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May this work be a humble contribution to the academic field and a useful reference for future research.

Abstract

The research project examines the design and construction of a sustainable twin smart dome house in Algeria's Wadi Souf desert region. Grounded on vernacular architecture and learning its lessons from environmental resilience in traditional Souf buildings, the proposal integrates indigenous Tuareg ingenuity with modern technologies. The twin domes are naturally shaped and interlinked through a shared central courtyard (houline), promoting natural ventilation, daylight distribution, and social interaction. Each dome consists of multiple levels and personal sleeping areas, in addition to integrated smart systems for lighting, thermal control, and security. With a focus on passive design methods of thermal mass, site orientation, and green technologies including solar panels and rainwater harvesting, the project resists hot arid climate adversity while enhancing comfort, energy efficiency, and architectural harmony. This form is a model for future eco-living under extreme conditions in that it unites cultural continuity and technological innovation.

ملخص

يبحث المشروع البحثي في تصميم وبناء منزل ذو قبة ذكية مزدوجة مستدامة في منطقة وادي سوف الصحراوية بالجزائر. استنادا إلى العمارة العامية وتعلم دروسها في المرونة البيئية في مباني سوف التقليدية، يمزج الاقتراح براعة الطوارق الأصلية مع التقنيات الحديثة. تشكل القباب المزدوجة بشكل طبيعي وترتبط من خلال فناء مركزي مشترك (حولية)، مما يعزز التهوية الطبيعية وتوزيع ضوء النهار والتفاعل الاجتماعي. تتكون كل قبة من مستويات متعددة ومناطق نوم شخصية، بالإضافة إلى أنظمة ذكية متكاملة للإضاءة والتحكم الحراري والأمن. مع التركيز على أساليب التصميم السلبي لكتلة الحرارة، وتوجيه الموقع، والتقنيات الخضراء بما في ذلك الألواح الشمسية وجمع مياه الأمطار، يواجه المشروع محنة المناخ الحار والجاف مع تعزيز الراحة وكفاءة الطاقة والانسجام المعماري. هذا النموذج هو نموذج للعيش البيئي في المستقبل في ظل ظروف قاسية من حيث أنه يوحد الاستمرارية الثقافية والابتكار التكنولوجي.

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general introduction

Housing is among the most fundamental human needs, a need that has been there since the earliest stages of human existence (Nurdini & Belgawan Harun, 2012; Kurian & Thampuran, 2001).

In Abraham Maslow's hierarchy of needs, housing is identified as a basic need that follows physiological needs like food and clothing.In the Paleolithic period, early man addressed this need with natural and makeshift structures like caves, tents, nomadic homes, mud houses, and wooden homes (Kwofie et al., 2011).

Housing in such a level was merely viewed as a provider of primary protection—a site to sleep and get sheltered at nighttime. With the advancement of human civilization, though, the ideology regarding housing underwent a significant change. No longer just regarded as a protective shelter, housing started being understood as a place fostering broader aspects of human life, including comfort, stability, and psychological health. This is a consequence of the constantly evolving relationship between human progress and the built environment, in which housing evolved from being a mere shelter to a basis of quality living.

People constructed their homes historically on actual needs, balancing their architecture within nature and using materials found nearby to the greatest degree. Houses traditionally did manage human comfort well by strategically utilizing natural sources of power. Such an outcome was not coincidental but a product of generations of constructors laboring in iterative cycles of trial and error in refining their competence step by step.

The strength of vernacular architecture is that it can integrate built forms in a harmonious manner into their specific settings. This creates harmony between climate, architecture, and human existence in a natural manner. The architecture not only attests to an intimate sense of harmony between people and nature but also manifests a subtle mixture of engineering and artistry.

Of specific note is that vernacular architecture incorporates multiple passive design methods for the sake of achieving thermal comfort inside buildings (Nahar et al., 2003).These conventional methods have been found to effectively produce comfortable living conditions through region-based answers that address local climatic factors and take advantage of surrounding environmental opportunities, such as neighborhood connections and natural elements.

In the arid areas, climatic conditions cannot be avoided in the external temperature in the daily and yearly cycle are tiny. Besides, on the grounds that the radiation is extremely extraordinary, it is essential to acquire the greatest conceivable security against its belongings by endeavoring to stop direct, yet in addition diffuse radiation, which is of significance in these environments.

Then again, ventilation is additionally vital to disperse the heat in the inside and to diminish the humidity of inside spaces.

from passive architectural solutions, Of specific note is that vernacular architecture Domes have been a major architectural element throughout history, from ancient times to the present day. In addition to their aesthetic and structural beauty, domes also possess passive environmental advantages, making them topical in current debates around sustainable building.

- Thermal Comfort : Walls and roof are dense and soak up the heat during the day and dispel it at night, so the interior remains cool in the daytime and warm at night

- Low Maintenance : Made of natural and locally sourced materials like earth, adobe, or stone. These are durable with minimal maintenance.

- Strong in Harsh Weather Domes are more resistant to wind, sandstorms, and earthquakes than flat roofs.

- Cultural & Emotional Value : Dome houses are serene, natural, and sacred, and appeal to local tradition.

Today, with the rise in global environmental problems and technological innovation, architecture is forced to reconcile traditional wisdom with modern innovation. The rediscovery of the dome as a smart, sustainable abode is an opportunity to combine ancient passive techniques with hi-tech construction technologies.

Problematic

Domes are ancient architectural structures that have been enduring shapes for centuries, valued for their structural strength and cultural identity. In contemporary history, domes have once again become center-stage in discussions about architecture due to their passive environmental benefits—like improved airflow, reduced material use, and greater resilience against harsh climates. These qualities make domes particularly significant from the perspective of sustainable design.

However, modern domes also have their limitations. Lacking ventilation or thermal control systems, they can trap heated air and become too hot inside—especially in hot, desert climates where the temperatures fluctuate extremely from one day to the next. Additionally, ordinary materials and methods may not react to today's performance requirements.

To respond to these challenges, architects and engineers are increasingly merging energy-efficient technology with passive design principles, creating new, intelligent architectural solutions. The smart dome is one such synthesis: a building that retains the environmental harmony of vernacular domes but with additional sophisticated systems for thermal comfort, energy efficiency, and environmental adaptability.

This thesis investigates ways domes can be reinterpreted through smart technology in order to build sustainable houses suitable for the hot-arid environment. The goal is to design an architectural model that is sensitive to prevailing environmental challenges yet maintains the wisdom within traditional forms

So the research key question of this work is how can smart dome design enhance thermal comfort in arid climates?

Hypothesis

to create synthesis between traditional architectural wisdom and contemporary environmental demands. The smart dome can emerge as a model of sustainable construction, combining passive design principles with present technology.

Objective

In the context of growing concern for the environmental impact of the built environment, sustainable architecture is now a global priority. This research aims to:

Investigate traditional dome building types in hot climates and evaluate its passive design strength and weaknesses.

Research smart technologies and how they can be integrated harmoniously into traditional dome buildings.

Recommend a comfortable thermally, efficient energy, and environmentally sustainable smart dome system.

Assist in the development of resilient, adaptive, and culturally responsive housing for future urban and rural conditions

Methdology

This study followed a clear and organized approach to understand how to design better housing in arid regions, especially in the city of Biskra. The main objective was to explore how shading strategies and traditional techniques can improve thermal comfort in hot and dry climates. The methodology was divided into three main parts: theoretical research, case study analysis, and a design proposal.

The first part involved **theoretical research**. The study began by collecting information from books, academic articles, and past research. This helped to build a strong knowledge base about important topics such as sustainable housing, passive cooling, solar orientation, and traditional architecture in arid regions. The goal of this step was to understand the climate challenges and the possible architectural responses to them.

The second part focused on **case studies**. Several housing examples from Biskra and other similar arid areas were examined. These examples showed how local houses use shading, thick walls, ventilation, and courtyards to protect people from the heat. The study looked at the building shape, orientation, window placement, and materials. This helped to identify traditional techniques that are still useful and could be adapted to modern buildings.

The final part of the methodology was **project design**. After learning from theory and real cases, the study proposed a housing project adapted to the arid climate. The design used passive strategies like proper orientation, natural ventilation, outdoor shaded spaces, and the use of courtyards. The aim was to create homes that are energy-efficient, comfortable, and respectful of local traditions and the environment.

In summary, the methodology of this study connected research, observation, and design. It helped to develop practical ideas for housing that works well in hot and dry regions, using both scientific knowledge and cultural heritage.

Thesis structure:

This work is divided into two main parts:

A **theoretical and conceptual part**, which presents key ideas about housing in arid zones, vernacular solutions, sustainability, and intelligent architecture.

An **analytical and design part**, which studies real cases, analyzes the Souf region, and proposes a housing project adapted to the hot and dry climate.

The structure of the thesis is based on three main chapters, in addition to a general introduction and a general conclusion:

General Introduction

This part introduces the main subject and explains the importance of the study. It describes the research questions, objectives, and the method used. It also explains why arid climate housing is a real challenge, and how shading strategies can provide solutions.

Chapter 1 – Theoretical and Conceptual Framework

This chapter presents the general ideas related to housing in arid zones. It discusses the characteristics of the climate and the need for passive solutions. It also explains traditional architecture, especially in the Souf region, and how it adapts to the environment. The chapter ends with a focus on smart housing and how new technologies can improve comfort and sustainability.

Chapter 2 – Case Studies and Analysis

This chapter studies the Souf region and its architecture. It gives a description of the urban and natural context. Then, it analyzes examples of dome houses and how they perform in terms of comfort and energy. The chapter also discusses the limitations of current housing and the possible improvements. It prepares the ground for the project design.

Chapter 3 – Design Phase: Smart Domes for Arid Housing

This chapter presents the proposed architectural project. It explains the design goals: to respect the climate, local culture, and improve quality of life. It gives details about the site, the building form (twin domes), and the interior organization. Then, it describes the passive strategies used: shading, ventilation, and smart systems. Finally, it shows the positive impacts of the design on comfort, water use, and energy saving.

General Conclusion

This final part gives a summary of the study and answers the main research question. It also gives practical recommendations to improve future housing projects in arid zones, using smart and traditional strategies for shading and comfort.

1. Chapter 1 : theoretical study : concepts and definition

Introduction

Housing has always been a fundamental human need, providing protection, comfort, and safety. Over time, people's ideas about housing have changed a lot. Today, housing is not only about shelter but also about making life comfortable and enjoyable. In this chapter, we will explore important concepts related to housing, especially what comfort means and how it affects people's lives. We will discuss different aspects of comfort, such as thermal comfort (feeling warm or cool enough), visual comfort (good lighting conditions), acoustic comfort (controlling noise), and ergonomic comfort (designs that fit people's physical needs). These concepts help architects understand how to build homes that not only protect from the weather but also make people feel relaxed, healthy, and happy. We will also look at how traditional architecture, especially in hot and dry climates, uses passive design methods to achieve comfort without using too much energy.

1.1 The concept of comfort

The word comfort can be used to describe a feeling of satisfaction, a sensation of warmth, or a physical and mental condition of well-being. Here, our interest is in how different meanings of comfort have come to influence indoor conditions and the approaches taken for regulating heat.

Comfort is a word that is by definition tied up with the way we evaluate objects and spaces—typically defined as the very marriage of use and design that creates a feeling of individual satisfaction. Comfort is famously difficult to define, however, although it is something we know. It is resistent to generalization, subject to culture, individual, even experience. So how can we define it in any useful sense?

The search for home comfort is strongly linked with the idea of habitability. According to Bollnow (2008), a habitable home space possesses some important features: it is a enclosure, an encapsulation from the outside world; it possesses spatial properties appropriate to the residents; it possesses furniture to satisfy and enhance the space; it is thermally pleasant; it is conscious of spatial arrangement; it is reflective of the character of its residents; it preserves the memory of the family; and, most of all, it is a family residence.

In discussing the comfort issue, one must make a distinction between comfort parameters—quantifiable values associated with the energy characteristics of an area—and comfort factors, user-specific variables that influence the perception of the parameters. Comfort arises as a result of the interaction between the two factors. Although architectural design largely influences the parameters, user-related factors such as age, activity type, and personal preference must also be taken into consideration in order to guarantee the design effectively achieves its desired aim .

1.1.1 Dimensions of Comfort:

Understanding the importance of comfort was the driving force behind this study. The aim is therefore to determine which dimensions contribute to the definition of the meaning of comfort in the built environment, and in particular when applied to residential buildings.

One of the main goals of architectural design is to provide comfortable living spaces. This was the reason for the so-called comfort dimensions.

Comfort dimensions should therefore be of most use to architects and other civil engineers in their design process. The question is, how many comfort dimensions have been able to fulfil this responsibility so far?

1.1.1.1 *Acoustic comfort:*

comfort is the state of well-being experienced in a suitable acoustic environment, where noise is controlled and managed.

> “It's not your neighbours that are making noise. It's your building that's not soundproofed well.” Prof. Jens-Holger Lindell, Noise Expert, Technical University of Denmark Acoustic

In reality, the acoustic comfort required for a particular space is determined by a complex combination of the soundproofing of partitions, the acoustic design and finishes of the room, and the noise and vibration reduction of building services (usually mechanical and electrical equipment). A more comprehensive measurement and design methodology is needed that better reflects the noise levels throughout this space. Therefore, more precise approaches must be used to specify and measure indoor acoustic comfort.

This comfort goes far beyond simple decibel measurements. It also includes sound quality and its impact on concentration, communication, rest and health. It is easy to measure the noise levels in a room after it has been constructed. But before then, correcting the noise levels can be costly and

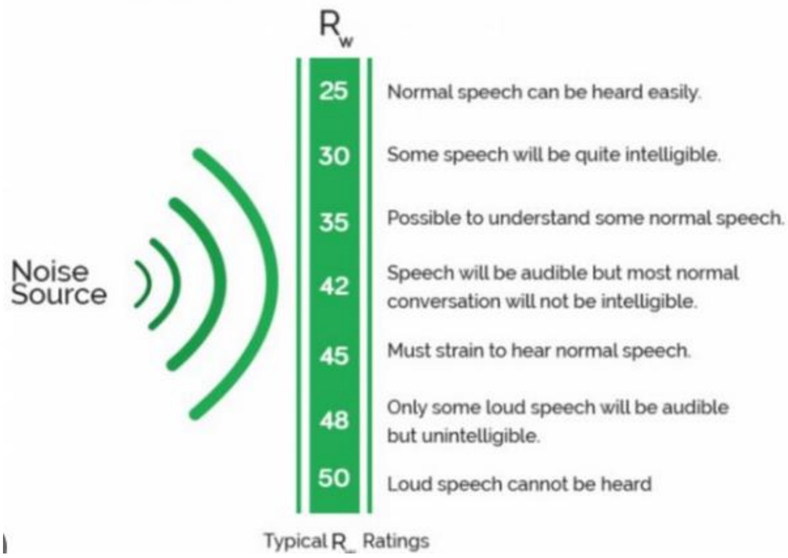

Figure 1 Figure01 : STC rating
Source https://brisaluminium.com.au/estimators-and-acoustic-rating-guides-to-take-offs/s

tedious. Hence, how to effectively specify and measure buildings to achieve the desired acoustic comfort during the design and construction phase becomes more important. Traditionally, noise pollution has been assessed by implementing a rating system called Sound Transmission Class (STC) or ISO Weighted Sound Attenuation (Rw). STC is essentially describes the ability of a :

Specialized materials that resist airborne noise. For example, each wall in a room may be given a specific STC rating, which indicates the average amount of exterior noise that can be blocked by the wall. The higher the rating, the more noise is "blocked" and prevented from transmitting through a particular material or wall.

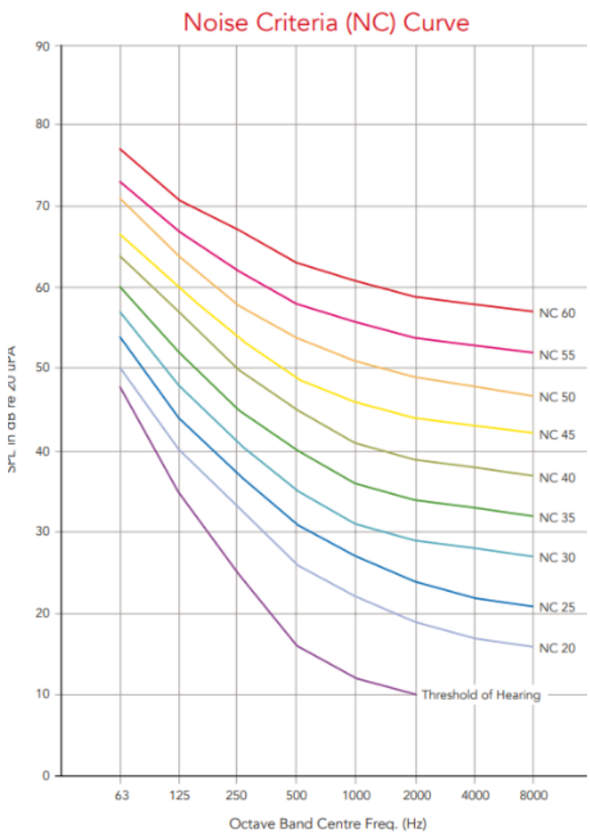

Figure 2 : noise criteria(NC) curve

The Noise Criteria (NC) rating is determined by measuring sound pressure levels in a chain of octave bands and comparing them to reference NC curves. The rating was developed to equate the perception of sound by humans with noise levels inside buildings, and to represent these acoustic conditions with a single numerical value.

Since it was invented, NC has widely been applied by acousticians as well as building designers to evaluate and control noise within the indoor environment. The greatest advantage of NC is that it quantifies background noise in a room and guarantees the occupants a level of acoustic comfort desired

Decibel (dB) sound pressure levels on a logarithmic scale are measured across a series of frequencies typically between 63 Hz and 8000 Hz.

