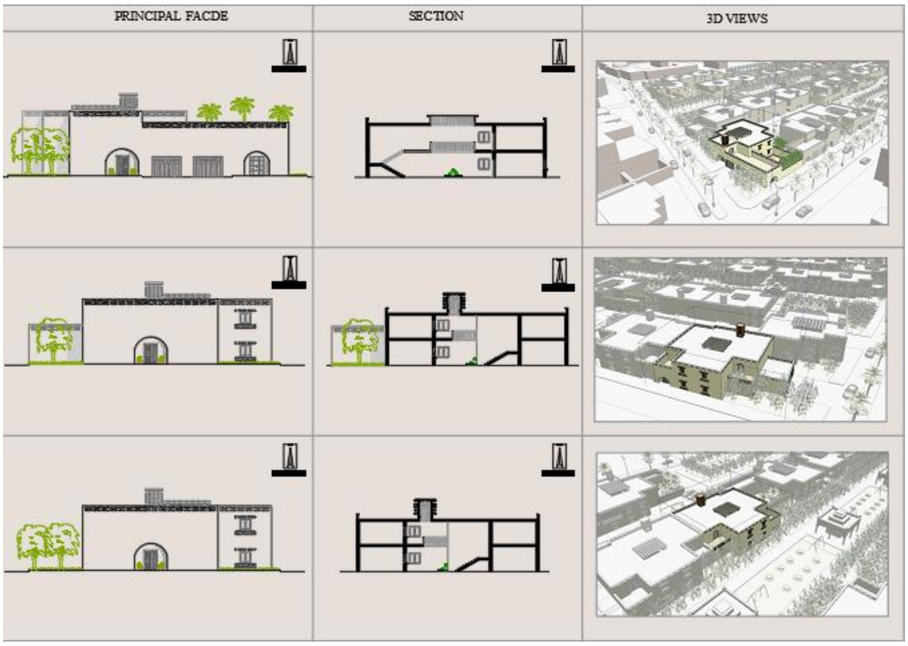
ANNEXES

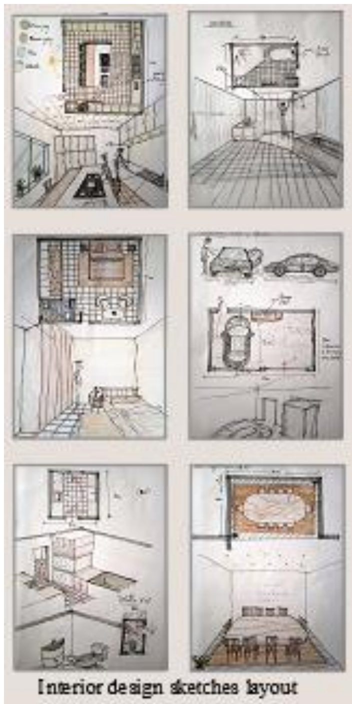
Annex 1: Graphic file of the project.





Al-Rimal Residential complex, Ouargla, Algeria





Annex 2: Simulation results report (Design Builder).

Sensitivity Analysis Report

Sensitivity analysis identifies how uncertainty in an output relates to uncertainty in the input parameters. This analysis identifies which input variables influence the simulation results the most.

The report consists of following sections:

1) Input Variables: Details of all simulation input with their distribution curves
2) Outputs (KPIs): Details of the outputs analysed.
3) Analysis Information: Analysis summary, details about input samples and output uncertainty.
4) Sensitivity Analysis Results: Graphs and statistical details identifying most influential parameters for each output.

1. Input Variables

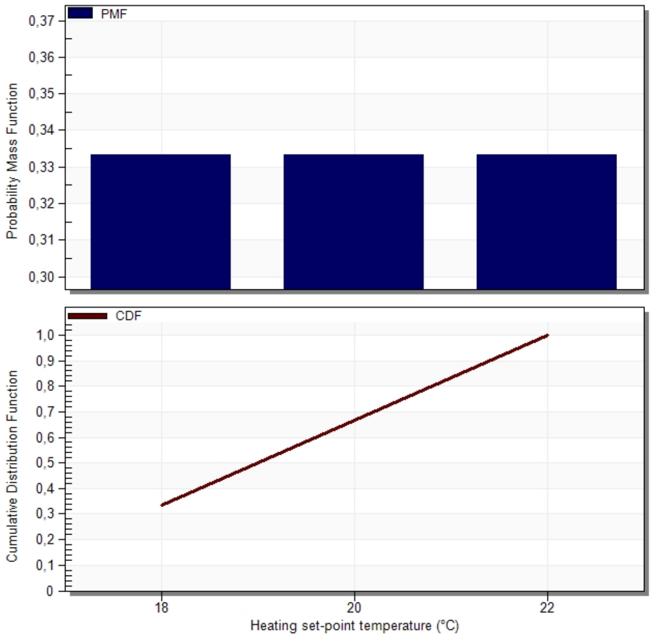
7 input variables were selected. Below are the details of each input.

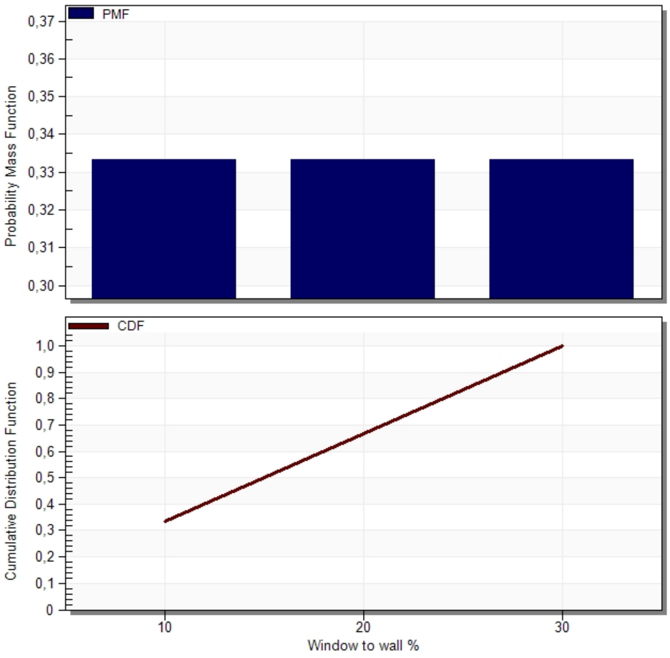
1.1 Input variable: Heating set-point temperature

Input Type:	Heating set-point temperature
Input Units:	°C
Probability Distribution:	20-Uniform(Discrete)
Distribution Characteristics:	Min.Val.: 18,00; Step Size: 2,00; Step No.: 3
Level:	3 Targets Selected

1.2 Input variable: Window to wall %

Input Type:	Window to wall %
Input Units:	No Units
Probability Distribution:	20-Uniform(Discrete)
Distribution Characteristics:	Min.Val.: 10,00; Step Size: 10,00; Step No.: 3
Level:	9 Targets Selected



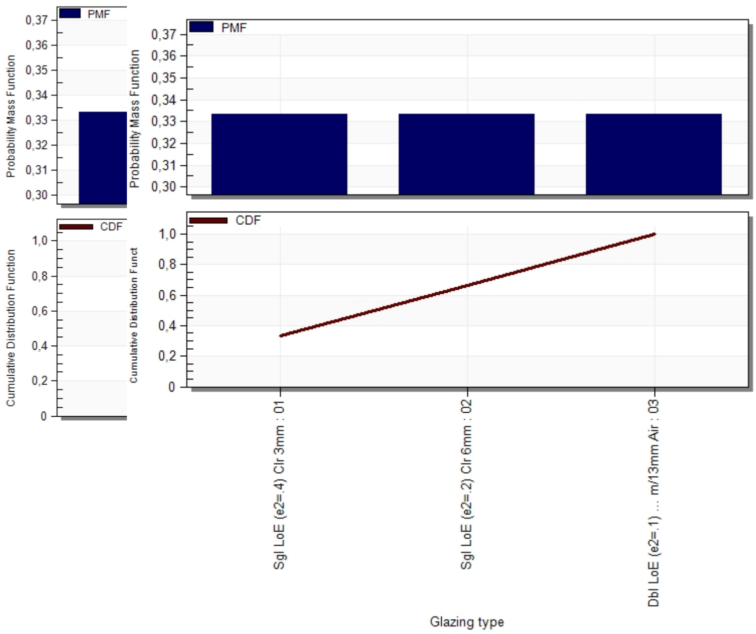


1.3 Input variable: Glazing type

Input Type:	Glazing type
Input Units:	No Units
Probability Distribution:	20-Uniform(Discrete)
Distribution Characteristics:	Prob: 0,333; Options: 3
Level:	8 Targets Selected

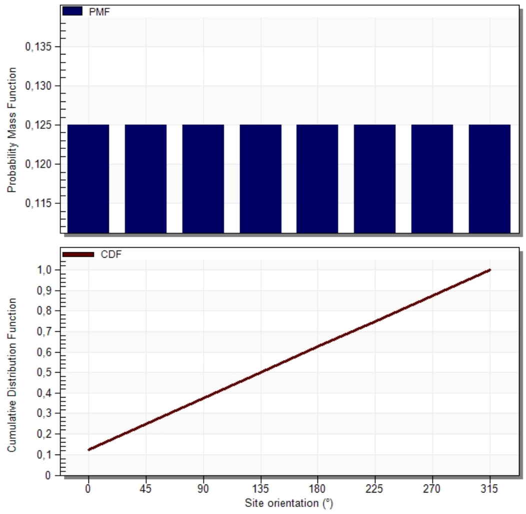
1.4 Input variable: Local shading type

Input Type:	Local shading type
Input Units:	No Units
Probability Distribution:	20-Uniform(Discrete)
Distribution Characteristics:	Prob: 0,333; Options: 3
Level:	8 Targets Selected



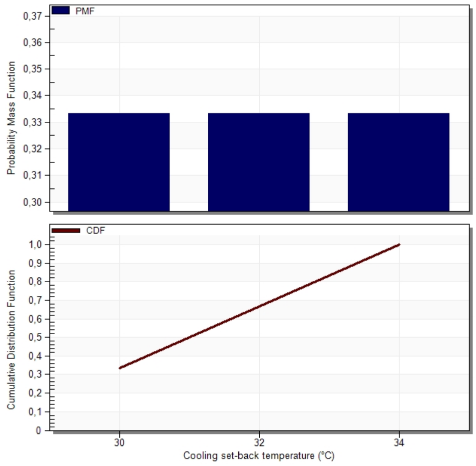
1.5 Input variable: Site orientation

Input Type:	Site orientation
Input Units:	°
Probability Distribution:	20-Uniform(Discrete)
Distribution Characteristics:	Min.Val.: 0,00; Step Size: 45,00; Step No.: 8
Level:	3 Targets Selected



1.6 Input variable: Cooling set-back temperature

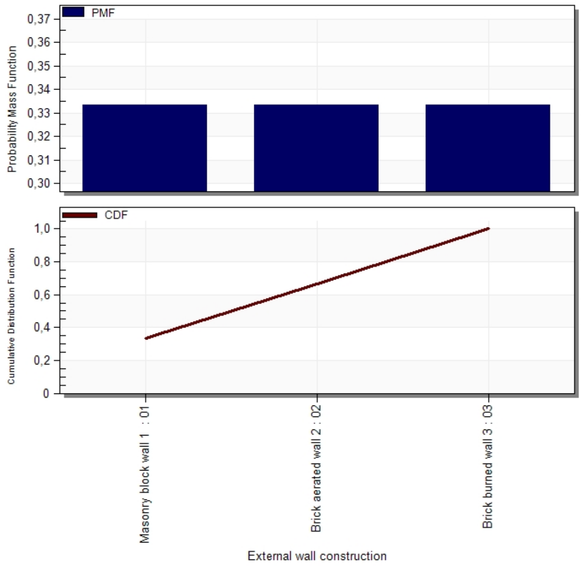
Input Type:	Cooling set-back temperature
Input Units:	°C
Probability Distribution:	20-Uniform(Discrete)
Distribution Characteristics:	Min.Val.: 30,00; Step Size: 2,00; Step No.: 3
Level:	3 Targets Selected



1.7 Input variable: External wall construction

Input Type:	External wall construction
Input Units:	No Units
Probability Distribution:	20-Uniform(Discrete)
Distribution Characteristics:	Prob: 0,333; Options: 3

Level: 7 Targets Selected



2. Outputs

5 output KPIs were selected. Below are the details of the outputs.

2.1 Output: CO2 (Embedded CO2)

Output Type:	Embedded CO2
Output Units:	kg

2.2 Output: Discomfort (Discomfort ASHRAE 55 Adaptive 80% Acceptability)

Output Type:	Discomfort ASHRAE 55 Adaptive 80% Acceptability
Output Units:	hr

2.3 Output: Cooling (Cooling (Electric))

Output Type:	Cooling (Electric)
Output Units:	kWh

2.4 Output: Heating (Heating (Gas))

Output Type:	Heating (Gas)
Output Units:	kWh

2.5 Output: LCA (LCA (Simple))

Output Type:	LCA (Simple)
Output Units:	kg

3. Analysis Information

This section summarises the overall analysis statistics and the range and distribution profiles of the actual values used for all the input variables in the simulation runs. The values are in accordance with the range and distribution profile selected in the analysis settings. The uncertainty in the outputs is also represented in form of histograms and summary statistics.