The results are plotted on an NC chart, on which a series of predetermined NC curves are drawn.

The NC rating is defined by the highest value on the measured curve that does not surpass the lowest intersecting NC curve.

A lower NC rating indicates a quieter space and is usually preferred in spaces where noise sensitivity is most important.

1.1.1.2 *Visuel comfort:*

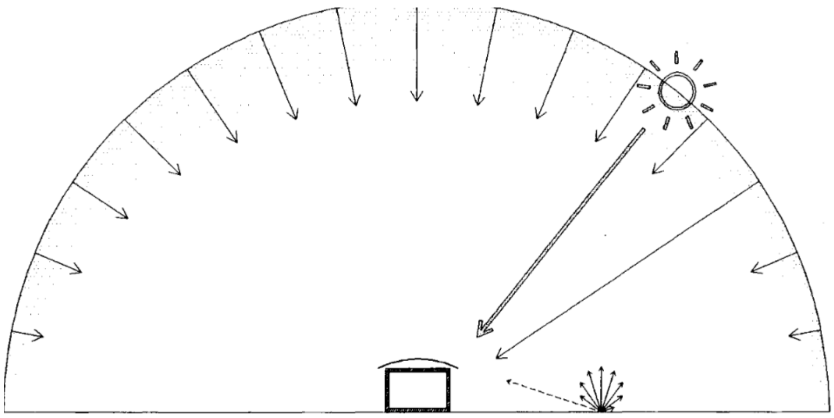

Figure 3 Sky dome and building, showing three incidences: direct sun, sky dome and albedo

Natural light is instrumental in our perception of interior space. It has an impressionistic quality, with areas of light presenting themselves discrete from one another and only unifying into a complete experience when the space is considered as a whole.

Under these circumstances, color is the determining factor—wall surfaces reflect and alter the color of the light they receive.

If we think of natural light as energy entering a building from the outside, then it's useful to understand that the way it enters the interior depends upon its source, which is categorized in three broad ways .

The first challenge in exploiting daylight is enabling its penetration into interior areas that are

otherwise separated from the outside by the building façade. The introduction of openings in the building envelope allows daylight entry—granted limited, but able to be controlled with precision. In any architectural design, there exist two distinct lighting problems:

Peripheral areas – areas that are adjacent to the outside of the building, in immediate proximity to natural light.

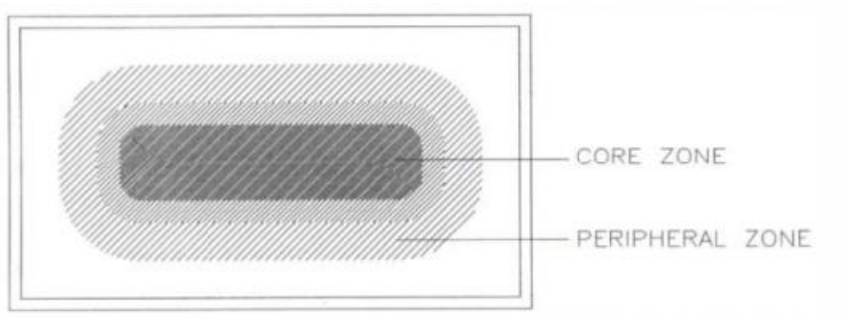

Figure 4 Peripheral zone and core zone of a building.

Core areas – interior spaces that have no direct exposure to the façade and need to utilize light transport systems.

Each of these zones presents unique challenges and demands particular design strategies Before specific systems for each of these zones are discussed, there are several general design concerns that affect daylight interaction within a building that must be considered.

1. Building Compactness

Compactness of a building defines the proportion of external envelope to internal volume—a higher density of internal spaces means that the potential for natural lighting is more limited. Less compact buildings allow more scope for daylight penetration since core spaces are reduced.

2. Porosity

Porosity refers to voids or open spaces in the building volume—such as courtyards or atriums—that connect the interior and the exterior. High porosity can provide the possibility of introducing daylight and natural ventilation to core zones. Courtyards, while not as effective as direct exposure, when appropriately designed, can offer substantial daylighting potential for interior spaces.

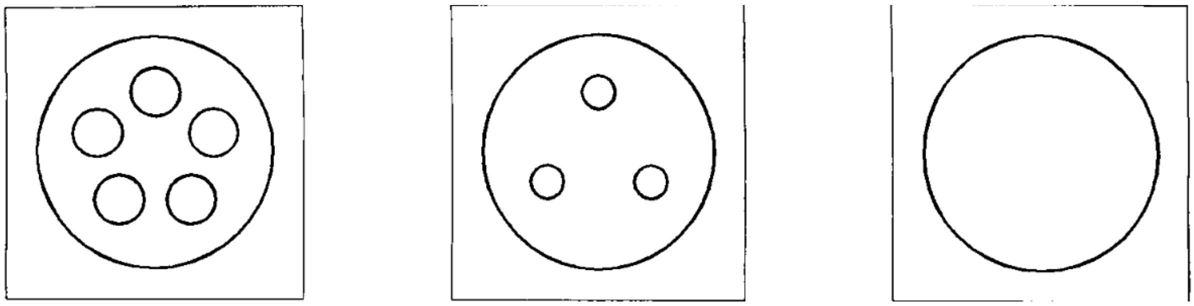

Figure 5 Degrees of porosity of a building
Source: Architecture_Comfort_and_Energy.pdf

3. Transparency of the Building Skin

The building envelope can range from completely opaque to completely glazed. While greater transparency will enhance peripheral daylight, successful lighting is more closely related to distribution and quality rather than quantity. In fact, large areas of glazing can cause glare and so be counterproductive in some cases.

4. Interior Geometry

The geometric characteristics of interior space—size, shape, proportion, and floor level differences—also influence the behavior of daylight.

Size: Room size has no direct effect on light distribution if openings are proportionally sized. Rooms of the same shape with proportionally sized windows will be illuminated in the same manner. Larger

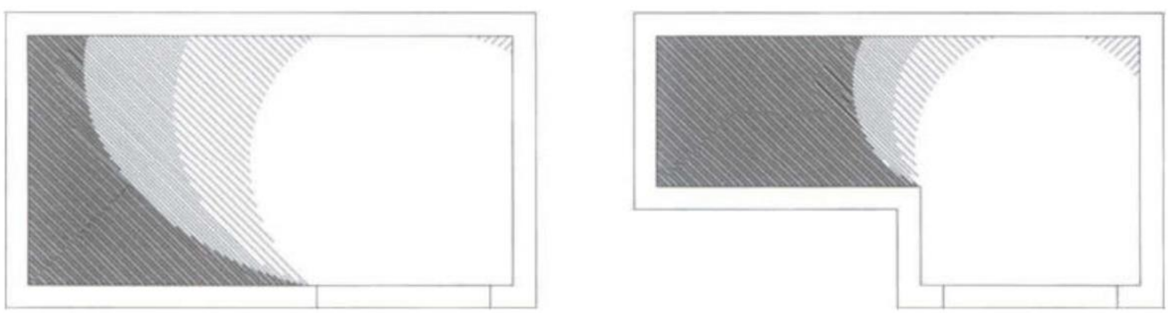

Figure 6 Relationship between shape and light distribution
Source: Architecture_Comfort_and_Energy.pdf

rooms, however, run the risk of having darkened interior areas unless vertical dimensions (e.g., ceiling height) are also increased.

Shape and Proportion: These become important on the basis of the position of windows. Long or irregular spaces with windows at one end will have non-uniform lighting. Side lighting will produce a steep fall-off in illuminance with distance, since the angle of visible sky reduces. The areas far away from the window can, therefore, be poorly lit despite the overall light level being sufficient.Zenithal Lighting: Light entry from overhead (e.g., skylights) provides more even distribution and is usually preferable in most cases.

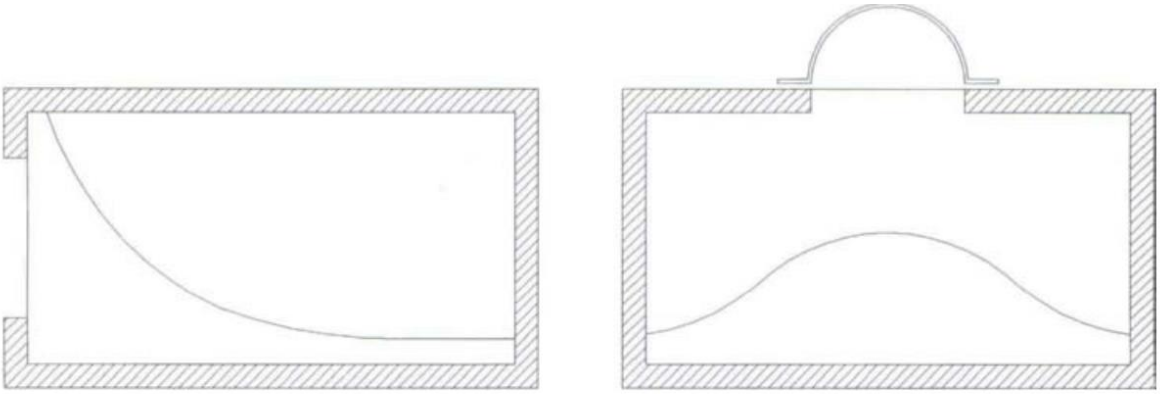

Figure 7 Lighting levels with lateral and zenithal openings
Source: Architecture_Comfort_and_Energy.pdf

Floor Level Variation: Changes in floor level affect both light and views. If the floor slopes down towards the interior, light distribution is better but the exterior view is reduced. The reverse slope accomplishes the reverse, enhancing view but limiting light penetration .

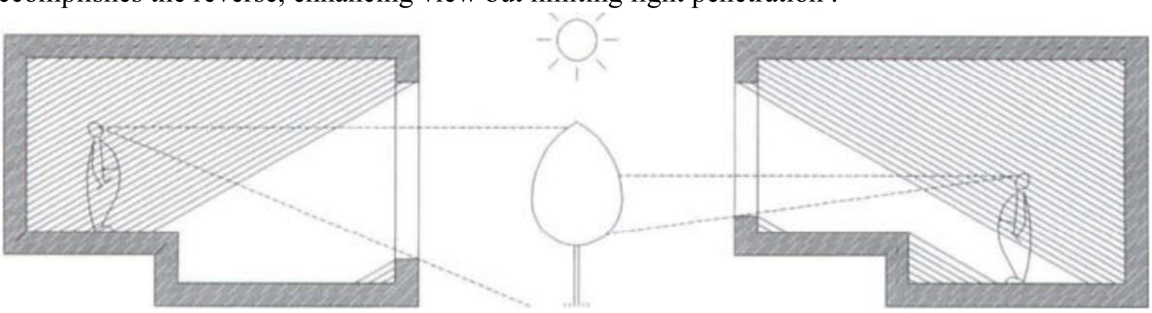

Figure 8 Variation of Ught and views in stepped premises Source: Architecture_Comfort_and_Energy.pdf.

1.1.1.3 Ergonomic comfort:

Ergonomic Design in Architecture

Ergonomic design is the practice of planning work environments and home settings to fit physical, psychological, and functional requirements of users. Its aim is to reduce discomfort, remove the possibility of injury, and enhance overall usability and health

.Ergonomic Principles of Architectural Design

The following fundamental principles can be utilized by designers and architects to promote user comfort and security:

- Human Scale: The dimensions of the design must be aligned with the average human height, reach, and movement distance.
- Accessibility: Ensure all features and spaces are accessible to users of all capabilities and mobility.
- Flexibility: Incorporate multi-functional, moveable furniture and adjustable layouts to meet various demands and uses.

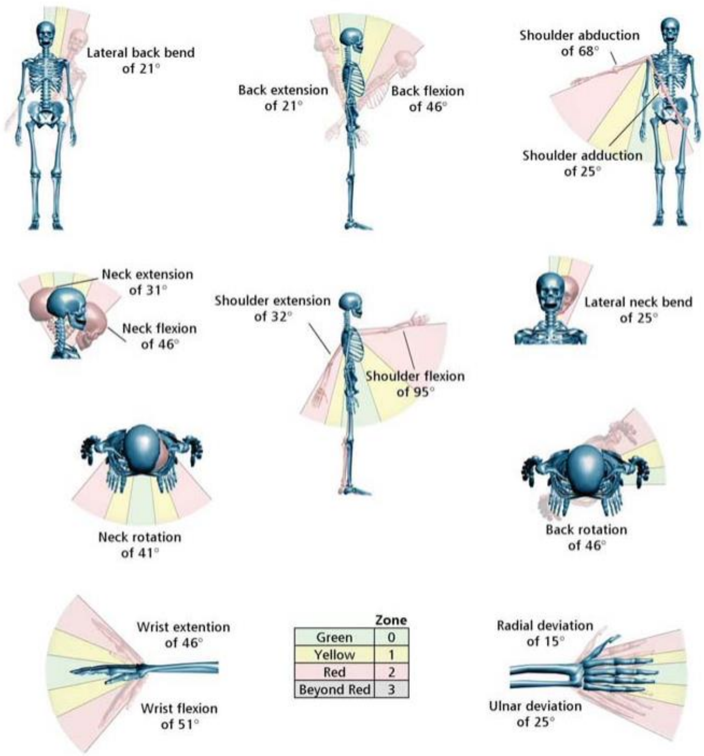

Figure 9 Various ranges of motion for different joints. For exact val-ues of each Zone, see Table A3 in the Appendix Source: ergonomicsanddesignreferenceguidewhitepaper.pdf

Key Elements of Ergonomic Design

- Adjustable furniture
- Designed to fit an assortment of body types and comfort and support preferences.
- Efficient spatial layout: Designed to reduce physical effort and promote effortless, intuitive movement.
- Natural lighting and ventilation: Used to promote health, improve mood, and reduce eye and respiratory strain.

Benefits of Ergonomic Architecture

Application of ergonomic principles to architectural design carries several important advantages:

- Improved productivity through reduced fatigue and distraction
- Decreased risk of musculoskeletal disorders and chronic strain injuries
- Improved occupant satisfaction and overall quality of life

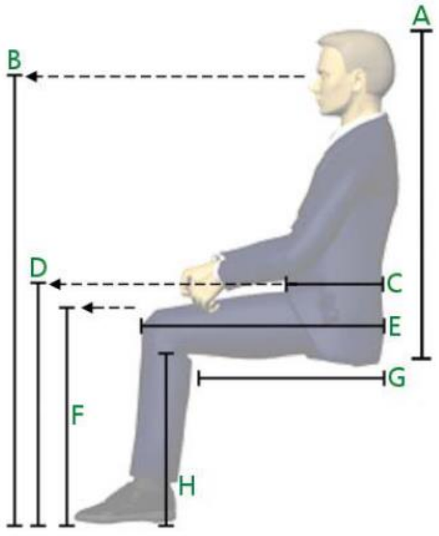

Figure 10 . Common anthropometric measurements for the seated position . Source: ergonomicsanddesignreferenceguidewhitepaper.pdf

Measurement	Letter	Female 5th – 95th%	Male 5th – 95th%	Overall Range 5th – 95th%
Sitting Height	A	31.3" – 35.8"	33.6" – 38.3"	31.3" – 38.3"
Sitting Eye Height	B	42.6" – 48.8"	46.3" – 52.6"	42.6" – 52.6"
Waist Depth	C	7.3" – 10.7"	7.8" – 11.4"	7.3" – 11.4"
Thigh Clearance	D	21.0" – 24.5"	23.0" – 26.8"	21.0" – 26.8"
Buttock-to-Knee	E	21.3" – 25.2"	22.4" – 26.3"	21.3 – 26.3"
Knee Height	F	19.8" – 23.2"	21.4" – 25.0"	19.8" – 28.0"
Seat Length/Depth	G	16.9" – 20.4"	17.7" – 21.1"	16.9" – 21.1"
Popliteal Height	H	15.0" – 18.1"	16.7" – 19.9"	15.0" – 19.9"
Seat Width	Not Shown	14.5" – 18.0"	13.9" – 17.2"	13.9" – 18.0"

Table 1: Values for 5th to 95th percentile males and females in the seat-ed position used in designing seating Source: ergonomicsanddesignreferenceguidewhitepaper.pdf

1.1.1.4 *Thermal comfort:*

Thermal comfort is the capacity of a building's design, space layout, and material composition to deliver a thermally comfortable indoor climate with minimal reliance on energy-hungry mechanical systems. Natural thermal comfort demands an adequate knowledge of local climatic conditions and the physical laws of heat transfer, including conduction, convection, and radiation.

Defining precisely each factor's effect on thermal comfort is inherently difficult, as varying perceptions of comfort depend greatly on physiological and behavioral factors such as activity level, metabolic rate, and clothing insulation. Therefore, building design does not attempt to satisfy all individuals, but attempts to satisfy the comfort requirements of most people and restrict discomfort to others. This can be achieved through the creation of flexible environmental conditions where individuals are able to control to some degree their own comfort level.

Typical metabolic heat generation for various activities*

Activity	Heat generation (W m^{-2})
Resting	
Sleeping	40
Reclining	45
Seated, quiet	60
Standing, relaxed	70
Walking (on the level)	
0.89 m s^{-1}	115
1.34 m s^{-1}	150
1.79 m s^{-1}	220
Office activities	
Reading	55
Writing	60
Typing	65
Filing, seated	70
Filing, standing	80
Walking about	100
Lifting/packing	120
Driving/flying	
Car	60–115
Aircraft, routine	70
Aircraft, instrument landing	105
Aircraft, combat	140
Heavy vehicle	185
Miscellaneous occupational activities	
Cooking	90–115
House cleaning	115–200
Seated, heavy limb movement	130
Machine Work	
Sawing (table saw)	105
Light (electrical industry)	115–140
Heavy	235
Handling 50 kg bags	235
Pick and shovel work	235–280
Miscellaneous leisure activities	
Dancing, social	140–225
Calisthenics/exercise	175–235
Tennis, singles	210–270
Basketball	290–440
Wrestling, competitive	410–505

Table 2 Table02: Typical metabolic heat generation for various activities /Source: Architecture_Comfort_and_Energy.pdf

Buildings should be designed such that they have a largely passive role to play in the provision of indoor thermal comfort, employing architecture and natural means. However, where feasible, active systems can be employed to support or supplement these passive methods.