500 simulation runs were requested. Total simulation runs retrieved were 500. Below is the summary of the simulation and statistics for uncertainty in input samples and outputs.

3.1 Sampling and Simulation Summary

This section of the report lists the settings used for the uncertainty propagation and subsequent simulations runs undertaken. The failed iterations, if any, have been excluded from the results presented here and have not been used in the analysis.

Sampling Method:	RANDOM
Samples Requested:	500
Samples Created:	500
Failed Iterations:	0
Successful Iterations:	500

3.2 Input Sample Details

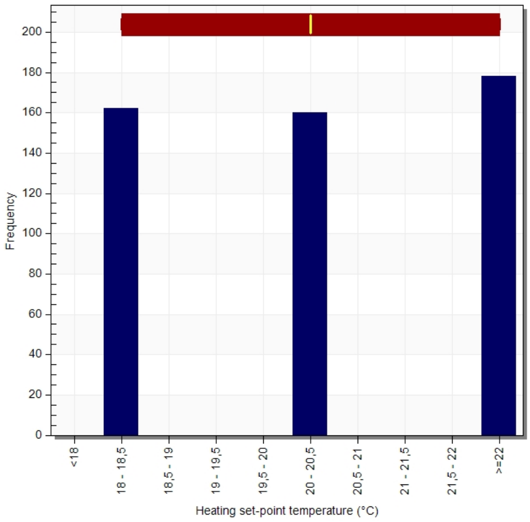
This section of the report lists the statistics for the samples generated, and used in the analysis, for all the inputs. The spread of sampled space is captured in the corresponding graphs.

3.2.1 Input variable: Heating set-point temperature

3.2.1.1 Summary Statistics: Heating set-point temperature

Mean	SD	Min	Q1	Median	Q3	Max
20	2	18	18	20	22	22

3.2.1.2 Input Distribution Histogram: Heating set-point temperature

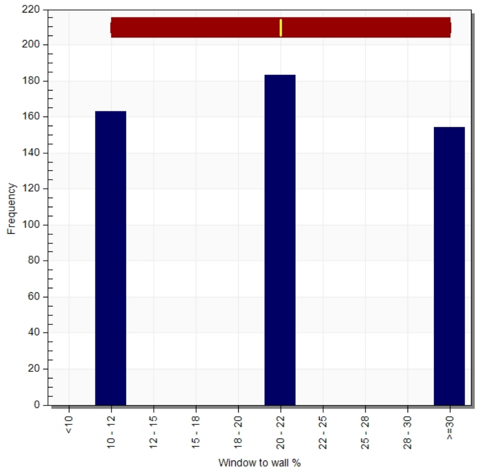


3.2.2 Input variable: Window to wall %

3.2.2.1 Summary Statistics: Window to wall %

Mean	SD	Min	Q1	Median	Q3	Max
20	8	10	10	20	30	30

3.2.2.2 Input Distribution Histogram: Window to wall %

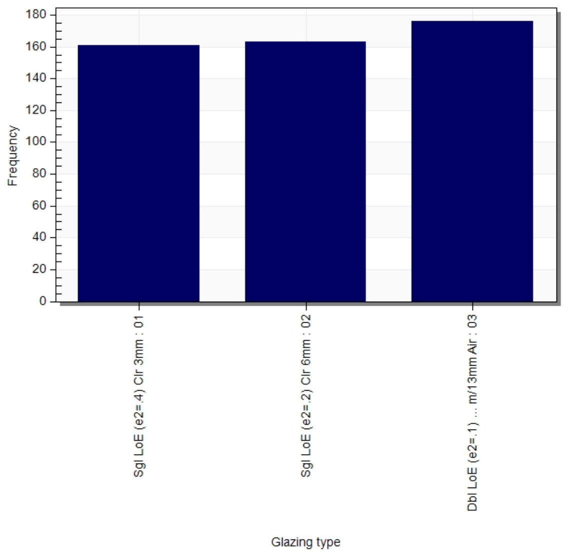


3.2.3 Input variable: Glazing type

3.2.3.1 Input Options' Frequency: Glazing type

Option Name	Frequency
Sgl LoE (e2=.4) Clr 3mm : 01	161
Sgl LoE (e2=.2) Clr 6mm : 02	163
Dbl LoE (e2=.1) ... m/13mm Air : 03	176

3.2.3.2 Frequency Distribution Graph: Glazing type

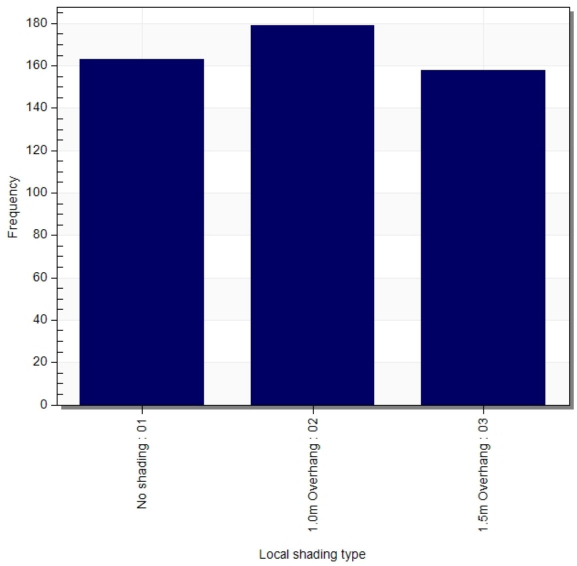


3.2.4 Input variable: Local shading type

3.2.4.1 Input Options' Frequency: Local shading type

Option Name	Frequency
No shading : 01	163
1.0m Overhang : 02	179
1.5m Overhang : 03	158