The climatic conditions indoors are influenced by a plethora of interrelated factors, including air temperature, humidity, air movement, and radiant heat exchange. Designers need to match these climatic factors with building material thermal properties, space geometry, and building envelope shape in order to increase natural thermal comfort.

- **Parameters of Thermal Comfort**:

Individual-Related Parameters:

➢ Metabolic Rate (Activity Level)

the metabolic rate, which can be described as the rate at which the chemical energy is being transferred to heat and mechanical energy by the metabolic reactions within the body. It is commonly measured as a ratio to total body surface area and varies from individual to individual. It may change with activity levels (e.g., lying or sitting quietly and walking) and external environment (e.g., ambient temperature or humidity). Since metabolic rate directly affects the amount of heat generated by the body, it is the key consideration in determining whether or not one is too warm, too cold, or neutrally thermic.

- Clothing and Thermal Insulation

Clothing insulation plays a significant role in thermal comfort because it has a direct influence on the loss of heat and, consequently, on the body thermal balance. Insulating clothing layers retain the body heat, heating a person up; however, they can also lead to overheating due to excessive heat suppression. In general, more insulating-capacity clothing is thicker. Effectiveness of insulation clothing can be influenced by the movement of air and relative humidity, which might reduce its performance depending on the properties of the clothing material

Clothing is the most significant regulator of heat loss. To quantify clothing insulation, the "clo" unit is used.

1 clo is equal to the insulation of a normal business suit with a cotton undergarment.

It is equivalent to a thermal resistance of 0.155 $m^2 \cdot K/W$, or a U-value (thermal transmittance) of 6.45 $W/m^2 \cdot K$.

Typical clothes values are:

0.25 clo – Short trousers with short-sleeved shirt

1.0 clo – Office suit with average underwear

2.0 clo – Winter suit with overcoat

4.5 clo – Ceniaic clothes

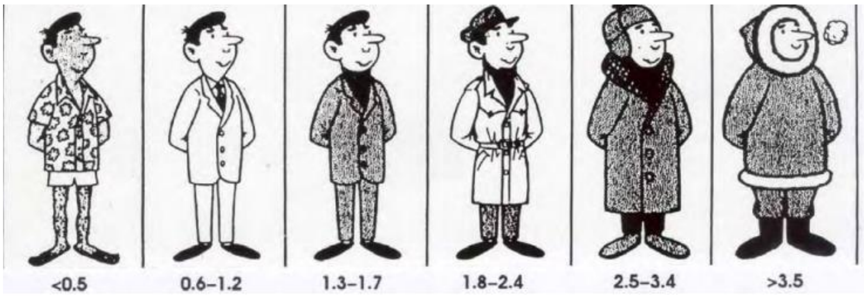

Figure 11 insulation of clothing in clo units Source: plea_2007_thermal_comfort.pdf

When assessing the total clo value of a set of clothes, the aggregate insulation is typically assumed to equal 0.82 times the sum of garment clo values for individual items of clothing, so as to cover overlapping and area coverage

TABLE 3 Insulating value of clothing elements

Man		clo	Women		clo
underwear	singlets	0.06	underwear	bra + panties	0.05
	T-shirt	0.09		half slip	0.13
	briefs	0.05		full slip	0.19
	long, upper	0.35		long, upper	0.35
	long, lower	0.35		long, lower	0.35
shirt	light, short sleeve	0.14	blouse	light	0.20
	light, long sleeve	0.22		heavy	0.29
	heavy, short sleeve	0.25	dress	light	0.22
	heavy, long sleeve	0.29		heavy	0.70
	+5% for tie or turtle-neck)				
vest:	light	0.15	skirt	light	0.10
	heavy	0.29		heavy	0.22
trousers	light	0.26	slacks	light	0.26
	heavy	0.32		heavy	0.44
pullover	light	0.20	pullover	light	0.17
	heavy	0.37		heavy	0.37
jacket	light	0.22	jacket	light	0.17
	heavy	0.49		heavy	0.37
socks	ankle length	0.04	stockings	any length	0.01
	knee length	0.10		panty-hose	0.01
footwear	sandals	0.02	footwear	sandals	0.02
	shoes	0.04		shoes	0.04
	boots	0.08		boots	0.08

Table 3 Insulating value of clothing elements /Source: plea_2007_thermal_comfort.pdf

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Environment-Related Parameters:

- Air Temperature refers to the ambient air temperature surrounding the human body. Optimum air temperature for stationary work generally lies between 20°C and 26°C, providing a comfortable heat climate for minimal physical activity.
- Radiant Temperature is radiation emitted by warm objects in the environment. This type of heat can impact thermal comfort significantly when devices or surfaces emit radiation, causing temperature increases in localized spots.
- Air Velocity is the speed at which air moves over the body. Efficient airflow can enhance comfort by allowing for heat dispersal. Indoor air velocity should ideally range from 0.1 to 0.2 m/s.
- Humidity is the concentration of water vapor in the air. Relative humidity has a significant impact on the body's ability to cool through evaporation. Safe relative humidities range from 40% to 70%, and these are typically sustainably regulated by air-conditioning.

Heat Exchange between the Human Body and the Environment:

- ➢ Heat Loss by Evaporation

E^{n} and E^{rr} are two components of evaporative heat loss.

E^{n} is the diffusion of water vapour through the skin, leading to heat loss. It is a passive mechanism that does not include thermoregulation on the part of the body.

E^{rr} accounts for heat loss due to active sweat secretion, which is controlled by the glands that secrete sweat.

The rate of evaporative heat loss from the skin ($E^r sk$) is influenced by the following factors:

- Relative humidity of the air (rh)
- Air temperature (ta)
- Relative air velocity (var)
- Skin temperature (tsk)

Clothing characteristics, including thermal resistance and vapor permeability (Icl)

Skin wettedness (w), i.e., fraction of skin surface covered by film of unevaporated sweat

- Respiratory Heat Loss

Exhaled air during breathing contains water vapor saturated at the body's internal temperature. Latent respiratory heat loss is generated because the energy necessary for evaporation is transferred from the lungs. Dry respiratory heat loss takes place because exhaled air contains a higher temperature than inhaled air.

The total respiratory heat loss (E^r) depends on:

- Activity level
- Air relative humidity
- Air temperature
- Convective heat loss

Convective heat loss refers to the transfer of heat from the body to the surrounding air. The convective heat flow rate (C) is calculated by the formula: $C = fcl \times hc \times (tcl - ta)$ [W/m²]

Where:

- fcl = clothed to nude body surface area ratio
- hc = average convective heat transfer coefficient between air and clothing or skin
- tcl = temperature of clothing surface
- ta = ambient air temperature

Convective heat loss depends on:

- Air temperature
- Average temperature of the clothed body surface
- Type of clothing worn
- Relative air velocity

- Radiative Heat Loss

Radiative heat exchange between human body and the environment is calculated using the equation: $R = 3.96 \times 10^{-8} \times fcl \times [(tcl + 273)^4 - (tr + 273)^4]$ [W/m²]

Where tr (mean radiant temperature) is the identical blackbody temperature of an ideal enclosure that would exchange the same amount of radiant heat with the body as the actual environment. It can be computed from: $tr = \Sigma (ti \times Fp,i)$

Where:

- ti = temperature of an isothermal surface (e.g., walls, windows, furniture, other individuals)
- Fp,i = view factor (angle factor) between the subject and surface i (see Appendix A for computation procedures)

Radiative heat loss depends on:

- Average body surface temperature of clothed person
- Mean radiant temperature
- Type of clothing

➢ Conductive Heat Loss

Conductive heat loss occurs when the body is in direct contact with solid objects—such as heat transfer from the body to a chair when sitting, or between the feet and floor when standing.

This aspect of heat loss, denoted by C^r, is difficult to measure precisely. Due to this, it is oftennot treated as an extra term, but rather included in the overall calculation for clothing thermal resistance.

1.1.1.5 Conclusion :

Architectural comfort is a multifaceted concept that extends far beyond the simple control of environment. It is a sensory, physical, and psychological sensation conditioned both by objective standards and individual perceptions. It varies from thermal and visual to acoustic, ergonomic, and spatial, all adding to defining the quality of life in built environments—most particularly in domestic environments where comfort affects intensely living everyday life.

The success of comfort design relies on the ability of an architect to strike a balance between measurable factors—temperature, lighting, decibel levels—versus human-based variables like behavior, expectations, and cultural beliefs. The holistic approach ensures the building not only performs well but also creates space that is secure, pleasant, and nourishing for the occupants.

Designing for comfort is not, in essence, about not feeling uncomfortable; it is about creating spaces that have a positive impact on well-being. By actively paying attention to the myriad of factors of comfort throughout the design process, architects and engineers can create living environments thatare not only efficient and sustainable but actually inhabitable—spaces that care for both body and mind.

1.2 Definition of housing:

Housing is arguably one of the most fundamental needs of human life, one which is so essential right from the beginning of human existence (Nurdini & Belgawan Harun, 2012; Kurian & Thampuran, 2001). According to Abraham Maslow's theory of hierarchy of needs, shelter is placed one of the fundamental needs, just after food and clothing is fulfilled.

In effect, housing is not just the supply of a physical shelter—it is the supply of an environment that renders living more livable. According to Lazenby (1977), four various environments influence human welfare: the physical, socio-cultural, psychological, and physiological environments.

1.2.1 Physical Environment

This setting has a direct impact on a person's comfort and well-being. In cities, individuals are constantly exposed to adverse factors like noise pollution, air pollution, traffic jams, and congestion. If given a choice, most would want to leave such conditions permanently for a better living environment.

1.2.2 Socio-Cultural Environment

This is the social context in which a person lives. Human beings are social creatures, and they are often confronted with varying degrees of social contact, norms, and expectations. Shelter that provides for good social contact and cultural identity enhances the quality of life.

1.2.3 Psychological Environment

This is an internal setting to the person. Problems arise when desired behavior and actual behavior differ—reflecting unmet psychological needs. Basic psychological needs are the need for social contact, affiliation, and belongingness within a group. Furthermore, people want self-esteem, self-respect, and admiration from others. When they do not receive these, psychological discomfort results.

1.2.4 Physiological Environment

The physiological environment means conditions that affect an individual's homeostatic balance, such as availability of sufficient space, fresh air, potable water, and indoor climate. In the event that these are not available, the physical well-being of the people in occupation is at stake.Finally, the house must not be thought of merely as a physical structure but as a coordinated environment to meet the whole spectrum of human needs—physical, social, psychological, and physiological—to promote overall health, comfort, and well-being.

1.2.5 Specific terminology of housing :

dwelling. —In general: A building designed or occupied as the living quarters for one or more families, or households, usually equipped with cooking, bathing, toilet, and, where necessary, heating facilities. Usu- ally thought of as a detached single-family house.

(Compare buildings: house; living unit.)

(Note. —Some building codes limit definition of a "dwelling" to a residence occupied by one family; others to two, three, or four families.)

lodging house. —A building, other than a hotel, inwhich persons are accommodated over night or for a more extended period for compensation. In codes and ordinances, lodging houses and boarding houses are often further qualified by number of persons accommodated or by number of rooms. {Compare house types: boarding house; buillings: hotel.)

housing:

1. The development of living facilities for human beings.

2. Living facilities for human beings.

residence. See buildings: residence.

Habitat: The natural or built-up environment where one or a community lives.

Habitation: The act or state of living in a place; could be a building or settlement.

Shelter: A basic structure that keeps one safe from the weather, normally discussed in humanitarian or disaster context.

Accommodation: General term for a home where people live or stay temporarily or permanently.

Home: A personal or psychological feeling of living; could not necessarily be a physical structure.

Domicile: Legal term for a permanent residence or legal home

1.2.6 Historical evolution of the dwelling concept

Historical Development of the Concept of DwellingOver time, human dwellings have developed continuously, responding to cultural changes, technological innovations, and evolving lifestyles. From primitive shelters to smart intelligent homes, the idea of housing has traveled through centuries of innovation and development. This report discusses the architectural and functional development of dwellings through significant historical periods.

1.2.6.1 Early Homes

Early homes of humans were simple, constructed out of natural products like mud, animal skins, and sticks. Early protection was provided by caves against the elements and wild beasts. While migrating, people established handmade shelters like huts and teepees.

Figure 12 Figure12 : african bushman and Bambuti hut/ source : earlyhousingunits.pdf

Teepees used by the North American indigenous peoples were cone-shaped, movable, and ideal for a wandering existence.

Manyattas, the Maasai traditional houses of Africa, were made of sticks, mud, and dung.

After the advent of agriculture, humans settled down and developed more fixed mud-brick and stone homes, and villages and early cities developed.

1.2.6.2 Ancient Civilizations

Egyptian Homes included mud-brick homes with flat roofs and courtyards. Gardens and decorated walls were present in richer homes

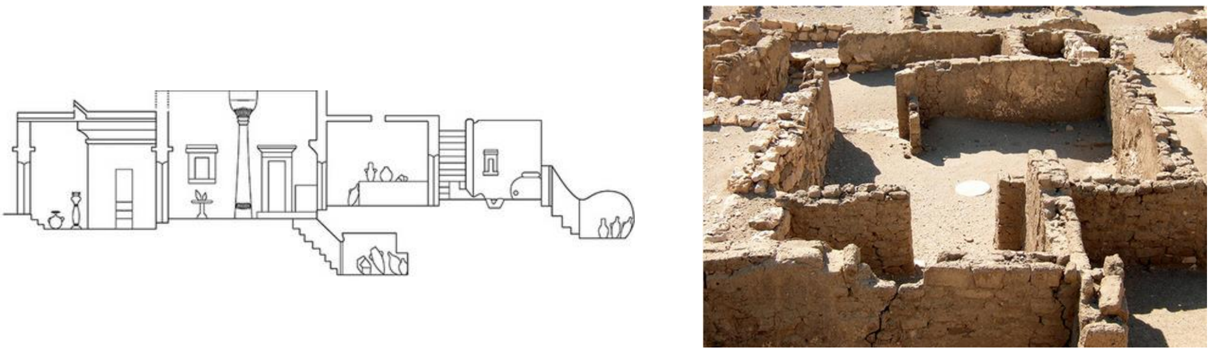


Figure 13 plan Deir el-Medina house based on the substantial architectural remains at the site. Rutherford Picture Library/ sourcre: https://brewminate.com/towns-and-houses-in-middle-and-new-kingdom-egypt/

Greek Houses featured stone structures, open courtyards, and colonnaded shade. The House of Dionysus is a prime example with its intricate mosaics.

Figure 15 the house of dionysos
source: https://stock.adobe.com/my/images/la-maison-au-dionysos-du-quartier-du-theatre-de-delos-en-grece/153134416

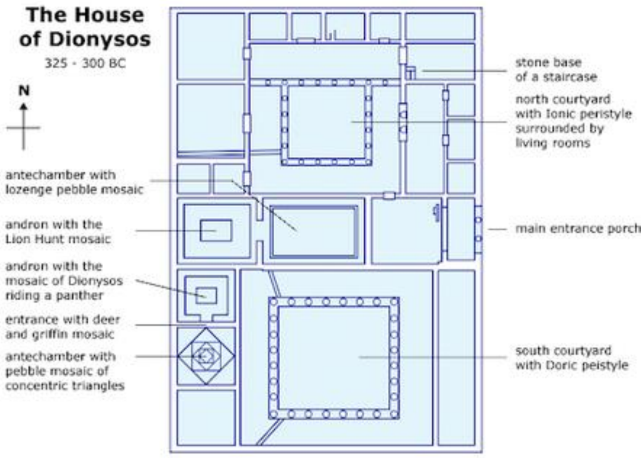


Figure 15 plan of dionysos hous source: https://www.pinterest.com/pin/pebble-mosaic-floor-pella--572520171361921783/

Roman Houses were multi-story villas with gardens, and features like indoor plumbing. Frescoes and statues adorned their interiors, as in the case of the House of the Faun in Pompeii. These houses not only served utilitarian needs but also symbolized wealth, culture, and social standing.

Figure 16 house of the faun / source: https://www.thoughtco.com/house-of-the-faun-at-pompeii-169650

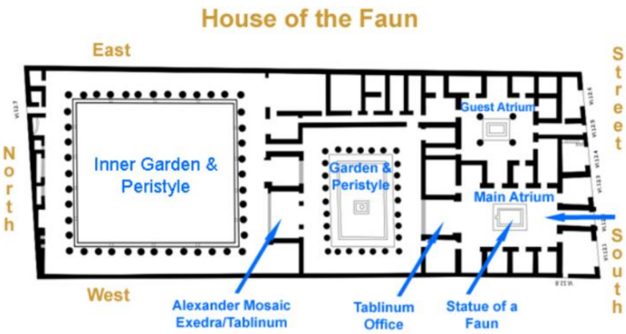


Figure 17 plan of the faun house / source: https://ar.inspiredpencil.com/pictures-2023/roman-atrium-house-plan

1.2.6.3 Middle Ages

Early Middle Ages: Homes were simple, wooden, or wattle and daub homes. Castles and fortified homes appeared to repel invasions.

Figure 18 celtic round house, also uses wattle and daub source: https://permies.com/t/224134/people-foundations-wattle-daub-houses

High Middle Ages: Gothic architecture was the norm with pointed arches and stained glass windows. Wealthy families lived in large stone homes with towers and courtyards.