3.2.4.2 Frequency Distribution Graph: Local shading type

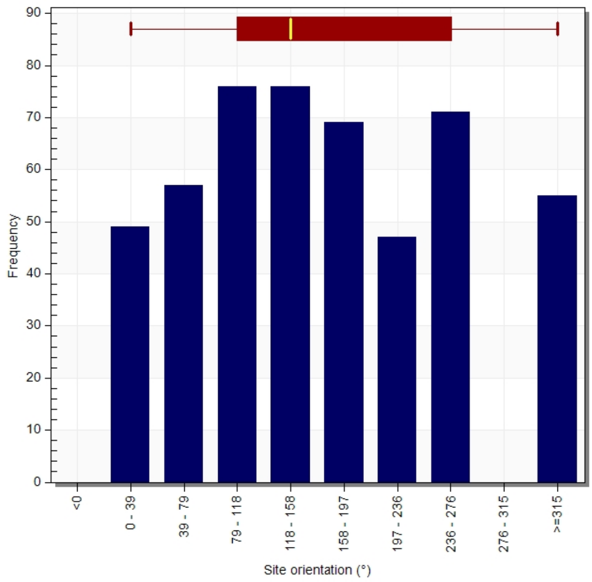


3.2.5 Input variable: Site orientation

3.2.5.1 Summary Statistics: Site orientation

Mean	SD	Min	Q1	Median	Q3	Max
158	98	0	90	135	270	315

3.2.5.2 Input Distribution Histogram: Site orientation

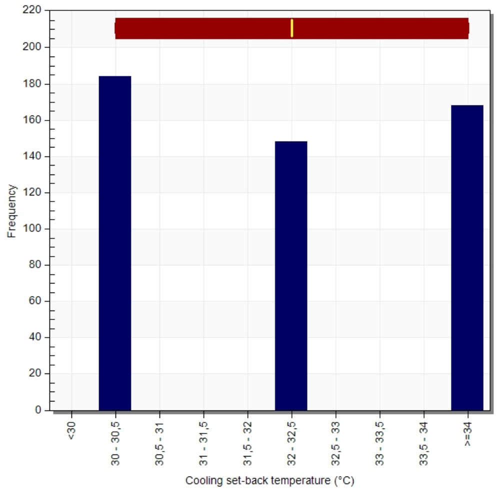


3.2.6 Input variable: Cooling set-back temperature

3.2.6.1 Summary Statistics: Cooling set-back temperature

Mean	SD	Min	Q1	Median	Q3	Max
32	2	30	30	32	34	34

3.2.6.2 Input Distribution Histogram: Cooling set-back temperature

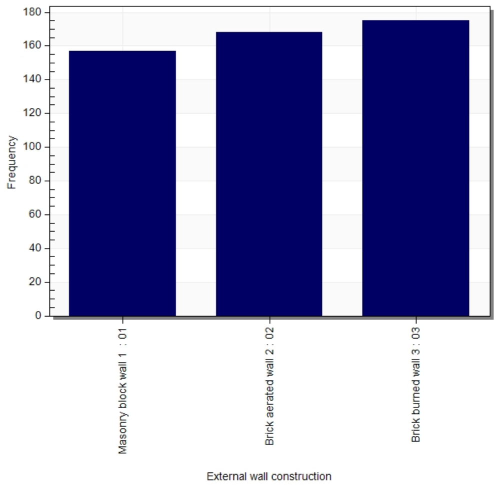


3.2.7 Input variable: External wall construction

3.2.7.1 Input Options' Frequency: External wall construction

Option Name	Frequency
Masonry block wall 1 : 01	157
Brick aerated wall 2 : 02	168
Brick burned wall 3 : 03	175

3.2.7.2 Frequency Distribution Graph: External wall construction



3.3 Output Uncertainty

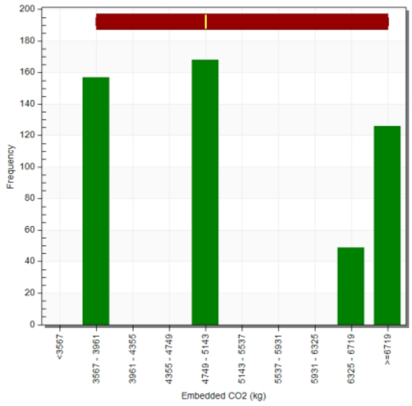
This section of the report presents the uncertainty analysis results for all the outputs requested. Summary statistics and corresponding graphs captures the spread of the outputs due to the variation in the inputs.