Figure 19 Restored and renovated 1879 gothic revival house in Highgate, North London. By Maddux Creative Source:https://www.reddit.com/r/InteriorDesign/comments/xytz3q/restored_and_renovated_1879_gothic_revi

Late Middle Ages: Homes became more complex. The Tudor style emerged with half-timbered facades. Manor homes had moats, large halls, and elaborate fireplaces. Houses were symbols of defense and status, reflecting medieval social hierarchies.

Figure 20 A Pasadena mansion /source: source :https://www.sacbee.com/news/california/article250839379.html

1.2.6.4 Industrial Revolution

Extending from the 18th to mid-19th century, the Industrial Revolution introduced new materials and urban residential developments.

Early Phase: Workers lived in plain brick or stone homes with effective floor plans.

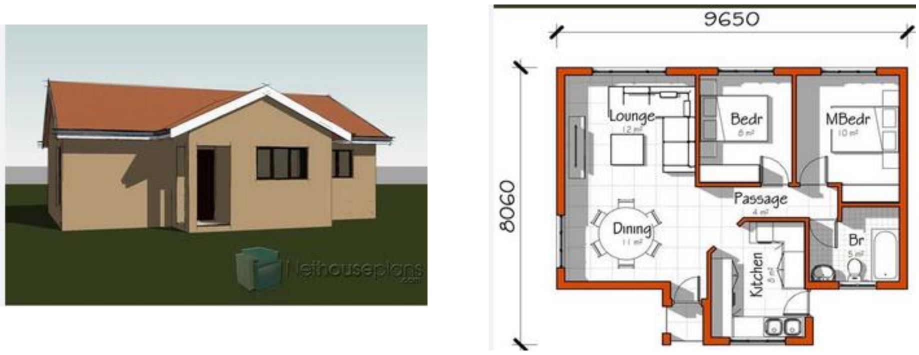


Figure 21 Room House Plans Low Cost Bedroom Plan Nethouseplansnethouseplans / Source: https://www.midotrust.com/

Mid Phase: Cast steel and iron allowed for larger Victorian houses, with ornamented facades, bay windows, and multi-story buildings.

Figure 22 victorian house / source: https://designbaddie.com/how-to-pick-the-ultimate-interior-design-career-niche-60-ideas/

Late Phase: The Arts and Crafts movement advocated traditional craftsmanship, while Art Nouveau brought flowing forms and detailed decoration.

Mass production collided with artistry as houses increased in size, sophistication, and beauty.

Figure 23 Hotel Tassel, Brussels / source: https://see.ballery.com/hotel-tassel-brussels-designer-victor-horta-and-emile-tassel-1700x1440-art-nouveau-style/

1.2.6.5 *The Modernsm*

in the early 20th century, Modernism dispensed with ornamentation in favor of function, simplicity, and new technology.

Early Modernism: Level roofs, geometric forms, and the International Style embraced minimalism. Steel, glass, and concrete revolutionized construction.

Figure 24 Villa Savoye / Le Corbusier / source: https://www.pinterest.com/pin/gallery-of-architecture-classics-villa-savoye-le-corbusier-5--467811480026498356/

Figure 25 : Modular homes being assembled with a crane at a construction site during dusk / sourcze:https://www.tallboxdesign.com/what-is-a-modular-home/

Mid Modernism: Prefabricated and modular homes offered affordability. Ranch homes employed open planning and conformity with nature.

Late Modernism/Postmodernism: The designs were less serious and more eclectic, embracing playfulness and expressive forms as well as personal touch.

Modernist homes emphasized efficiency, innovation, and simplicity, while Postmodern homes added personality and narrative.

Figure 26 The Nationale-Nederlanden office building, more often recognised as 'The Dancing House' source: https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a901-10-things-you-did-not-know-about-dancing-house-prague/

1.2.6.6 *Smart Homes*

Smart homes represent the next generation of house evolution, integrating digital technology into daily life.

Early Smart Homes: Automation was straightforward—limited to lighting and heating control through remote systems.

Figure 27 Shows smart IoT-based home automation system using various sensingdevices / source: https://www.mdpi.com/2071-1050/14/17/10717

Mid Smart Homes: Voice assistants and energy efficiency features were in vogue. Green design with smart thermostats and solar panels were in vogue

.

Figure 28 solar panel installation source: https://www.pblackhall.co.uk/can-i-have-solar-panels-on-my-house/

Advanced Smart Homes: Contemporary homes offer convenient automation—context-aware systems, modular architecture, smart furniture, and personalized user experiences.

Figure 29 Smart home isometric flat vector concept. A man using smart phone is managing appliance of his house. / source: https://www.dreamstime.com/stock-illustration-smart-home-isometric-flat-vector-concept-man-using-phone-managing-appliance-his-house-image634

Conclusion:

Housing is far more than mere physical shelter—it is a dynamic, evolving idea that adapts to the needs of human beings of the world, to technological advancements, and to values of socio-culture. From ancient mud and hide shelters to smart, energy-efficient homes with AI and automation, housing history is the mirror of civilization's journey through time.

The concept of housing today is no longer merely the structure itself but also the quality of the physical, social, psychological, and physiological environments it provides. Housing has progressed from a purely utilitarian function—keeping one out of the weather—to an elemental component of identity, culture, and well-being. Specific words such as dwelling, accommodation, or domicile convey in nuanced language how people relate to their homes legally, emotionally, and socially.

The evolution of homes—the move from ancient huts to modern smart homes—offers shifts in materials, technologies, aesthetics, and lifestyle trends. Each step in the past is a shift not only in the way people live, but also in the way they want to be at home: from survival and safety to beauty, comfort, and electronic convenience.

Lastly, understanding the housing as a complex and dynamic concept is what architects, urban planners, and policymakers must understand in order to design environments that are reactive to the complexities of contemporary life

1.2.7 Housing typology:

The household's quality of life is significantly influenced by the spatial structure of its housing space—this includes the unit type, unit layout, building/site layout, and open space configuration.

Discomfort and stress are often the outcomes when such spatial configurations impose or imply patterns of living that are incongruent with household expectations, role performances, or cultural values. When this occurs, residents may find themselves in a position of incongruence between designed intent and lived experience.

1.2.7.1 Individual Housing:

Self-Built Housing

Self-built housing refers to residential structures built through and/or occupied on an informal basis and/or without regulation and/or legality. Informal housing is most often in violation of noted building regulations, zoning laws, or land ownership laws. Slum housing, shanty towns, squatter settlements, or informal settlements are names often used to refer to such housing.

Some of the characteristic features of informal housing are:

- Lack of access to basic infrastructure and public utilities (e.g., clean water, sanitation, electricity)
- Substandard construction and overcrowding
- Inadequate secure land tenure or risk of eviction

This has become more common in the developing world, where the high rates of population growth and urbanization have outstripped the supply of affordable, formal housing. United Nations estimates indicate around one billion people worldwide live in slums.

While their often-precarious and marginal status is a common feature, informal settlements are also resilient and dynamic communities bearing such defining features as:

- Well-defined social and cultural standards
- Strong community ties and social networks
- Informal economies and self-organization

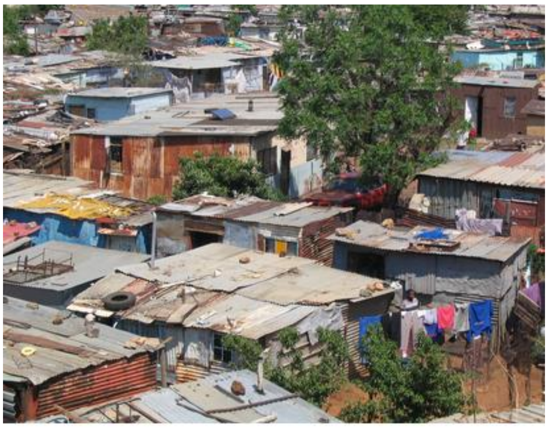


Figure 30 Figure29 : Township» en Afrique du Sud source : https://www.rfi.fr/fr/afrique/20190404-afrique-sud-campagne-anc-faubourgs-johannesburg

They are an integral part of the urban fabric, which requires inclusive, responsive planning approaches that take both their weaknesses and strengths into account

Planned Housing :

Planned housing refers to those residential developments which are planned out carefully and constructed from scratch, as opposed to developing gradually over a lifetime. They comply with a master plan and try to create synergistic, functional, and often mixed-use communities.

- Breakdown of key points:

- Master-planned communities: These are typically built on previously undveloped land and have master planning for homes, road infrastructure and utilities, amenity space (parks and community centers), and sometimes commercial or retail space.
- Planned Unit Developments (PUDs): A type of planned housing that allows greater design and land-use freedom than typical zoning. PUDs can offer combinations of housing types (single-family dwellings, townhomes, apartments) and generally share community facilities, with residents typically belonging to a homeowners' association (HOA) responsible for maintaining shared spaces.

➢ Key Characteristics:

Pre-planned layout: Layout, architectural style, and general appearance are determined in advance.

Amenities incorporated: Often include parks, playgrounds, and community centers, and occasionally schools, shopping, and work within walking distance.

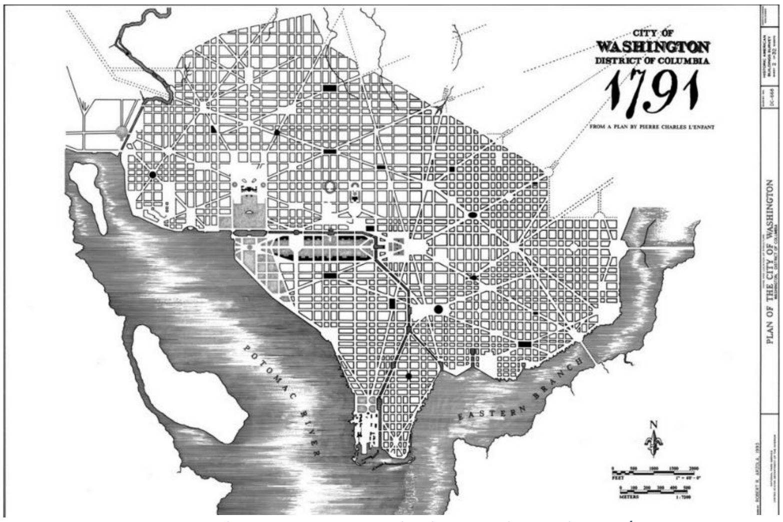


Figure 31 Washington, D.C. was built as a planned city / source: https://en.wikipedia.org/wiki/Planned_community#/media/File:L'Enfant-McMillan_Plan_of_Washington,_DC,_Washington,_District_of_Columbia,_DC_HABS_DC,WASH,612-_(sheet_2_of_32).tif

Homeowners' associations (HOAs):
Planned housing frequently includes HOAs that manage and upkeep communal facilities and enforce community rules.

Focus on community: Designed to establish a sense of community through the availability of shared spaces and planned activities.

Vernacular housing

Vernacular housing is the type of housing that reflects the principles of architecture traditional. Regardless of the countries and periods, this architecture, represents all the buildings designed by artisanal and artistic cultures.

Generally speaking, these cultures are based on individual modes of production and autonomous, in contrast with industrial modes of production.

It is an architecture that uses resources (materials) extracted or produced locally, for reasons cultural and economic, it evolves very slowly hence the idea,

Figure 32 type of housing that reflects the principles of architecture traditional.

obviously false, that the traditional architecture is immutable.

The traditional house corresponds to the habitat of a domestic group formed by several conjugal families. It is organized around the patio, central courtyard "West eddar" at open sky, source of light and ventilation, the rooms that frame it consecrate the individuality of the marital cell, keeping the balance of the group. The commons and outbuildings are often located on the side of the entrance and contribute to isolating from the street the actual dwelling which it still occupies the bottom of the plot, the entrance, composed of an interweaving of chicane vestibules, plays the role of filter between the outside (the street) and the interior (the domestic space).

1.2.7.2 Semi-Collective Housing (Low-Density Multi-Family Housing)

These types of housing are made up of attached home units in which every unit is typically under distinct land ownership. They are common in medium-density inner city developments.

- Semi-Detached Units

Figure 33 An example of terrace housing / source: Housing_Typologies.pdf

- Are made up of two adjacent housing units.
- Layouts are mirror images of each other.
- The units share a single party wall on one side.
- Open space is typically available in front, rear, and on one side of each unit.
- Parking is typically available on the property, external to the building.

- Townhouses

These are multi-story dwelling units which are situated in new subdivision housing. Each unit shares one or more bordering units by common walls.

Typically set up with a more vertical design (multi-level).

Ownership can be varied: some are individually owned (townhomes), while others could be co-owned by the provisions of shared ownership arrangements (condominiums). Townhomes usually have integral parking (within the unit itself).

Figure 34 Figure33: An example of townhomes / source: Housing-Types-Definitions---English.pdf

- Row Housing

Made up of a uniform, unbroken line of houses, all having common interior side walls. Recognized as one of the most accepted medium-density housing forms.

Figure 35 An example of row housing / source: Housing_Typologies.pdf

The buildings are planned parallel or perpendicular to the street, which allows configurations to be varied.

Unlike townhouses, row houses and semi-detached houses normally feature exterior parking schemes rather than built-in garages .

- Apartments

A structure built to contain multiple separate households.

Each household possesses its own self-contained unit within the larger structure.

Units frequently share common characteristics such as entrances, hallways, stairwells, and possibly amenities (e.g., laundry rooms, gyms, or courtyards).

Apartments can vary in height and size, from low-rise buildings to high-rise towers, and may be rented or owned (as in condominiums.

Figure 36 Figure35: An example of apartments / source: Housing-Types-Definitions---English.pdf

Collective Housing (High-Density Multi-Family Housing):

- Vertical architecture

Collective housing is a name given to high-density residential buildings that are constructed to accommodate multiple families within a single building, typically in the form of vertical expansion such as residential skyscrapers or towers.

The history of vertical living began as a response to the lack of urban land because of the bulk migration from rural to urban centers, starting with the Industrial Revolution up to the Modernist era. During this period, architects were searching for viable means of housing the growing urban labor force. Tall buildings were therefore habitually designed according to a model of stacked horizontal floors, all serviced by a central vertical core—more commonly an elevator shaft.

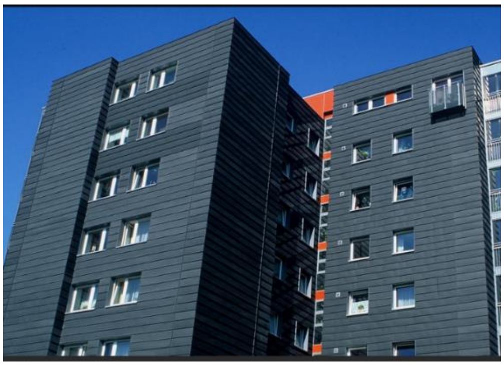


Figure 37 Figure36: An example of collective housing, Münster (Germany) source: https://www.vmzinc.com/collective-housing,-munster-%28germany%29

- Yet this form of housing had a host of ills:
- Noise, pollution, and crime
- Loss of privacy and loss of connection to the human scale
- High maintenance needs and strain on city infrastructure
- Minimal spontaneous social contact, due to dependence on elevators rather than shared horizontal circulation

Responding to these issues, design solutions have been proposed to enhance quality of life in vertical communities. They include:

- Provision of communal space on various levels (e.g., gardens, terraces, shared lounges)
- Encouraging social interaction and community formation within the building
- Design with greater consideration for human behavior, accessibility, and privacy

The aim is to transcend mere efficiency, and in the direction of collective housing solutions that are both dense and habitable

4. Additional Types and Subcategories:

➢ Cluster Housing

Cluster housing, according to Untermann, is "the most basic and longest-lasting form of human habitation." Cluster housing, by definition, encourages a greater sense of community than the average suburban single-family dwelling.

It is evident when comparing the leading characteristics of each:

- Cluster over linear form
- Urban density in contrast to sprawl
- Public space instead of private enclosure
- Pedestrian use prioritized over automobile use
- Focus on neighborhood life rather than isolated individualism

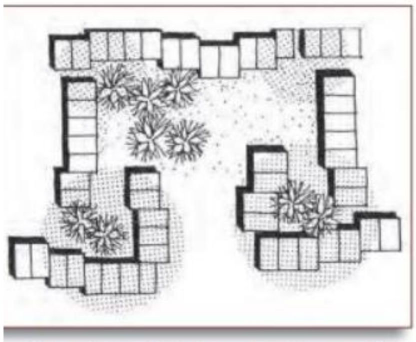


Figure 38 Figure37: An example of cluster housing / source: Housing_Typologies.pdf

Cluster housing typically consists of clusters of dwellings arranged around shared open areas, courtyards, or footpaths, promoting contact, mutual responsibility, and a more socially mixed environment

➢ Mixed-use housing

Mixed-use housing merely refers to development plans that involve more than one use or function in a building or a single area of development. The plan is designed to create multi-functional areas that bring residential, commercial, and other purposes together in close proximity.

Figure 39 Figure38: An example of mixed-use housing / source: Housing-Types-Definitions---English.pdf

A mixed-use development may comprise varied elements, including:

- Residential dwellings
- Offices and retail

- Medical and health facilities
- Recreational areas
- Commercial or even light industrial functions

The spatial arrangement of these uses can be:

- Vertical – with housing located above other functions such as shops, cafés, or offices
- Horizontal – with housing situated next to commercial or service-oriented spaces within the same development

Mixed-use developments aim to improve walkability, reduced commuting, and more vibrant city living, and this is the primary strategy in sustainable and integrated city planning.

Co-housing

Co-living is a modern housing model where members who share common interests, values, or lifestyles live together under one roof within a communal setting that fosters high levels of community—basically a large extended family.

Figure 40 An example of co-housing / source: Housing-Types-Definitions---English

In a typical co-living setup:

- Residents rent individual private rooms .
- within a larger shared house.
-
- They share facilities, such as kitchens, living rooms, bathrooms, workspace, and at times facilities like a gym or lounge.
- Architecture supports community interaction, collaboration, and affordability.
- Co-living is generally appealing to young professionals, remote workers or digital nomads, or those seeking social interaction and low-cost housing in urban environments.

This type of housing promotes the sharing of resources, socialization, and lifestyle flexibility, thus making it extremely popular in urban areas with high house costs and limited space.

1.2.7.3 Temporary or Transitional Housing


Figure 41 transitional housing located at Building 116 of the West Los Angeles Veterans Affairs Campus source: https://www.va.gov/greater-los-angeles-health-care/stories/a-home-away-from-home-temporary-housing-programs-vital-to-mission-of-ending-veteran-homelessn

Transitional housing is the provision of temporary housing that is designed to provide short-term assistance to vulnerable individuals or families in transitioning into stable, permanent housing arrangements.

Transitional housing is a temporary residential setup that not only offers shelter but also support services to help residents recover stability, rebuild their lives, and move to permanent housing.

finally in conclusion housing typology is a point of departure from which we can understand how different types of residential settings respond to human needs, socio-economic conditions, and urban pressure for expansion. From disorganized self-built settlements to extremely rationalized collective housing, housing form variation demonstrates the complex dynamics among cultural identity, way of life, economic capability, and spatial limitation.

Each typology—individual, semi-collective, collective, or new types like mixed-use and co-living—is worthwhile or not. Informal housing is resourceful and resistant to self-organization by the community but lacks infrastructure. Planned and vernacular housing prioritize utmost harmony with social values, climate, and tradition. Collective and vertical housing provide solutions to urban density but are prone to issues of livability and human encounter. In addition, new typologies such as cluster housing, mixed-use developments, and co-living are more inclusive, sustainable solutions to contemporary life needs.

Ultimately, no typology is suitable for every location. Effective housing must be responsive to the activities of its residents, the character of its environment, and the longer-term imagination of urbanists. Accepting the variability of housing typologies is the initial step in creating inclusive, flexible, and humanly scaled housing arrangements that can really enhance the quality of life

1.2.8 Characteristics of housing design in Arid Zones:

Humans have a natural ability to maintain a fairly constant body temperature within certain limits of the environment—through involuntary physiological responses, appropriate clothing, or alterations in activity. But in harsh environments such as the hot desert climates of the Sahara, these natural processes often prove insufficient. Under such conditions, it is the responsibility of the built environment to provide thermal comfort, enabling the residents to undertake their daily activities comfortably and securely.

Comfortable temperature or thermal comfort is a subjective feeling, which may vary from person to person. Nevertheless, if the major environmental factors such as temperature, air movement, and humidity are controlled, an acceptable indoor environment can be achieved. This is usually achieved by means such as adequate thermal insulation, efficient window systems, appropriate heating and ventilation facilities, and occupancy and environmental change responsive regulation devices.

In the tropics, particularly in summer, overheating is the major problem. This can be mitigated by designing cross ventilation, utilizing solar shading devices on doors and windows, or—where necessary—air conditioning. But in desert climates, discomfort is not caused by the mean temperature itself, but by its daily large amplitude. One of the finest passive solutions is to employ high thermal inertia materials, which absorb heat during the day and shed it at night—coincident with natural cooling when windows may be opened.

Though each building is critical to thermal comfort, the larger urban context also plays a part. Cities are typically warmer than their rural settings due to the urban heat island (UHI) effect from compact development, vehicle and building heat emissions, lack of vegetation cover, and low airflows. This highlights both climate-responsive buildings and city planning strategies concerning solar exposure, wind, vegetation cover, and surface materials (albedo).

In the arid areas, climatic conditions cannot be avoided. Houses here have centuries of experience in reacting to social, cultural, and environmental constraints, devising solutions that can be applied to stimulate sustainable buildings today. Demands now for fast, cheap construction, though, have led to abandoning architecture's interface with the climate, resulting in energy-consuming buildings requiring too much mechanical cooling.

A climate-resilient design begins with the location selection. Although a location will not influence temperature or humidity directly, it greatly influences sunlight exposure, wind, and rain. For centuries, sensitive observation has guided building placement in relation to terrain slope, solar orientation, and natural windbreaks.

Traditional desert architecture is rich in significant lessons for passive thermal management. Methods such as evaporative cooling, convection, night-time radiation, thermal mass,

subterranean design, and moisture buffering have been successfully applied to moderate harsh environments.

Selection of construction materials is equally important. Thermal response depends basically on thermal resistance and heat capacity. Minimum loss of heat is to be ensured by good airtightness, and optimum comfort ensured through natural ventilation. These are possible with the adoption of tested-in-time commonsense principles proved in centuries of traditional practice modified in terms of season and day and night demands.

In this context, we will say that the bioclimatic architecture must take into account the following principles:

- Use solid materials to increase thermal inertia,
- Remove weak points, such as thermal bridges, or balconies that are integral with the rest of the building, and act as cooling fins,
- Provide insulating glass units (e.g. double glazing), which must be protected by shutters, blinds and caps, while favoring the natural lighting of the spaces,
- Avoid summer overheating by protecting the building with appropriate vegetation,
- Use architectural protective devices such as opaque roof, cap,

Thus, the thermal performance of the building can be improved by various methods of passive cooling, independent of air conditioning units. On the other hand, the use of a single technique for the prevention of overheating in summer cannot be effective. In fact, a judicious combination of the different techniques, in the manner of architecture traditional, can give favorable living atmospheres, without resorting to devices of extras

1.2.9 Interrelationship between Comfort and housing design:

In spite of the fact that it appears to be that any contemporary compositional plan can tackle its concerns of natural control through artificial systems, this isn't totally evident in our way of life. Moreover, in numerous different societies structures have been (and are as yet being fabricated) worked with an intense attention to the limits forced by the environment in which they are found. Manufacturers with few specialized assets are compelled to plan their structures in close relationship to their usefulness as a boundary against the environment.

In our modern buildings, on the other hand, the unreasonable confidence in artificial systems prompts plans which ignore the environment and turn out structures that are both physiologically and mentally inhospitable. To concentrate on the connection among environment and famous design, we ought to group the various sorts of environments, first of all, tracked down in the world. In the event that we make an improved on generally examination, temperature can be viewed as the most delegate parameter, both in its normal qualities and in annual and daily varieties.

We believe humidity to be in a roundabout way shown by such thermal varieties, since the more the greater the variety the more the greater the continentality of the environment, and in this manner the lower its humidity.

despite this, to have the option to make an overall examination of the environment as respects its impact on the structures and arrangements of famous design, we work on the more intricate reality by grouping environments into specific fundamental sorts which empower us to reach straightforward inferences from compositional investigation.

Starting here on we will comprehend that any real environment is a weighted combination of these essential sorts.

This improved on grouping will allow us to see that the most outrageous instances of environment are those which have a more clear design arrangement, while the architecture found in temperature climates paradoxically ends up being more complex , since the structures need to adjust to evolving conditions, and don't allow single arrangements. The previous permits us to recognize three fundamental sorts of environments:

(a) COLD CLIMATES, typical of high latitudes or great heights in medium latitudes, with very low temperatures, seasonal variation with the changes of winter-summer sunshine levels, an always pleasant solar radiation and aggressive winds when they come from the direction of the corresponding pole

(b) DRY WARM CLIMATES, typical of deserts close to the Equator, with high average temperatures and high temperature variations in the daily cycle, very low humidity and very directional solar radiation, no cloud cover and practically no rainfall, and dry winds which are warm, heavy with dust, and also very aggressive.

(c) WET WARM CLIMATES, typical of subtropical coastal regions, with high average temperatures and little day-night and seasonal variations, high humidity and heavy rainfall, high and relatively diffuse solar radiation, and variable winds which can easily be of hurricane strength. To these three basic types, two further quite exemplary cases can be added:

(d) WINDY CLIMATES, which are found along with any of the previous cases with the presence of intense and frequent winds, or in temperate climates in which wind can become the main factor in the design of buildings.

To these three basic types, two further quite exemplary cases can be added:

(e) COMPLEX CLIMATES, as a rule temperature climates displaying, though with less intensity, the conditions of the previous cases in their variations throughout the year. In this case

The greatest problem of architecture is its capacity to adapt to these changes by means of flexible solutions.

<u>Hot dry climates</u>

In the districts with this kind of environment an endeavor is normally made to exploit the extraordinary temperature variety during the day-night cycle, deferring the entrance of heat beyond what many would consider possible so it arrives at the inside around evening time, when it is least bothersome.

For this reason, materials of great thermal inertia are utilized, for example, mud as adobe blocks or mud walls, thick stone and every one of the potential blends of these arrangements.

Houses in these environments are regularly organized in minimal patterns, one extremely close to another, leaving little divisions as alleys or courtyards. Hence, the surfaces presented to sunlight based radiation are diminished and the constructed weight per unit of volume involved is expanded, which raises the thermal inertia of the ensemble

The generation of shade between neighbouring buildings reduces the warming of their walls by radiation and at the same time enables them to be cooled by contact with the fresh air at night.

In these structures with extraordinary thermal inertia , how their openings are taken care of will be of fundamental significance: windows ought to be completely shut during the hottest hours of the day, not allowing in either the light or the hot air from outside.

Around evening time these windows ought to be completely opened to utilize the cooling impact of nighttime ventilation.

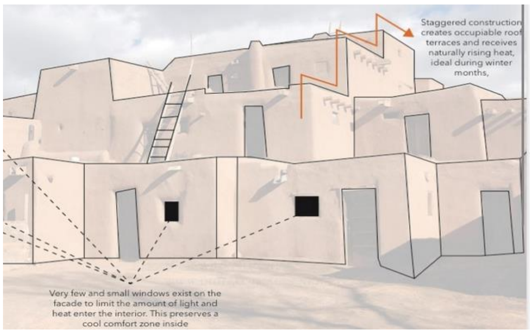


Figure 42 Characteristics of housing design in hot dry climat / source: https://www.infurnia.com/

In the homes found in these environments the kitchen is situated outside, consequently trying not to add intensity to inside spaces which could deteriorate their daily environments.the structures is painted white or in light varieties that reflect the radiation as much as possible.

The openings confronting the outside are not many and of a little size, frequently set in the most elevated piece of the walls to lessen the radiation on the ground, to help hotter air in the house to get out, and to get the most ideal lighting with the base entrance of radiation.

In these areas the presence of water is vital, and consequently an endeavor is constantly made to hold rain water, safeguarding it from dissipation through capacity in underground tanks below the dwelling.

These tanks additionally increment the thermal inertia of the structure and some of the time cool it through the evaporation effect which, though small, provides some continual damping and cooling for the floors of the houses.

Different assets used to diminish the impacts of the sun on structures are eave , blinds and lattice in the openings, vegetation to shield from the radiation on the walls on the paving of outside spaces, etc.

Larger scale solutions are public spaces such as streets or squares, and even entire towns, covered with immense barriers against radiation by means of canvases, cane meshes, etc.

One more sort of arrangement found all around the world is the development of underground residences by digging caves where the land grants, looking for the temperature soundness that is constantly found at a specific profundity under ground level and making significantly more inhabitable insides.

Another component average of the architecture of these environments, though it is also present in other environments, is the courtyard. The cooler damp night air is retained in these areas, keeping conditions pleasant during the day because the yard is protected from solar radiation, dry winds and sand Winds .

With the supplement of water and plants, these yards become reviving wells in the core of the structure. In specific cases, particularly in Arab nations, wise use is made of a mix of two yards, one in shade and the other sunny , to make a characteristic wind current from the cooler patio to the hotter one, establishing a particularly pleasant environment in the intermediate premises.

In different cases, as in the Moroccan mountains, exceptionally high and restricted courtyards are underlying structures a few stories high, going about as that ventilate the inverted chimneys deepest zones of the structure. The fundamental plan of the courtyards house, which can be found in a wide range of societies and environments, consequently finds in warm-dry locales its best working circumstances and its most noteworthy value as an arrangement of climatic improvement of engineering.

In the warm-dry environments of various zones of the Earth we frequently find comparative structures. For instance, it is normal to utilize heavy enclosure wallings, adobe or mud walls or tops of exceptionally extraordinary thickness.

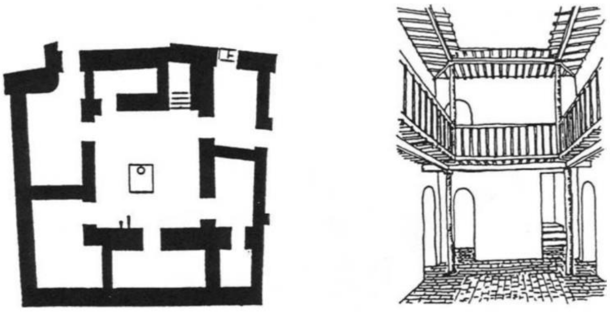


Figure 43 Figure42 : Layout and courtyard of a housing in Ur (Mesopotamia).
source: Architecture_Comfort_and_Energy.pdf

These are much of the time supported by their underlying capability, however essentially satisfy a climatic capability, as is shown by the cases in which they act basically as a covering for load-bearing wooden designs. One more common arrangement in these locales is that of the twofold rooftop or twofold wall with a ventilated inner space.

This is ordinarily found in environments that are warm and dry for most of the year however have a rainy season during which conditions approach those of warm-wet environments. For this situation it is normal to construct enclosure wallings combining the use of straw and clay, , with the accompanying outcomes:

(1) The straw layer, that must be recharged every year, safeguards the lower dirt layer from the water during the stormy season.

(2) a similar straw safeguards the majority of the rooftop from the immediate impacts of the sun, staying away from heat capacity and the roundabout warming of the inside by radiation re-transmitted during the dry time frame.

(3) The vacant space between the two layers offers extra protection on exceptionally warm days and the dirt layer, with its warm dormancy impact, manages within repercussions of outside temperature varieties.

(4) The idleness of the inside space is improved since the straw layer goes about as an external protection for the wall faces, a circumstance that is hypothetically the most good for warm dependability in for all time involved structures.

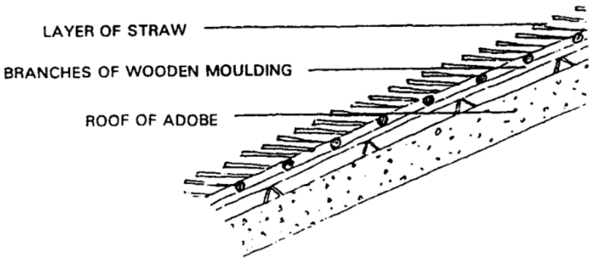


Figure 44 Orisa housing (India). / source: Architecture_Comfort_and_Energy.pdf

<u>Hot humid climates</u>

in the external temperature in the daily and yearly cycle are tiny. Besides, on the grounds that the radiation is extremely extraordinary, it is essential to acquire the greatest conceivable security against its belongings by endeavoring to stop direct, yet in addition diffuse radiation, which is of significance in these environments.

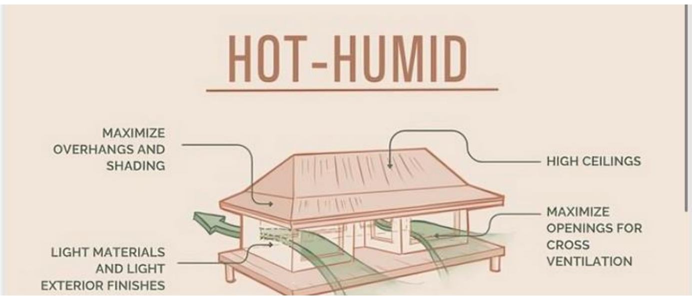


Figure 45 Characteristics of housing design in hot humid climat / source:https://www.pinterest.com/pin/565272190748517613/

Then again, ventilation is additionally vital to disperse the heat in the inside and to diminish the humidity of inside spaces. Consequently, the structures have huge openings shielded from the sun, while the commonplace implantation of structures utilizes long narrow structures that are free and far off from one another, endeavoring not to make barriers for the breezes between the various structures.

To make air dissemination arrive at the entire inside space in these environments, openings possessing the entire wall face are utilized to permit the air to circle, with assurance from radiation and onlookers through of lattices, blinds, etc

Disregarding these gadgets this arrangement consistently involves issues of security and a complete absence of insurance from noise. In traditional residences in these zones the rooftop is a vital component, since it needs to go about as a parasol and umbrella simultaneously.

At times, the rooftops are separated into an extraordinary number of covering rooftops, one concealing the other, among which the air can flow, hence abstaining from overheating. Likewise regular in these zones are rooftops with a steep slope to drain off the frequent rains.

They favor the thermal delineation of more hotter air at the top, where openings are made to let this air out. The exceptionally highlighted roof bear the cost of insurance from radiation and from the rains . They additionally offer ventilation and sometimes form porches.

or on the other hand open galleries, creating shady intermediate spaces by day and spaces shielded from the cool damp air around evening time, which makes it conceivable to lay or rest on exceptionally hot days.

In essentially all cases the rooftops are light to stay away from heat capacity from radiation, with a structure that allows a certain 'breathing' of their layers to keep away from condensation inside and favor cooling via air course.

The floors of the structures are brought up in many cases, to acquire better openness to the breezes, security from floods in case of tempests, and assurance against bugs and little creatures.

These raised floors are constructed so they are additionally penetrable to the air, thus completing the ventilation of the entire envelope of the house.

A normal ecological arrangement of these environments, which we could consider to address the insignificant natural surroundings, is the hammock. Utilized for dozing or rest, these grant air dissemination every which way, and the swinging movement creates the overall development of the air with least of exertion. The hammock. has no, rather than thermal inertia, sleeping cushions, which are awkward in these environments.

To summarize, in these climatic zones the job of security that we ordinarily characteristic to the structure brings about the most unimportant compositional developments.