3.3.1 Output: CO2 (Embedded CO2)

3.3.1.1 Summary Statistics:

Mean	SD	Min	Q1	Median	Q3	Max
5193	1276	3567	3591	5123	6719	6719

3.3.1.2 Output Uncertainty Histogram:

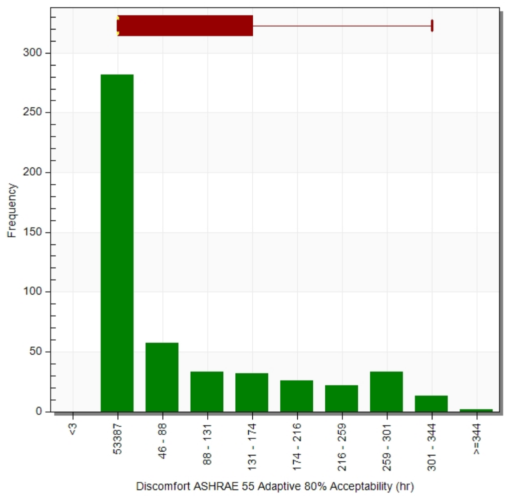


3.3.2 Output: Discomfort (Discomfort ASHRAE 55 Adaptive 80% Acceptability)

3.3.2.1 Summary Statistics:

Mean	SD	Min	Q1	Median	Q3	Max
83	95	3	13	35	135	344

3.3.2.2 Output Uncertainty Histogram:

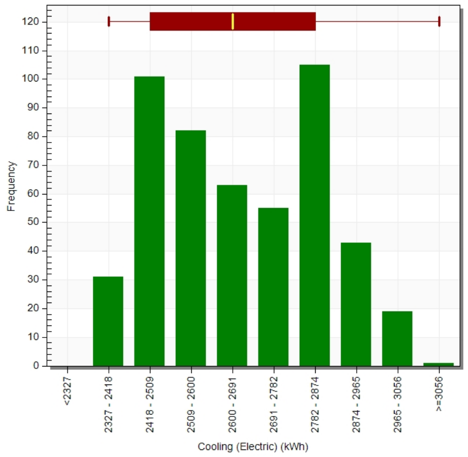


3.3.3 Output: Cooling (Cooling (Electric))

3.3.3.1 Summary Statistics:

Mean	SD	Min	Q1	Median	Q3	Max
2663	176	2327	2505	2632	2814	3056

3.3.3.2 Output Uncertainty Histogram:

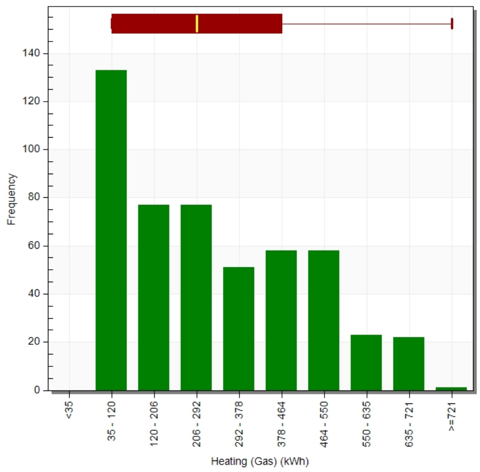


3.3.4 Output: Heating (Heating (Gas))

3.3.4.1 Summary Statistics:

Mean	SD	Min	Q1	Median	Q3	Max
287	186	35	118	244	444	721

3.3.4.2 Output Uncertainty Histogram:

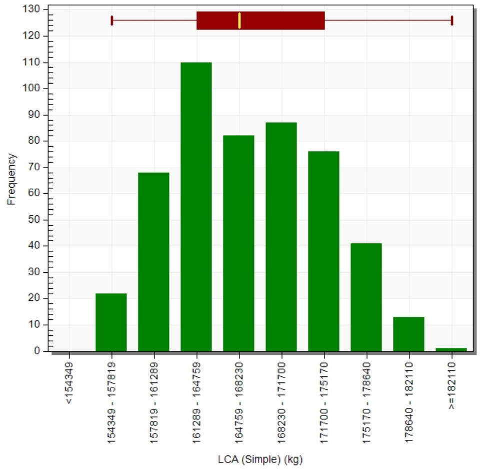


3.3.5 Output: LCA (LCA (Simple))

3.3.5.1 Summary Statistics:

Mean	SD	Min	Q1	Median	Q3	Max
167331	5977	154349	162418	166944	172025	182110

3.3.5.2 Output Uncertainty Histogram:



4. Sensitivity Analysis - Regression

Random sampling method is used for setting up the analysis. Regression method is used for this sensitivity analysis.

Regression analysis (multiple linear regression) is a statistical method that estimates the relationships among input variables. Regression analysis helps to understand how the typical value of the output changes when any one of the input variables is varied (assuming that the input variables are independent of each other). The Standardised Regression Coefficient (SRC) output the sensitivity of each input variable, thereby, identifying the most and least important variables. While, other regression outputs like 'adjusted R-squared' value and 'p-value' help in determining the level of confidence and reliability of the results.

Summary of the influential factors for each output

Embedded CO2 is most strongly influenced by External wall construction. The input and output are directly related. Increasing External wall construction leads to increase in Embedded CO2. Glazing type, Heating set-point temperature, Window to wall %, Site orientation, Local shading type and Cooling set-back temperature do not have a notable influence on Embedded CO2, therefore, these inputs can be ignored in further analysis of Embedded CO2 for this model.

Note: P-value of some (or all) of the inputs is high, suggesting that there is low level of confidence in their result values. Interpretations made specifically for Heating set-point temperature, Window to wall %, Site orientation, Local shading type and Cooling set-back temperature inputs should be read with caution.

Discomfort ASHRAE 55 Adaptive 80% Acceptability is most strongly influenced by Heating set-point temperature, however there is an inverse relationship. Increasing Heating set-point temperature leads to a decrease in Discomfort ASHRAE 55 Adaptive 80% Acceptability. Discomfort ASHRAE 55 Adaptive 80% Acceptability is also strongly influenced by External wall construction. Discomfort ASHRAE 55 Adaptive 80% Acceptability is also moderately influenced by Local shading type. Site orientation, Glazing type, Cooling set-back temperature and Window to wall % do not have a notable influence on Discomfort ASHRAE 55 Adaptive 80% Acceptability, therefore, these inputs can be ignored in further analysis of Discomfort ASHRAE 55 Adaptive 80% Acceptability for this model.

Note: Adjusted R Squared Value of the analysis is not very high, suggesting that the current input variables partially explain the overall uncertainty in the output. The overall results of this analysis can be relied upon, but with care. Additionally, P-value of some (or all) of the inputs is high, suggesting that there is low level of confidence in their result values. Interpretations made specifically for Glazing type, Cooling set-back temperature and Window to wall % inputs should be read with caution.

Cooling (Electric) is most strongly influenced by External wall construction. The input and output are directly related. Increasing External wall construction leads to increase in Cooling (Electric). Cooling (Electric) is also strongly influenced by Local shading type. Cooling (Electric) is also moderately influenced by Glazing type and Site orientation. Window to wall %, Cooling set-back temperature and Heating set-point temperature do not have a notable influence on Cooling (Electric), therefore, these inputs can be ignored in further analysis of Cooling (Electric) for this model.

Note: Adjusted R Squared Value of the analysis is not very high, suggesting that the current input variables partially explain the overall uncertainty in the output. The overall results of this analysis can be relied upon, but with care. Additionally, P-value of some (or all) of the inputs is high, suggesting that there is low level of *confidence in their result values. Interpretations made specifically for Cooling set-back temperature and Heating set-point temperature inputs should be read with caution.*

Heating (Gas) is most strongly influenced by Heating set-point temperature. The input and output are directly related. Increasing Heating set-point temperature leads to increase in Heating (Gas). Heating (Gas) is also strongly influenced by External wall construction. Local shading type, Glazing type, Cooling set-back temperature, Window to wall % and Site orientation do not have a notable influence on Heating (Gas), therefore, these inputs can be ignored in further analysis of Heating (Gas) for this model.

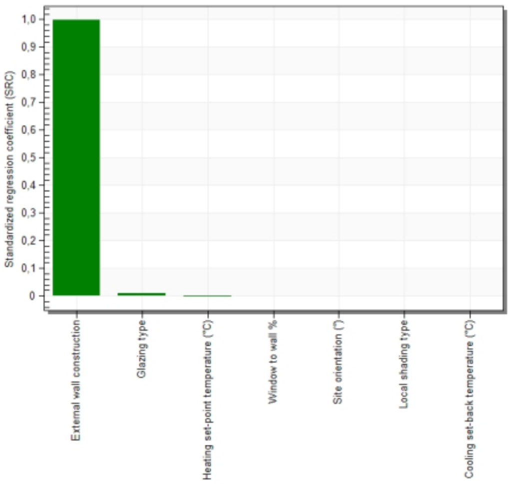
Note: P-value of some (or all) of the inputs is high, suggesting that there is low level of confidence in their result values. Interpretations made specifically for Glazing type, Cooling set-back temperature, Window to wall % and Site orientation inputs should be read with caution.