In these warm-wet zones, regular light can turn out to be significantly more bothersome than in warm-dry zones, since the sky creates an exceptionally extreme brightness this way and that, effectively causing stunning impacts.

Hence, the openings are frequently covered with dark colors cane meshes that decrease the brightness penetrating entering the inside from the outer layer of the openings.

The roofs are painted white to disseminate the light as equitably as conceivable in the inside. This equivalent capability is performed by lattices and grilles tracked down in Arab nations and the exhibitions and galleries that go about as areas of shade and safeguarded augmentations of the indoor region towards the public space.

During the zones where the damp heat is just occasional, housing configuration can turn out to be somewhat more perplexing. At times in urban zones extremely high roofs are utilized, where the hot air is defined and the air in the lower part of the rooms, which is the involved part, is cooler. In different cases, in case of changing from wet to dry heat , houses are worked with a light construction covered with canvases or awnings, which in the dry season contract and permit air to flow among their fibers, and which widen in stormy circumstances to frame practically waterproof, conservative cross sections.

Complex environments

As we have proactively referenced above, temperature environments frequently have entirely factor conditions over time, which force famous design to utilize substantially more mind boggling arrangements than on account of the more outrageous environments.

This intricacy is made manifest in the utilization of adaptable system , with components or blends of components of the structure that can undoubtedly change their natural activity as per the atmospheric conditions. The most average of the adaptable system s are:

• Versatile shade system , for example, the ordinary louver blind that permits the passage of radiation and ventilation to be controlled essentially and advantageously.

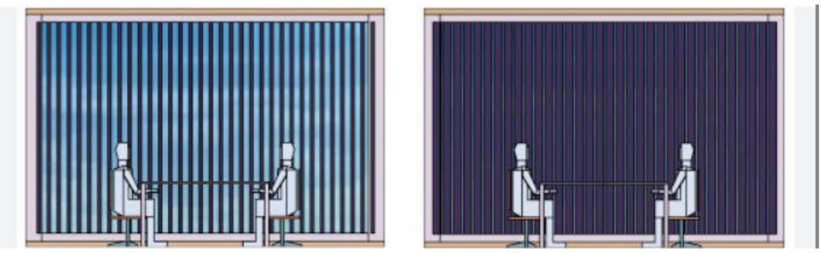


Figure 46 the ordinary louver blind and Versatile protection in the openings, screens / source: https://www.sciencedirect.com

• Versatile protection in the openings, screens, shades, and so forth, which empower the progression of intensity and light to be controlled, over all in winter.

• Gaps that can be totally opened, allowing greatest control of ventilation and permitting the free entry of air and daylight when fitting.

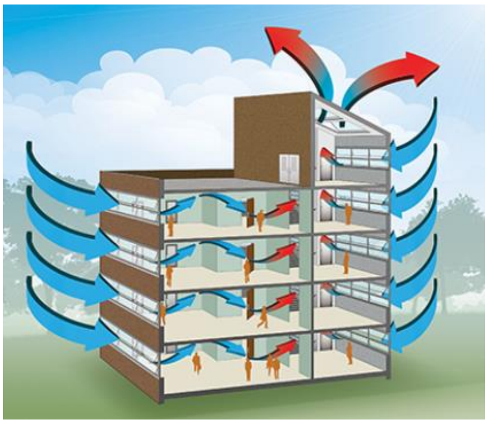


Figure 47 gaps / source: https://www.pinterest.com/pin/648940627559588433/

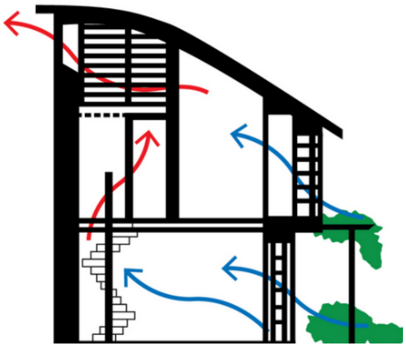


Figure 48 middle spaces / source: https://www.pinterest.com/pin/763571311795996133/

• Middle spaces among indoor and open air regions, which can produce ideal microclimates, as has proactively been referenced previously. These can likewise be involved at various seasons of day and times of the year, in this manner adding to the structure's practical potential outcomes.

With this extraordinary number of assets, the famous design of mild environments as a general rule, and the Mediterranean environment specifically, tackles the troublesome issue of utilizing one sole building structure to oppose contrasting climatic circumstances that, however less significantly, recreate the qualities of the outrageous environments dissected previously.

These environments have the issue of cold in winter, which can be dry or wet; however this qualification was of no significance in freezing environments, it includes various arrangements here. They can likewise be extremely hot in summer, with high or low humidity , on occasion with similar power as the models managed above, however these atmospheric conditions keep going for more limited periods.

At last, there is the issue of the transitional seasons, spring and pre-winter, where in brief timeframes the climatic circumstances can change starting with one outrageous then onto the next. However this multitude of circumstances may not be basic independently, taken overall they have led to this intricacy and abundance of arrangements in famous architecture in these environments, which as a matter of fact makes it more muddled than that of additional outrageous conditions. At the point when tested by climatic changes, building arrangements become more perplexing, looking for in the connection among inside and outside an energy activity that we call a 'filter ' between various natural circumstances, rather than utilizing most arrangements of the 'barrier ' type that we have tracked down in easier and more forceful environments.

In conclusion The relationship between house form and climate—especially in hot-dry deserts, hot-humid, and mixed climates—is deep and essential. In extreme conditions such as hot-dry deserts or warm-humid climates, the house is a shelter as much as it is a climatic modification device. The traditional architecture of these countries offers centuries of solutions using local materials, passive architectural principles, and close understanding of human comfort.

Design in arid areas emphasizes thermal inertia, compact urban patterns, small shaded apertures, courtyards, below-ground features, and whitewashed finishes to mitigate fluctuating extreme temperatures. Conversely, in tropical hot-humid climates, design emphasizes maximum ventilation, light porous materials, shading devices, and elevated floors to address humidity and continuous heat.

Complicated climates, like temperate regions with changing conditions, need adaptive architectural solutions. These consist of movable shading, adaptive insulation, transition spaces, and flexible opening systems that adjust to seasonal and daily changes.Lastly, sustainable housing must come full circle on climate-responsive design, integrating bioclimatic expertise and advanced technology. Comfort is not a technology result but a product of insightful design choices that react to the climate and human behavior. The constructed environment, in sensitivity to local climate, not only enhances comfort but also reduces energy dependence, promotes health, and enhances people-people-place connection

1.3 climate and architectural challenges in arid zones :

Arid environments are extremely diverse by their terrain forms, their soils, their fauna, their flora, their water balances and the human activities that take place there, Because of this diversity, we cannot give a practical definition of arid environments.

However, the common element of all arid regions is aridity. This is usually expressed as a function of precipitation and temperature. A useful "representation" of aridity is the following climatic aridity index:

P = precipitation

ETP = potential evapotranspiration, calculated by the Penman method, taking into account atmospheric humidity, solar radiation and wind. This index makes it possible to define three types of arid zones:

The hyper-arid zone

(aridity index 0.03) includes areas devoid of vegetation, with the exception of a few scattered bushes. A true nomadic pastoralism is frequently practiced there. The annual rainfall is low, and rarely exceeds 100nmillimeters. The rains are infrequent and irregular, sometimes non-existent for long periods that can last several years.

The arid zone

(aridity index 0.03-0.20) is characterized by pastoralism and the absence of agriculture, except where there is irrigation. The native vegetation is usually scarce, consisting of annual and perennial grasses and other herbaceous plants as well as bushes and small trees. Rainfall is extremely variable, with annual amounts ranging from 100 to 300 millimeters.

The semi-arid zone

(aridity index 0.20-0.50) can support rainfed agriculture with more or less regular production levels. Sedentary animal husbandry is sometimes also practiced there. The native vegetation is represented by various species, such as grasses and grass-like plants, non-grass grasses and small bushes, shrubs and trees. The annual precipitation varies from 300-600 to 700-

800 millimeters, with summer rains, and from 200-250 to 450-500 millimeters with winter rains.

Arid conditions are also found in the sub-humid zone (aridity index 0.50-0.75).

The term "arid zone" is used here to collectively designate hyper-arid, arid, semi-arid and sub-humid zones

➢ Temperatures

The climatic pattern of arid zones is often characterized by a relatively "cool" dry season, followed by a relatively "hot" dry season and finally a "moderate" rainy season. In general, significant fluctuations in daytime temperatures are

observed within these seasons. Very often, during the "cool" dry season, daytime temperatures reach between 35 and 45 degrees centigrade, while nighttime temperatures drop to 10 to 15 degrees centigrade.

Daytime temperatures can approach 45 degrees centigrade during the "hot" dry season

and fall to 15 degrees centigrade during the night. During the rainy season, temperatures can range from 35 degrees centigrade during the day to 20 degrees centigrade at night.

➢ Atmospheric humidity Although precipitation and temperature are the essential factors of aridity, other factors also intervene. The humidity of the air is important for the water balance of the soil. When the moisture content of the soil is higher than that of

the air, the water tends to evaporate into the air. Otherwise, the water will condense in the soil.
Humidity is usually low in arid areas

1.3.1 Analysis of how these conditions impact building design and energy consumption:

In architectural design the knowledge of microclimate elements is important: wind and local breezes, sun and shadows, humidity and vegetation, etc if well utilised, can strongly contribute to the thermal well-being of the inhabitants. If these elements are manipulated by the creativity of the architect they often inspire new architectural shapes: therefore an accurate knowledge of local climate factors and of the thermal characteristics of construction materials must be part and parcel of the architect's background information and a source of inspiration in the creative process.

- Radiation, solar exposure and fenestration:

Due to solar radiation's large intensity compared with terrestrial sources, solar heat control is critical in summer months, especially. Most often, light-coloured or reflective exterior coatings are used as a means for this. Finally, careful architecture can reduce the impact of sun exposure by providing fenestration orientation and scaling, as well as the optimal placement of solar shading devices.

Effective solar control must also consider the daily path and the apparent seasonal path of the sun. Though site investigations are often required for special analysis, the following are general design guidelines:

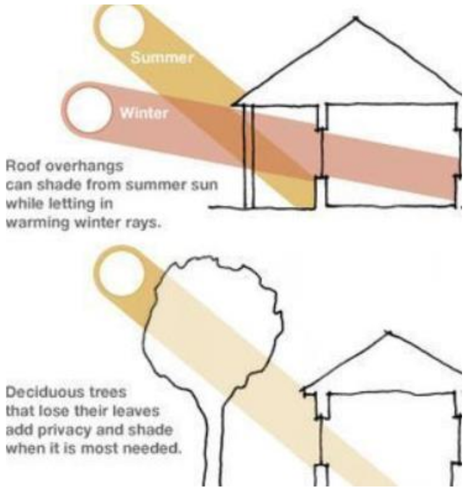


Figure 49 Diagram showing solar shading from trees and overhangs/ source: https://www.pinterest.com/pin/805299977094828888/

North-facing buildings (in the Southern Hemisphere; opposite for the Northern Hemisphere) are most subject to passive solar control. These can usually be shaded in summer with moderate roof overhangs or horizontal projections, but still allow useful winter sun penetration due to the lower angle of the sun.

Where overhangs are not sufficient, exterior wall faces have to be painted white to maximize reflectivity and minimize absorption of heat. North-facing windows need to be shaded on the exterior with architectural elements such as shutters, louvres, or awnings, or with the help of deciduous cover, which shades in summer and provides solar access in winter after leaves fall.

East and west facades are the most problematic to protect against solar radiation due to the steep sun incidence angle in the morning and afternoon. Thus, these aspects need to be minimized in design and glazing on them should be curtailed or done away with wherever possible.

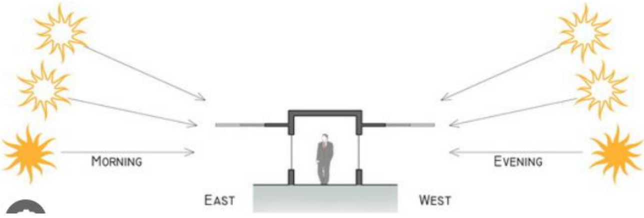


Figure 50 HORIZONTAL SHADING DEVICES / source: https://in.pinterest.com/pin/422142165075520695/

By using these principles, undesired heat gain can be lowered considerably in buildings, increasing thermal comfort while lowering the dependence on mechanical cooling systems.

- Conduction, insulation and Heat capacity:

In hot, dry climates with big diurnal temperature ranges, a thick building envelope made of materials such as brick, adobe, concrete, or stone can go a long way in moderating interior temperatures. These materials store heat in their mass and transfer it slowly from the hotter to the colder side. Under transient conditions initially, the heat transfer rate is less than that which would be expected on the basis of thermal resistance alone. Following thermal equilibrium (steady-state) having been achieved, the heat transfer proceeds at a predictable rate—though comparatively slow for high-mass materials.

For optimum performance, the envelope's thickness can be regulated to harmonize with local temperature cycles, with the aim of damping and retarding internal temperature variations. In the desert or temperate climates, outside air can become very hot during the day. As the heat gradually works its way inward, night falls, and outside temperatures drop, allowing trapped heat inside the building to reverse direction and gradually work its way outward In areas with extreme diurnal temperature fluctuations, i.e., hot and dry climates, the building envelope plays a critical function in modulating indoor thermal conditions. During the daytime, the envelope's

thermal mass—constructed from high heat capacity materials such as concrete, stone, or adobe—slowly absorbs and retains heat, delaying its transmission indoors. As the ambient temperature falls at night, the stored heat is slowly dissipated, traveling back in the direction of the cooler outside.

This thermal lag not only reduces excessive heat gain during the day but also reduces heat loss from the interior at night, thereby moderating indoor temperatures.

Conversely, in hot and humid climates where nighttime temperatures remain high, building envelopes should be constructed using materials of low thermal mass. This enables the building to respond rapidly to any cooling breezes or slight reductions in temperature, improving thermal comfort. Natural or mechanical ventilation is typically required in these climates to reduce air temperature and also humidity levels. The exterior surfaces must also be finished in materials or coatings with high reflectance of solar radiation, thereby limiting heat gain and optimizing thermal performance.

- Air movement, convection and ventilation:

Except in the case of unusually high ambient air temperatures, air movement generally benefits cooling by augmenting conductive, convective, and evaporative heat loss from the body. It is thus generally more energy efficient to augment natural air flow or to circulate interior air than to rely solely on mechanical cooling systems. Air movement, both natural and mechanical, not only regulates interior air temperature and humidity but also assists in odor and noise removal.

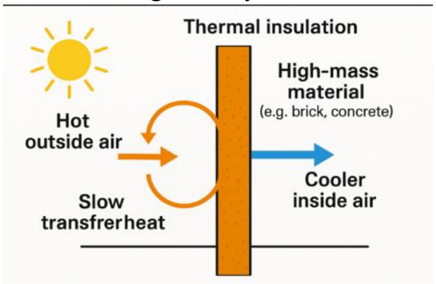


Figure 51 Conduction, insulation and Heat capacity source: https://chatgpt.com/

Natural ventilation within a building is caused by two principal forces, namely wind and thermal (or convective) effects. While wind generally predominates over convection, each process drives the air from a high-pressure area to a low-pressure area. As wind impacts the shape and orientation of the building, pressure differences across the envelope are induced. To achieve effective natural ventilation, designers can place air intakes in regions of high pressure and outlets in low-pressure zones created by wind flows.

Thermal-forced (convective) ventilation results from gradients of air density between cold and hot air. As these forces are relatively weaker compared to wind, larger openings tend to be required in order to facilitate effective airflow. Operable windows find application in most building configurations for managing volume, velocity, and direction of natural ventilation.

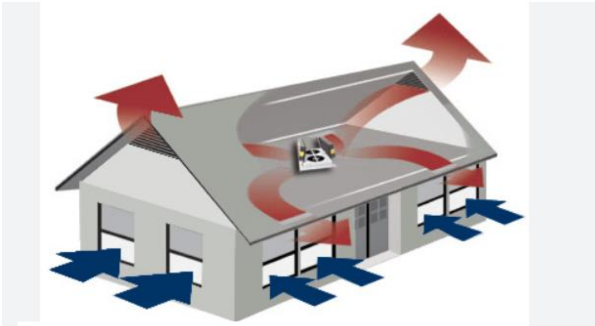


Figure 52 Natural ventilation within a building / source: https://www.ecomena.org/

Roof ventilators—such as the ones installed in Dome A—are advantageous in aiding supplementary vertical air flow in buildings.

In hot climates, both convective and wind-driven ventilation is essential in lightweight structures, which have little thermal mass as well as insulation. These structures are highly susceptible to overheating due to solar radiation and internal heat gains from human activities such as cooking, bathing, and even respiration.

High ventilation rates during winter are not wanted in cold climates, since they normally lead to enormous losses of heat. The extent of convective heat loss is typically calculated on the basis of peak wind speeds, so that naturally wind-sheltered buildings conserve more energy and require less heating. Furthermore, such wind shelter preserves the thin insulating air film that clings to the exterior of the building, which can be dispersed by high winds. Sheltering also reduces the impact of wind-borne rain, minimizing moisture penetration into the building envelope.