LCA (Simple) is most strongly influenced by External wall construction. The input and output are directly related. Increasing External wall construction leads to increase in LCA (Simple). LCA (Simple) is also strongly influenced by Heating set-point temperature and Local shading type. LCA (Simple) is also moderately influenced by Glazing type and Site orientation. Window to wall % and Cooling set-back temperature do not have a notable influence on LCA (Simple), therefore, these inputs can be ignored in further analysis of LCA (Simple) for this model.

Note: Adjusted R Squared Value of the analysis is not very high, suggesting that the current input variables partially explain the overall uncertainty in the output. The overall results of this analysis can be relied upon, but with care. Additionally, P-value of some (or all) of the inputs is high, suggesting that there is low level of confidence in their result values. Interpretations made specifically for Window to wall % and Cooling set-back temperature inputs should be read with caution.

4.1 Output: CO2 (Embedded CO2)

4.1.1 Sensitivity Analysis Graph



4.1.2 Result Interpretation

Adjusted R-squared value

It represents goodness of fit of the complete model. It indicates how much variation of the output is explained by the input variables.

For the output: 'CO2 (Embedded CO2)', the 'adjusted R-squared' value of '0,9998' is high, suggesting that most of the key sensitive input variables have been identified. Only a few input variables might be left that can improve the results. The current results can be usefully considered to identify most and least sensitive input variables.

p-value

This value tells if the input variable has a statistically significant effect on the output.

Some input variables have a p-value more than 0.05, suggesting that there is low level of confidence in their respective regression result values. They are the following:

1. Heating set-point temperature (0,2208)
2. Window to wall % (0,4548)
3. Site orientation (0,5206)
4. Local shading type (0,9485)
5. Cooling set-back temperature (0,9830)

Improvement Suggestion: The p-value can be lowered by increasing the number of simulations. Alternatively, the input variable with the insignificant 'p-value' can be removed and the analysis can be re-run. However only one input variable should be removed at a time because a input variable that is insignificant in the presence of the others may become significant when some of another input variable is removed. (Note: The applicability of 'p-value' threshold of 0.05 is up to the modeller's judgement as marginal increase over 0.05 in 'p-value' can also be acceptable)

Standardised regression coefficient (SRC)

This value tells the relative sensitivity of the input variables to the output. Its absolute value ranks the input variables in order of sensitivity the importance and the sign identifies, if relationship to the output is direct or inverse. The list below ranks the variables in decreasing level of importance. (High Importance: **Green**, Medium Importance: **Yellow**, Low Importance: **Red**).

1. **External wall construction**
2. **Glazing type**
3. **Heating set-point temperature**
4. **Window to wall %**
5. **Site orientation**
6. **Local shading type**
7. **Cooling set-back temperature**

4.1.3 Summary of Fit

Adjusted R Squared Value	**0,9998**

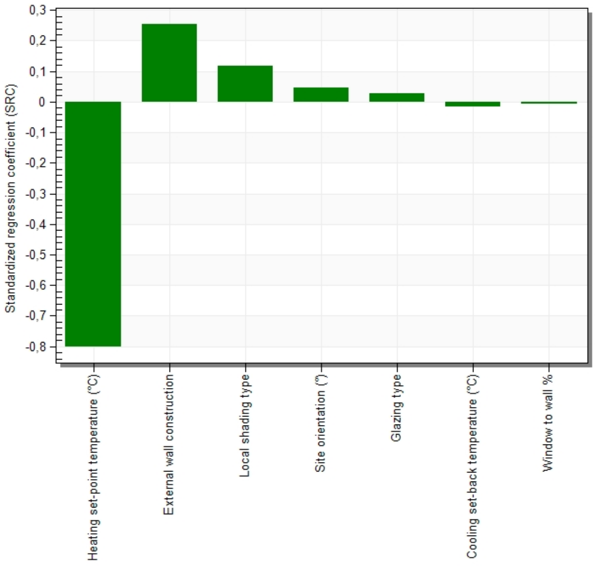
4.1.4 Regression Coefficients

Variable	**Reg. Coef.**	**Std. Reg. Coef.**	**Std. Error**	**P Value**
Intercept	1992,9055	0,0000	18,3642	**0,0000**
External wall construction (No Units)	1564,7159	0,9996	0,9230	**0,0000**
Glazing type (No Units)	12,8214	0,0083	0,9078	**0,0000**
Heating set-point temperature (°C)	-0,5567	-0,0007	0,4541	**0,2208**
Window to wall % (No Units)	-0,0710	-0,0004	0,0949	**0,4548**
Site orientation (°)	0,0049	0,0004	0,0076	**0,5206**
Local shading type (No Units)	-0,0603	0,0000	0,9322	**0,9485**
Cooling set-back temperature (°C)	0,0096	0,0000	0,4483	**0,9830**

Note:Regression results show the relative importance of the different variables. However, these can't determine whether the variables are important in a practical sense. To determine practical importance case specific understanding is necessary, along with ensuring that other statistical indices ('p-value' and 'adjusted R-squared' value) are acceptable"

4.2 Output: Discomfort (Discomfort ASHRAE 55 Adaptive 80% Acceptability)

4.2.1 Sensitivity Analysis Graph



4.2.2 Result Interpretation

Adjusted R-squared value

It represents goodness of fit of the complete model. It indicates how much variation of the output is explained by the input variables.

For the output: 'Discomfort (Discomfort ASHRAE 55 Adaptive 80% Acceptability)', the 'adjusted R-squared' value of '0,7455' is not very high, suggesting that the current input variables partially explain the uncertainty in the output. Some more input variables need to be identified to improve the results. Alternatively, some of the current input variables are insignificant and can be removed. The current results can be still be used to screen out less sensitive input variables.

p-value

This value tells if the input variable has a statistically significant effect on the output.

Some input variables have a p-value more than 0.05, suggesting that there is low level of confidence in their respective regression result values. They are the following:

1. Glazing type (0,2440)
2. Cooling set-back temperature (0,5121)
3. Window to wall % (0,7764)

Improvement Suggestion: The p-value can be lowered by increasing the number of simulations. Alternatively, the input variable with the insignificant 'p-value' can be removed and the analysis can be re-run. However only one input variable should be removed at a time because a input variable that is insignificant in the presence of the others may become significant when some of another input variable is removed. (Note: The applicability of 'p-value' threshold of 0.05 is up to the modeller's judgement as marginal increase over 0.05 in 'p-value' can also be acceptable)

Standardised regression coefficient (SRC)

This value tells the relative sensitivity of the input variables to the output. Its absolute value ranks the input variables in order of sensitivity the importance and the sign identifies, if relationship to the output is direct or inverse. The list below ranks the variables in decreasing level of importance. (High Importance: **Green**, Medium Importance: **Yellow**, Low Importance: **Red**).

1. **Heating set-point temperature**
2. **External wall construction**
3. **Local shading type**
4. **Site orientation**

5. **Glazing type**
6. **Cooling set-back temperature**
7. **Window to wall %**

4.2.3 Summary of Fit

Adjusted R Squared Value	**0,7455**

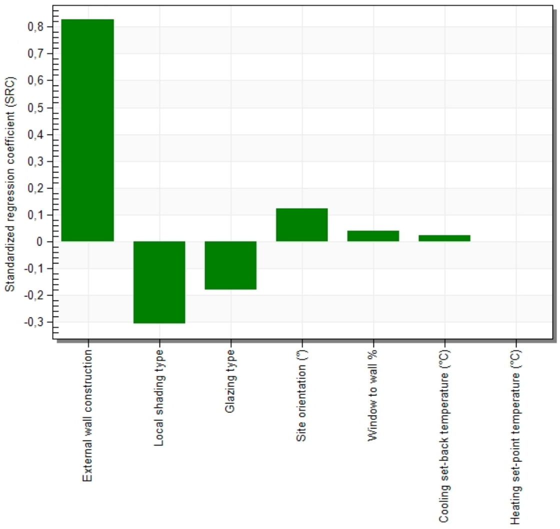
4.2.4 Regression Coefficients

Variable	Reg. Coef.	Std. Reg. Coef.	Std. Error	P Value
Intercept	932,8134	0,0000	52,8810	**0,0000**
Heating set-point temperature (°C)	-46,0204	-0,7994	1,3076	**0,0000**
External wall construction (No Units)	29,8105	0,2558	2,6578	**0,0000**
Local shading type (No Units)	14,0715	0,1188	2,6844	**0,0000**
Site orientation (°)	0,0456	0,0473	0,0218	**0,0373**
Glazing type (No Units)	3,0492	0,0264	2,6141	**0,2440**
Cooling set-back temperature (°C)	-0,8469	-0,0150	1,2909	**0,5121**
Window to wall % (No Units)	-0,0777	-0,0065	0,2733	**0,7764**

Note:Regression results show the relative importance of the different variables. However, these can't determine whether the variables are important in a practical sense. To determine practical importance case specific understanding is necessary, along with ensuring that other statistical indices ('p-value' and 'adjusted R-squared' value) are acceptable"

4.3 Output: Cooling (Cooling (Electric))

4.3.1 Sensitivity Analysis Graph



4.3.2 Result Interpretation

Adjusted R-squared value

It represents goodness of fit of the complete model. It indicates how much variation of the output is explained by the input variables.

For the output: 'Cooling (Cooling (Electric))', the 'adjusted R-squared' value of '0,8184' is not very high, suggesting that the current input variables partially explain the uncertainty in the output. Some more input variables need to be identified to improve the results. Alternatively, some of the current input variables are insignificant and can be removed. The current results can be still be used to screen out less sensitive input variables.

p-value

This value tells if the input variable has a statistically significant effect on the output.

Some input variables have a p-value more than 0.05, suggesting that there is low level of confidence in their respective regression result values. They are the following:

1. Cooling set-back temperature (0,2145)
2. Heating set-point temperature (0,9878)

Improvement Suggestion: The p-value can be lowered by increasing the number of simulations. Alternatively, the input variable with the insignificant 'p-value' can be removed and the analysis can be re-run. However only one input variable should be removed at a time because a input variable that is insignificant in the presence of the others may become significant when some of another input variable is removed. (Note: The applicability of 'p-value' threshold of 0.05 is up to the modeller's judgement as marginal increase over 0.05 in 'p-value' can also be acceptable)

Standardised regression coefficient (SRC)

This value tells the relative sensitivity of the input variables to the output. Its absolute value ranks the input variables in order of sensitivity the importance and the sign identifies, if relationship to the output is direct or inverse. The list below ranks the variables in decreasing level of importance. (High Importance: **Green**, Medium Importance: **Yellow**, Low Importance: **Red**).

1. **External wall construction**
2. **Local shading type**
3. **Glazing type**
4. **Site orientation**
5. **Window to wall %**
6. **Cooling set-back temperature**
7. **Heating set-point temperature**

4.3.3 Summary of Fit

Adjusted R Squared Value	**0,8184**

4.3.4 Regression Coefficients

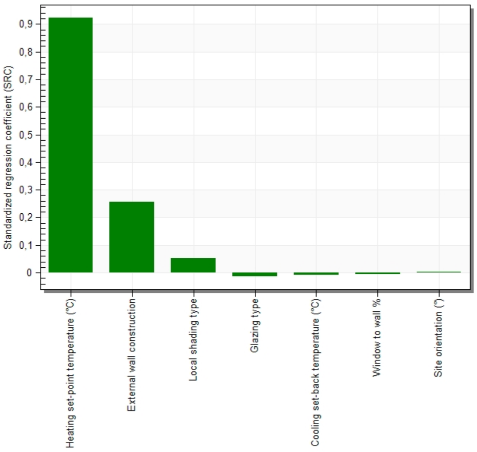
Variable	Reg. Coef.	Std. Reg. Coef.	Std. Error	P Value
Intercept	2379,3367	0,0000	82,6257	**0,0000**
External wall construction (No Units)	177,9953	0,8258	4,1527	**0,0000**
Local shading type (No Units)	-66,5887	-0,3041	4,1943	**0,0000**
Glazing type (No Units)	-38,3252	-0,1792	4,0845	**0,0000**
Site orientation (°)	0,2193	0,1229	0,0341	**0,0000**
Window to wall % (No Units)	0,8876	0,0403	0,4270	**0,0382**

Cooling set-back temperature (°C)	2,5069	0,0240	2,0171	**0,2145**
Heating set-point temperature (°C)	-0,0313	-0,0003	2,0432	**0,9878**

Note:Regression results show the relative importance of the different variables. However, these can't determine whether the variables are important in a practical sense. To determine practical importance case specific understanding is necessary, along with ensuring that other statistical indices ('p-value' and 'adjusted R-squared' value) are acceptable"

4.4 Output: Heating (Heating (Gas))

4.4.1 Sensitivity Analysis Graph



4.4.2 Result Interpretation

Adjusted R-squared value

It represents goodness of fit of the complete model. It indicates how much variation of the output is explained by the input variables.

For the output: 'Heating (Heating (Gas))', the 'adjusted R-squared' value of '0,8946' is high, suggesting that most of the key sensitive input variables have been identified. Only a few input variables might be left that can improve the results. The current results can be usefully considered to identify most and least sensitive input variables.

p-value

This value tells if the input variable has a statistically significant effect on the output.