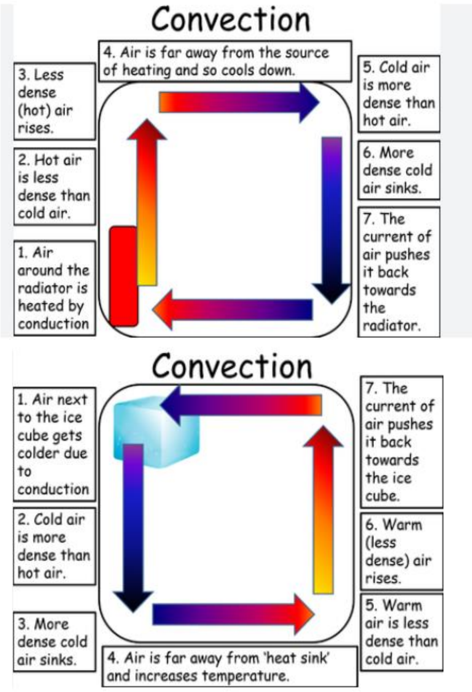


Figure 53 About Convection / source: https://keystagewiki.com/index.php/Convection

The convective air flow within a building depends on climatic conditions outside and thenvelope thermal response. For example, if internal air comes into contact with a fairly cool surface, its density increases and it descends to the floor, cooling even more as it goes. Simultaneously, warmer air towards the middle of the room ascends to occupy the cooler air's space, establishing a convective cycle. This flow is reversed when the envelope has been sufficiently heated to heat the surrounding air at the perimeter, which rises and pushes cooler air that falls close to the center of the building. Similarly, solar-heated surfaces generate new internal convection currents. Wind-driven ventilation and fan operation can also interact with and modify these natural convective currents.

- Relative humidity and condensation:

Relative humidity is a percentage that is a measurement of the water vapor content in the air relative to its maximum capacity at a specific temperature. This relative humidity can be decreased by increasing the air's temperature. When the air temperature drops to the point where relative humidity reaches 100%, the temperature at this stage is referred to as the "dew point." When the temperature drops below this

Figure51 : About Convection / source: https://keystagewiki.com/index.php/Convection

point, the excess water vapor condenses, forming fog or dew, as one may observe on window panes in cold weather.

The most significant condensation issues arise when there is an insulated barrier between warm, humid air on one side and cold, dry air on the other. In such circumstances, in winter particularly, a warm, moist indoor environment from sources such as breathing, cooking, and bathing is likely to condense. This is especially true where there is ample winter rain. In hot, humid climates, the same scenario can cause condensation in air-conditioned, dehumidified structures. The more water content in the air, the higher the vapor pressure, which drives water vapor from areas of higher vapor pressure to areas of lower vapor pressure. When there is warm moist air on one side of a wall and cool dry air on the other, water vapor flows through the wall from the wet side to the dry side. As the vapor moves through the wall, the dew point temperature progressively decreases. The temperature within the wall also progressively decreases from the warm side to the cold side, depending on the thermal resistance of the wall layers.

Wherever the wall temperature is less than the dew point, the excess water vapor will condense, creating a local decrease in vapor pressure. Water vapor from the surrounding high-pressure areas will migrate to the condensation point until the pressure or temperature difference is reduced to the point where the condensation will cease.

To prevent any insulating material within the wall from becoming moist, it is necessary to have a vapor barrier—a plastic or metal foil sheet that is continuous, for example—between the insulation layer and the warm side of the wall, in as close a position as possible to the latter. Proper ventilation on the cool side of the wall will also permit moisture to drain from that surface, preventing issues of condensation.

Conclusion:

Arid environments, with all their intricate ecological complexity, are marked by the challenge of extreme aridity—extensive irregular precipitation, high solar radiation, low humidity, and large diurnal temperature ranges. These harsh climatic conditions are stringent limits for buildings, with a requirement for climate-conscious, resource-using, and culturally sensitive design strategies.

The fundamental challenge in arid environments is achieving thermal comfort while minimizing energy consumption. Building design must therefore address four primary climate factors: radiation, conduction, convection, and humidity. Passive design strategies—rooted in both vernacular wisdom and scientific principles—are essential.

Solar radiation is managed using careful orientation of buildings, shaded windows, reflective materials, and exterior shading devices excluding hot summer sunlight and allowing winter light. Materials with thermal massing such as adobe, masonry, and concrete are used to collect heat on a daily basis and then release it at night, hence reducing changes of temperature through thermal lag. The envelope is now an active buffer between stressful exterior conditions and comfort in the interior.

Natural ventilation is an important part, depending on wind pressure and thermal convection to remove internal heat and drive airflow. Ventilation depends on the shape of buildings, their orientation, and placement of openings, intakes, and outlets. In light buildings lacking thermal inertia, this ventilation is crucial to prevent overheating.

Humidity and condensation are secondary concerns. Although dry climates usually have little atmospheric moisture, sharp temperature variations between the indoor and outdoor will still result in condensation—especially where insulated or air conditioned. Effective vapor barrier placement, adequate ventilation, and multiple wall assemblies are required in preventing moisture buildup that can compromise materials and indoor health.

In brief, excellent architecture in dry climates is not a question of resisting the climate, but conforming to it. That means using climate microclimates knowledge, embracing local materials, drawing on passive energy flow, and trading thermal inertia off against ventilation. A close understanding of the dynamic interaction between heat, air, and moisture and form and material allows architects to create buildings that are habitable, long-lasting, and economical with energy in even the most adverse climates on the planet.

1.4 sustainable architecture and smart building technologie:

The last few years have witnessed the concept of sustainability emerging as a shared goal among numerous fields. Some of the milestones of the movement include the First International Conference on Sustainable Construction in 1994, which was held in Tampa, Florida. This conference brought together individuals across various fields to interact and explore various approaches for the definition of sustainable construction.

Charles Kibert gave a fundamental principle for building higher consensus within the sustainable construction sector during the conference. He defined sustainable construction as:

"The creation and operation of a healthy built environment based on ecological principles and resource efficiency"

(Kibert, 2007, p. 595).

This definition revolves around making sure that the built environment is compatible with the ecological systems and optimally utilizing the resources. Pinheiro (2006) reports that the most critical resources for sustainable building are materials, soil, energy, and water—each of which must be professionally taken into consideration and managed throughout the process of building.

building design begins with a deep understanding of the site—its natural beauty, complexities, and ecological context. Ecological design attempts to integrate any new systems that are being added into the natural functions already present in the site. Such ecological processes—performed by nature—are providing habitats, monitoring the path of the sun, purifying the air, collecting, filtering, and storing water.

Through inspiration from these ecosystems, building designers can put elements in structures that emulate or complement various ecosystem functions. For example, artificial buildings can be engineered to possess features that reflect natural environments, and this enables species that thrive in the natural world to adapt and thrive in the urban environment. Constructing such environments in cities is of particular importance for survival and preservation of biodiversity and ecosystem wellness (Thomas, 2009).

Suistainable building employs several basic principles, strategies, and technology, which are divided into five key elements:

Sustainable Site Design

- Conserves natural existing features
- Minimizes site disturbance
- Increases biodiversity and reduces environmental footprint

Water Conservation and Quality

- Encourages water conservation
- Collects and reuses rainwater
- Purifies water through filtration and natural processes

Energy and Environment

- Encourages energy efficiency
- Incorporates renewable energy sources
- Reduces greenhouse gas emissions

Indoor Environmental Quality

- Improves occupant health and comfort
- Employs natural ventilation and daylight
- Minimizes indoor air pollutants and thermal comfort improves

Materials and Resources Conservation

- Fosters the utilization of local, renewable, and recycled materials
- Reduces construction waste
- Triggers life-cycle thinking in material selection

Overview of smart building technologies and their role in energy efficiency.

smart building technologies use data and correspondence innovations (ICT) to empower mechanized building tasks and control. They can improve tenants' solace and efficiency while utilizing less energy than a customary structure. While regular structures have frameworks working autonomously, shrewd structures use ICT to associate structure frameworks together to upgrade activities and entire structure execution.

Savvy structures likewise permit administrators and tenants to connect with the structure, giving perceivability into its activities and noteworthy data. Furthermore, savvy structures can speak

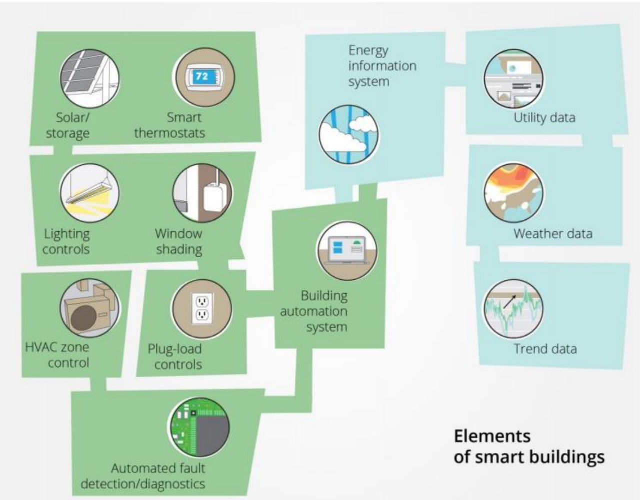


Figure 54 Elements of smart building / source: https://www.researchgate.net/figure/Overview-of-smart-building-technologies_fig1_356542711

with the power framework, an element that is turning out to be progressively significant for utility interest reaction sending. Albeit the best entrance of shrewd advancements in existing structures has been in workplaces, their utilization is filling consistently in all structures types.

- Air conditioning. Shrewd warming, ventilation, and cooling (central air) frameworks utilize various sensors for observing and control. Programming deciphers data from different sensor focuses to upgrade the air conditioning framework's activity while further developing tenant solace. Shrewd air conditioning controls can restrict energy utilization in abandoned building zones, distinguish and analyze blames, and decrease central air use, especially during seasons of pinnacle energy interest.
- Lighting smart lighting comprises of cutting edge controls that integrate daylighting and high level inhabitance and darkening capabilities to wipe out overlit spaces. Luminaire lightlevel controls are quickly creating and earning market respect. Request reaction programs are boosting step and consistent darkening control. Brilliant lighting system can be controlled remotely and planned into lighting the executives frameworks. Remote controls work with more straightforward retrofits, while lighting the board stages let clients access controls through electronic dashboards.
- Plug loads. Plug loads incorporate the many kinds of compact office and various hardware in structures. In existing structures smart attachment load controls comprise of autocontrolled containers and plug extensions that depend on time booking, movement detecting, or burden recognition to totally remove capacity to gear that isn't being used. Some brilliant plug extensions can detect the essential burden, like a PC, and work fringe gadgets as needs be. For concentrated control, plug load timetables can be customized into lighting and building the board system (BMS).
- Window concealing smart window system deal with how much sun based intensity and light that enters the structure. System, comprise of latent and dynamic window coating and movies that answer changes in daylight or temperature, and auto-controlled conceals that are booked to work at explicit times to control light levels and sunlight based heat gain. In retrofits, shrewd concealing advances have the best energy-reserve funds likely in structures with untinted, single-sheet windows.
- Computerized system advancement. While a conventional structure mechanization system (BAS) depends on preset timetables and set focuses for building tasks, robotized system enhancement (ASO) depends on constant criticism. ASO utilizes ICT to gather and dissect building system functional and energy execution information and roll out expectant improvements in tasks in light of outer factors, for example, inhabitance designs, weather conditions estimates, and utility rates. Cloud-based remote structure observing is filling in prominence. This approach lets building administrators (or outsider energy administration merchants) screen building execution through electronic energy the executives stages.
- Human activity. Administrators can communicate with a savvy working through PC dashboards — easy to use intuitive presentations of building tasks and energy use. Dashboards permit the structure administrator to dissect all building information midway and get cautions on deficiencies recognized

Benefits of smart technologies for energy consumption:

- Cost Reserve funds
- Brilliant innovation can assist with cutting all out energy uses and service bills by advancing energy
- utilization and limiting waste. Clients might track down ways of limiting expenses and fortify
- their monetary manageability by having the option to screen and direct energy utilize all the more really.
- A decrease of 34.78% in power utilization, from 765,228.16 to 499,067.01 kWh, was made
- conceivable by savvy structures (Energy Saving in Shrewd Structures, 2023). By:

- Advancing energy utilization through continuous observing and the executives.
- Perceiving and settling energy-squandering rehearses; these shrewd advances can help

- lower energy costs.
  - Incorporating energy-saving strategies and innovation
  - Scaling back energy use during active times
- Natural Manageability
- By consuming less energy and emanating less ozone depleting substances, shrewd advances advance
- natural manageability. Shrewd innovation might diminish the ecological impact of
- structures and assist with making a more economical future by empowering the utilization of environmentally friendly power
- sources and energy effectiveness. Brilliant energy the executives advancements are fundamental for
- advancing natural supportability in savvy urban areas. By advancing energy utilization,
- incorporating environmentally friendly power sources, and advancing practical transportation, these
- innovations can assist with decreasing the ecological effect of metropolitan regions and add to a more
- feasible future (Harmony et al., 2021). Lessening ozone harming substance emanations is one of the
- ecological advantages of brilliant structures (Henderson and Henderson, 2022). This is
- achieved by further developing energy utilization observing and dealing with the carbon
- discharges of materials associated with CO_2. By:
  - Cutting ozone depleting substance outflows and energy utilization.
  - Empowering the utilization of sustainable power sources, savvy innovation can increment
- natural supportability.
  - Advancing maintainable structure techniques and materials; improving energy
- proficiency and cutting waste
- Further developed Solace and Efficiency
- By advancing structure frameworks like lighting, warming, and ventilation, savvy innovation may
- increment tenant solace and efficiency. Shrewd innovations can deliver a
- more agreeable inside climate and alter settings as indicated by human inclinations,
- accordingly working on the personal satisfaction or working circumstances (Savvy Home Innovation for
- More Solace, n.d.). To amplify building proficiency and diminish ecological
- influence, savvy structures ensure that energy use is followed and overseen continuously. Brilliant
- innovation can expand solace and efficiency through:
  - Further developing temperature and lighting conditions.
  - Giving constant contribution on stickiness and indoor air quality
  - Working on the general solace and feel of the structure
  - altering building frameworks in light of inhabitance and client inclinations.
- Improved Dependability and Versatility
- Brilliant innovations, which screen execution, distinguish deserts, and recognize potential worries
- continuously, can expand the strength and steadfastness of building frameworks. Savvy

- innovation can save free time and increment framework steadfastness by empowering proactive
- support and investigating. Rather than just getting a good deal on support, savvy
- structures utilize contemporary innovation to associate safe, harmless to the ecosystem, and
- useful viewpoints in a more coordinated, dynamic, and reasonable structure (Plc, 2023). Through the
- following strategies, savvy innovation can further develop strength and dependability:
    - Following structure frameworks and distinguishing any issues.
    - Giving quick criticism on the usefulness of the framework
    - Working with preventive upkeep and investigating
    - Improving generally speaking framework uptime and trustworthiness
- Information Driven Independent direction
- Brilliant innovations give shoppers helpful data about building execution and energy
- use, engaging them to pursue information driven choices to amplify energy use. Clients might apply
- explicit energy-saving measures and track the effect on utilization by dissecting energy information
- also, spotting designs. Brilliant designs understand that an office's general expense incorporates not simply the
- building's development yet in addition its continuous activity and upkeep costs (Elliott, 2022).
- Information driven direction might be helped by brilliant innovation in the accompanying ways:
    - Giving continuous information on building execution and energy use
    - Investigating energy information to recognize patterns and examples
    - Enabling customers to go with information driven decisions to augment their energy

Conclusion:

Sustainable design and intelligent building technologies together offer a revolutionary paradigm of thinking about how we create, build, and maintain the built environment. Taking its cues from natural ecological systems and optimal use of resources, sustainable architecture attempts to harmonize human activities with nature by preserving biodiversity, conserving valuable resources, and minimizing environmental impact. At the same time, intelligent technologies build on these ideals by embedding intelligence within buildings—streamlining energy use, reducing operating costs, and improving occupant comfort.

Intelligent technologies such as automated heating, ventilating, and air conditioning, lighting, plug load control, and window shading systems collaborate with green strategies to create buildings that are not only energy-efficient but also adaptive, resilient, and user-centered. Real-time data aggregation and performance tracking allow stakeholders to make intelligent decisions based on data, optimizing energy saving while maintaining long-term performance.

Through combining ecological consciousness and technological innovation, the integration of smart systems and sustainability introduces an increasingly sustainable and regenerative built environment. Through being holistic in its thinking, this synergy is critical in addressing the environmental concerns of today, making the economy sustainable, and enhancing the quality of life of both present and future generations

1.5 The concept of smart dome

Exploring future forms of habitation reveals one of the most grave concerns for architecture. When nature demands instant responses, ideas such as domed cities become evident. These structures embody a potential response to environmental volatility, wherein innovation converges with resilience (Sterling, 2010).

Domed cities are huge enclosed areas, climate-controlled and pressurized beneath a transparent or opaque dome. Like the outer skin of a home, these types of domes isolate and shield occupants from extreme or toxic external environments and enhance visual contact with greenery (Adonina, 2020).

Historically, the concept reaches back to literature in the 19th century and the dawn of science fiction. Mary Griffith's Three Hundred Years Hence (1836) detailed underwater glass-domed communities. Domes have since that time been envisioned as utopian refuges or dystopian shelters that protect inhabitants from pollution, war, and climatic catastrophe (Bleiler & Bleiler, 1990; Chu, 2018).

With the technology booms of the 1960s and 70s, domed city discussions gained speed. In the coming era of heightened climate change and energy scarcity worries, their feasibility returned into consideration in the 21st century. Sensor networks and digital integration nowadays bring the feasibility of domed cities to a new plane, in combination with the ideas of smart cities.

These designs possess numerous benefits: more pedestrian-friendly spaces, reduced energy demands, and stable internal climates. They can potentially reduce the impacts of climatic variability to a minimum while optimizing health and comfort. While examples at large scale are yet to be realized, small-scale experimental schemes indicate that the era of domed habitation might be forthcoming (Lovelock, 2000).

1.5.1 Evolution of Domes in Architecture:

The evolution of domes plays a significant role in architectural history worldwide. Shapes and construction techniques reflect cultural, technological, and aesthetic evolution with time.

Persian Domes: Persian domes began in Mesopotamia and evolved with innovations such as squinches and brackets for transition from square bases to circular domes. Inner shells were typically semi-circular or pointed, while outer shells were bulbous and conical.