Some input variables have a p-value more than 0.05, suggesting that there is low level of confidence in their respective regression result values. They are the following:

1. Glazing type (0,4071)
2. Cooling set-back temperature (0,6270)
3. Window to wall % (0,7706)
4. Site orientation (0,8736)

Improvement Suggestion: The p-value can be lowered by increasing the number of simulations. Alternatively, the input variable with the insignificant 'p-value' can be removed and the analysis can be re-run. However only one input variable should be removed at a time because a input variable that is insignificant in the presence of the others may become significant when some of another input variable is removed. (Note: The applicability of 'p-value' threshold of 0.05 is up to the modeller's judgement as marginal increase over 0.05 in 'p-value' can also be acceptable)

Standardised regression coefficient (SRC)

This value tells the relative sensitivity of the input variables to the output. Its absolute value ranks the input variables in order of sensitivity the importance and the sign identifies, if relationship to the output is direct or inverse. The list below ranks the variables in decreasing level of importance. (High Importance: **Green**, Medium Importance: **Yellow**, Low Importance: **Red**).

1. **Heating set-point temperature**
2. **External wall construction**
3. **Local shading type**
4. **Glazing type**
5. **Cooling set-back temperature**
6. **Window to wall %**
7. **Site orientation**

4.4.3 Summary of Fit

Adjusted R Squared Value	**0,8946**

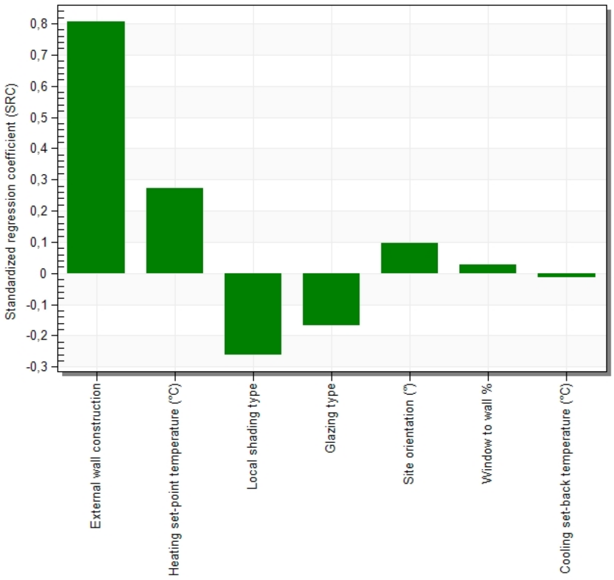
4.4.4 Regression Coefficients

Variable	Reg. Coef.	Std. Reg. Coef.	Std. Error	P Value
Intercept	-1911,4490	0,0000	66,5131	**0,0000**
Heating set-point temperature (°C)	103,9929	0,9241	1,6447	**0,0000**
External wall construction (No Units)	58,5367	0,2570	3,3429	**0,0000**
Local shading type (No Units)	12,2845	0,0531	3,3764	**0,0003**
Glazing type (No Units)	-2,7283	-0,0121	3,2880	**0,4071**
Cooling set-back temperature (°C)	-0,7894	-0,0071	1,6237	**0,6270**
Window to wall % (No Units)	-0,1003	-0,0043	0,3438	**0,7706**
Site orientation (°)	0,0044	0,0023	0,0275	**0,8736**

Note:Regression results show the relative importance of the different variables. However, these can't determine whether the variables are important in a practical sense. To determine practical importance case specific understanding is necessary, along with ensuring that other statistical indices ('p-value' and 'adjusted R-squared' value) are acceptable"

4.5 Output: LCA (LCA (Simple))

4.5.1 Sensitivity Analysis Graph



4.5.2 Result Interpretation

Adjusted R-squared value

It represents goodness of fit of the complete model. It indicates how much variation of the output is explained by the input variables.

For the output: 'LCA (LCA (Simple))', the 'adjusted R-squared' value of '0,8111' is not very high, suggesting that the current input variables partially explain the uncertainty in the output. Some more input variables need to be identified to improve the results. Alternatively, some of the current input variables are insignificant and can be removed. The current results can be still be used to screen out less sensitive input variables.

p-value

This value tells if the input variable has a statistically significant effect on the output.

Some input variables have a p-value more than 0.05, suggesting that there is low level of confidence in their respective regression result values. They are the following:

1. Window to wall % (0,1733)
2. Cooling set-back temperature (0,4847)

Improvement Suggestion: The p-value can be lowered by increasing the number of simulations. Alternatively, the input variable with the insignificant 'p-value' can be removed and the analysis can be re-run. However only one input variable should be removed at a time because a input variable that is insignificant in the presence of the others may become significant when some of another input variable is removed. (Note: The applicability of 'p-value' threshold of 0.05 is up to the modeller's judgement as marginal increase over 0.05 in 'p-value' can also be acceptable)

Standardised regression coefficient (SRC)

This value tells the relative sensitivity of the input variables to the output. Its absolute value ranks the input variables in order of sensitivity the importance and the sign identifies, if relationship to the output is direct or inverse. The list below ranks the variables in decreasing level of importance. (High Importance: **Green**, Medium Importance: **Yellow**, Low Importance: **Red**).

1. **External wall construction**
2. **Heating set-point temperature**
3. **Local shading type**
4. **Glazing type**
5. **Site orientation**
6. **Window to wall %**
7. **Cooling set-back temperature**

4.5.3 Summary of Fit

Adjusted R Squared Value	0,8111

4.5.4 Regression Coefficients

Variable	Reg. Coef.	Std. Reg. Coef.	Std. Error	P Value
Intercept	141940,3661	0,0000	2867,5279	0,0000
External wall construction (No Units)	5924,8962	0,8078	144,1200	0,0000
Heating set-point temperature (°C)	992,2292	0,2739	70,9078	0,0000
Local shading type (No Units)	-1935,6734	-0,2597	145,5650	0,0000
Glazing type (No Units)	-1227,3429	-0,1687	141,7512	0,0000
Site orientation (°)	5,8500	0,0963	1,1844	0,0000
Window to wall % (No Units)	20,2107	0,0269	14,8201	0,1733
Cooling set-back temperature (°C)	-48,9535	-0,0137	70,0019	0,4847

Note: Regression results show the relative importance of the different variables. However, these can't determine whether the variables are important in a practical sense. To determine practical importance case specific understanding is necessary, along with ensuring that other statistical indices ('p-value' and 'adjusted R-squared' value) are acceptable"