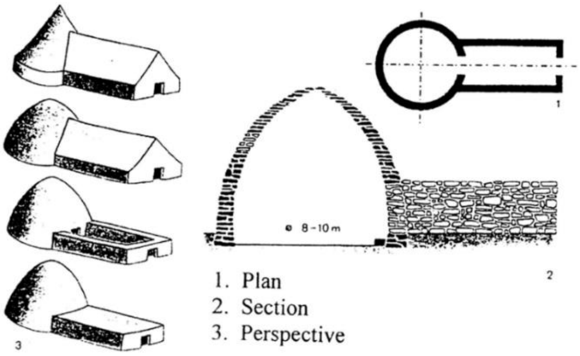


Figure 55 Drawing of shelters found in the excavation of Mesopotamian shelter/ source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

Examples are mud-brick domes of the Achaemenid period, wooden domes of the Parthian Empire, and stone domes with plastered interiors of the Sasanian period.

The Samanid Mausoleum brought regular octagonal bases, which influenced Islamic architecture.

Figure 56 Ruins of the Sarvestan Palace / source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

Roman and Byzantine Domes: Roman engineering with concrete made possible gigantic domes, such as the Pantheon.

Figure 57 Pantheon/ source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

The initial domes were shallow and featured oculi. Byzantine domes, such as those found in Chora Church and the Pantokrator complex, became taller, more complex, and structurally advanced, often supported by pendentives.

Figure 58 Dome at Chora Church / source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

Italian Renaissance: Renaissance architects revived classical dome construction with mathematical precision. Brunelleschi's dome for Florence Cathedral, built with interlocking shells, remains the largest masonry dome. Ribbed and spoked-wheel designs dominated this era.

Figure 59 Santa Maria del Fiore / source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

South Asian Domes: The Islamic period introduced the dome to South Asia, with design evolving from the Tomb of Balban to Mughal marvels like Humayun's Tomb and the Taj Mahal. Domes here employed brick cores, concrete shells, and architectural ornamentation like chattris. Sikh architecture subsequently adopted ribbed domes based on lotus motifs.

Figure 61 Humayun's Tomb/ source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

Figure 60 Figure58: Taj Mahal/ source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

Modern Domes: The Industrial Revolution gave us iron and steel, making it possible to build gigantic domes like Kazan Cathedral .

Figure 62 domes like Kazan Cathedral / source: https://www.re-thinkingthefuture.com/architectural-styles/a2615-evolution-of-domes-in-architecture/

in the 20th century with the geodesic dome. The geodesic dome is a series of equilateral triangles that form a thin-shell structure. The combination of the triangle and the sphere in geometry results in a system that is very strong, light, and self-supporting.

This arrangement has several advantages:

Structural strength and durability.

Material efficiency.

Sustainability.

Figure 64 : The geodesic dome / source: /ArtigoTheskaAHFE2017.pdf

Figure 63 Panoramic view of Eden Project domes / source: /POWEROFDOMESINARCHITECTURE.pdf

1.5.2 Benefits of domes in terms of structural integrity and thermal regulation:

Strength of Dome Structure Domes are among the most efficient and long-lasting architectural buildings due to the inherent geometric strength. Its rounded, self-contained form offers even distribution of structural loads with minimal stress points and maximum stability. Unlike typical flat or angular roofs, a dome defends against exterior pressures such as wind and seismic forces on its own. It is especially reliable in regions that are prone to hurricanes, earthquakes, and other devastating weather conditions.

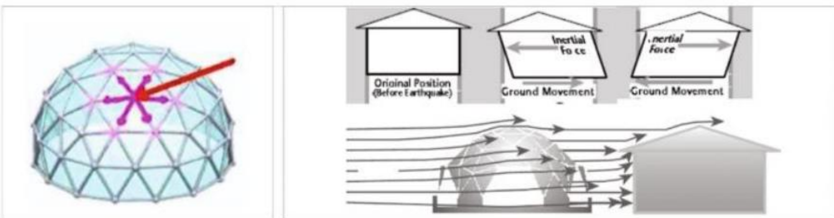


Figure 65 Strength of Dome Structure / source: /ArtigoTheskaAHFE2017.pdf

The dome shape allows for gigantic interior volumes to be obtained without the need for interior columns or bearing walls. Strength is also augmented with size and can be made to change with materials utilized and constructions used, making it versatile and durable.

Thermal, Acoustic, and Luminous Comfort

Domes provide better thermal comfort through natural currents of air created by their dome shape. Warm air that rises is distributed efficiently, reducing zones of heat or cold inside the building. This makes the internal temperature more constant and warmer, reducing the requirement for mechanical heating or cooling.
The minimal surface-area-to-volume relationship of domes inhibits heat exchange with the external environment, retaining interior heat in the winter and coolness in the summer. Domes may incorporate reflective material that reflects radiant heat inward—an advantage in cold climates.
Translucent or glazed panes are utilized by numerous dome structures to produce greenhouse conditions. They allow light but retain heat inward, making domes suitable for plant culture, environmental shelter, and energy-conserving residential applications.

Environmental Efficiency and Air Quality

Due to their shape, domes are ideally suited for the integration of passive solar energy methods. They can be constructed to capture the most solar gain, warm and sunny by nature during the day. Systems such as wood stoves, solar heaters, or radiant floor systems can be easily integrated to further extend the energy-efficient system of the dome.
Domes are also capable of excellent natural ventilation. High and low strategic openings permit effective air exchange, which prevents stagnation of the air, reduces humidity, and limits the growth of
mold and bacteria. Such a characteristic allows them to operate in spaces required for odor control and air cleanliness, such as workshops or kitchens.

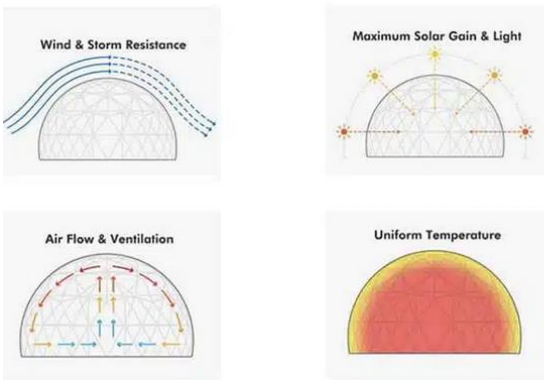


Figure 66 thermal comfort avd air quality/ source: https://www.csuohio.edu/sites/default/files/61A-The%20Unique%20Properties%20of%20the%20Geodesic%20Dome.pdf

Acoustic and Lighting Performance

Domes are also very good at sound. The curved interior of the dome reflects and redirects sound waves in a more even manner, allowing for greater clarity and volume. This has made domes in demand for use in auditoriums, houses of worship, and performance halls. The structure can also isolate external sounds to create a quiet inner environment.

Natural light is also a strength of dome design. Skylights and strategic placement of windows along the curved surface admit an abundance of daylight deep into the interior space. This reduces dependence on artificial lighting, reducing energy consumption and creating a healthy, well-lit environment. In off-grid or green configurations, LED lighting systems powered by solar panels can illuminate dome interiors at night.

Figure 67 Acoustic and Lighting Performance / source: /ArtigoTheskaAHFE2017.pdf

1.5.3 Smart dome systeme and environmental integration

Technologies for temperature regulation, solar shading, and ventilation within smart domes:

- Montreal Dome, Quebec, Canada (1967)

The Montreal Dome, as seen in Figure 19, is a novel architectural dome in Parc Jean-Drapeau on Île Sainte-Hélène, originally constructed as the United States Pavilion for Expo 67. The dome was the design of Richard Buckminster Fuller and is an embodiment of his geodesic architectural theory. It was constructed as a Class 1, Frequency 16 Icosahedron with a steel framework and acrylic panels, forming a closed system with a controlled internal environment.

Figure 19 Expo 67 or Montreal dome is a geodesic dome designed by Buckminster Fuller and built by steel members and acrylic cells. (courtesy of Houghton Harcourt)

Figure 20 Zoom view on Montreal dome shows the repeating steel icosahedrons covered by acrylic cells. (courtesy of Houghton Harcourt)

Figure 21 Plan of Montreal dome shows the multi functions inside one space. (courtesy of Houghton Harcourt)

Figure 68 Montreal Dome, Quebec, Canada (1967) / source: /POWEROFDOMESINARCHITECTURE.pdf

The dome's structural system was made up of triangular and hexagonal steel modules draped with plastic, creating the effect of a multifaceted jewel when sunlight passed through. The interior featured a complicated shading system that controlled the temperature, while the spatial organization involved four immense thematic platforms on seven levels.

Tragedy occurred when, on May 20, 1976, a fire while undergoing renovations destroyed the acrylic coating; the steel structure, however, remained intact. In August 1990, Environment Canada recycled the location as an interactive museum devoted to ecological concerns, in this case, water environments. Exhibits cover climate change, air quality, eco-technologies, and sustainable development.

This dome was built according to Fuller's Dymaxion principle—a term he coined by combining "dynamic," "maximum," and "tension." The geodesic dome operates on the principle of "continuous tension and discontinuous compression," where individual compression members are hung within a continuous network of tension members. The underlying geometry, derived from an icosahedron, subdivides pentagonal shapes into smaller triangles, with all nodes existing on a shared spherical surface (Figure 20). The design , presents a multi-functional megastructure consolidated in a single space.

- Reichstag Dome, Berlin, Germany (1999) The Reichstag Dome, shown in Figure 66, is a domed glass structure on the roof of the reconstructed Reichstag building in Berlin, symbolizing the reunification of Germany. The dome, which was designed by architect Sir Norman Foster, offers a 360-degree view of Berlin and allows direct visual contact with the parliamentary chamber below, symbolizing the democratic principle that "the people are above the government."

Figure 69 Elevation of Reichstag shows the Foster's dome on the top of the building / source: /POWEROFDOMESINARCHITECTURE.pdf

Two spiral ramps twist upwards within the dome, evoking a double-helix, to a viewing platform and symbolically unite transparency and civic engagement. Foster integrated novel environmental elements into the dome's design. A mirrored cone at the center (Figures 67–68) deflects sunlight down into the plenary hall beneath, and simultaneously disperses visitors' reflections into multiple

facets, metaphorically representing the people's unity and diversity.

Figure 71 Elevation of Reichstag shows the Foster's dome on the top of the building / source: /POWEROFDOMESINARCHITECTURE.pdf

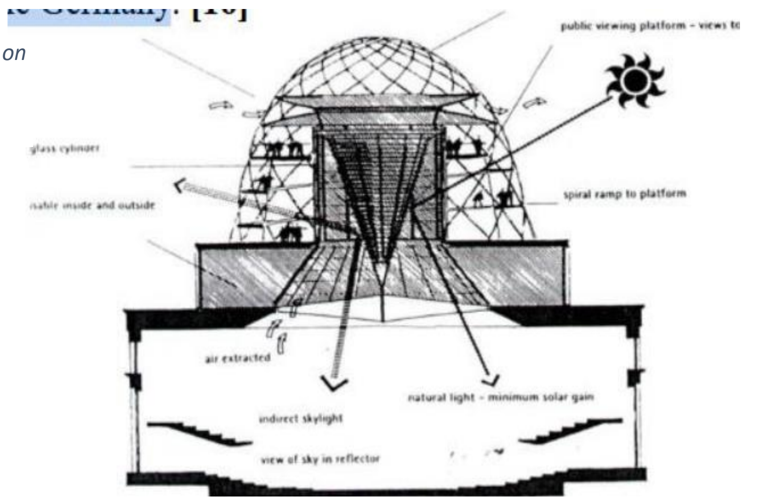


Figure 70 The mirrored cone in thebcenter of the dome transfers sunlight into the parliament hall through the inner dome / source: /POWEROFDOMESINARCHITECTURE.pdf

This is supplemented by a large kinetic louver system (Figure 69) that closes electronically to keep out excessive sunlight, minimizing solar heat gain and glare. These green design

features significantly reduce the carbon footprint of the dome, making it not just a technological but also a symbolic landmark for Germany's transformation from its troubled past to its democratic and green present.

Figure 72 The photovoltaic kinetic louver obstructs entering the direct sunlight . source:/POWEROFDOMESINARCHITECT

- Sony Center Dome, Berlin, Germany (2000)

Completed in 2000 and situated at Potsdamer Platz, the Sony Center is a modern architectural concept in Berlin's urban landscape. Helmut Jahn, by novel structural engineering, has influenced the design of the dome to adhere to the function of a folding beach umbrella.

The construction of the dome includes:

Peripheral support by the roofs of neighboring buildings.

A ring truss of steel supported on these

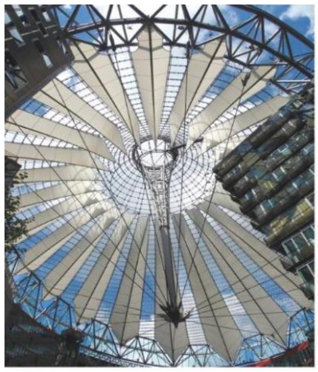


Figure 73 Interior view of Sony Center dome shows the tensile structure system and the teflon sails/ source:/POWEROFDOMSSESINARCHITECTURE.pdf

A flying king post in the middle, braced by steel tension cables, which are tied both to the

ring and to the post, creating kinetic equilibrium.

A roof canopy made of Teflon-coated textile sails and glass units (16 mm thick, with an area of 3,500 m²), hung over the cables.

The roof rises to a height of 67 meters and is 102 meters in the main axis and 77 meters in the secondary axis. It is 50% average translucency and allows ambient daylight with responsiveness to solar conditions.

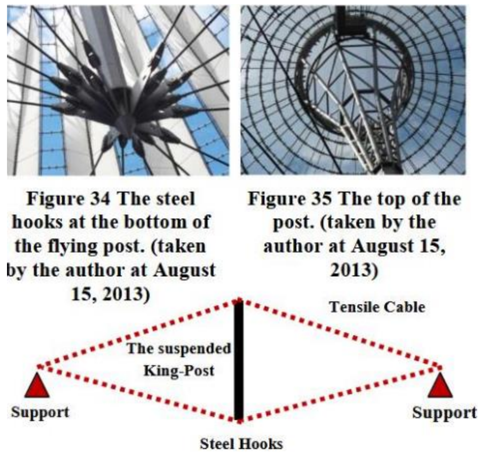


Figure 74 A flying king post in the middle, braced by steel tension cables, which are tied both to the ring and to the post, creating kinetic equilibrium source:/POWEROFDOMESINARCHITECTURE.pdf

The Sony Center functions as an urban agora, blurring public and private realms. The interior creates a 'virtual city' within versus the traditional city without. Architectural thresholds—through gates and passageways—evoke a metaphoric passage into the digital from the real age.

Design emphasizes luminosity over illumination, using façades and the roof as active screens filtering and modulating natural and artificial light. The self-cleaning Teflon sails incorporate solar sensors that respond automatically to sunlight intensity, optimizing energy efficiency and thermal comfort. At night, the sails illuminate the space with vivid light projections, transforming the dome into a kaleidoscope of color and motion, reminiscent of a spaceship. As a sponsored project by Sony, the center creates a new concept of public space that welcomes the sophistication of modern cultural, social, and technological interaction

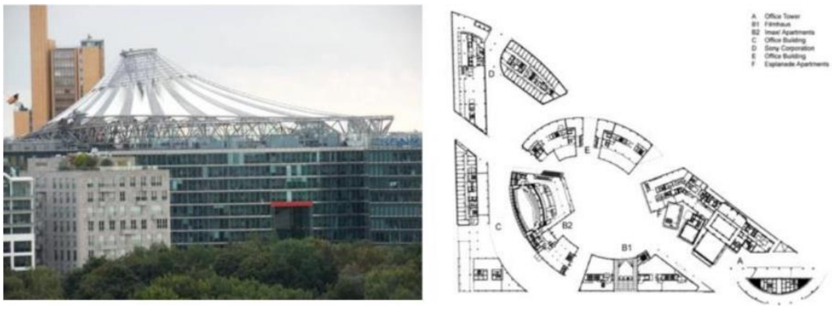


Figure 75 The Sony Center functions / source:/POWEROFDOMESINARCHITECTURE.pdf

	. Montreal Dome (1967) – Buckminster Fuller	. Reichstag Dome (1999) – Norman Foster	Sony Center Dome (2000) – Helmut Jahn
Temperature Regulation:	Controlled internal environment: The dome was originally a closed system intended to have a uniform indoor climate. Complicated shading system: The interior had systems to control solar gain and heat.	Reflected cone in the center bounces and disperses the natural light within the parliamentary chamber, reducing the utilization of artificial lighting and heat sources. Kinetic louver system manages the solar gain actively by closing electronically when responding to sunlight intensity	Self-cleaning Teflon-coated fabric sails respond to solar radiation through solar sensors, maximizing heat control. The translucent materials manage heat gain without sacrificing ambient daylight.
Solar Shading	Acrylic panels and plastic draping created a jewel-like translucency, diffusing direct sunlight. Shading system assisted in maintaining internal solar heat gain	Kinetic louvers are used as dynamic solar shading to avoid excessive sunlight entering during high sun hours. The cone of mirrors also reduces glare and optimizes daylight use efficiently.	Teflon sails and 16 mm-thick glass modules reduce direct sunlight and glare. The 50% translucency provides light and protection balance, reducing overheating.
Ventilation	Although not strictly described in the text, geodesic design naturally encourages passive ventilation and, being a closed system, would have contained mechanical ventilation.	The structure encourages natural ventilation, with passive airflow up the dome and through spiral ramps, enhancing thermal comfort with minimal energy use.	The building promotes air flow in the open—not completely enclosed—using natural ventilation within the central courtyard space. Its design blurs indoor/outdoor boundaries, helping dissipate heat and avoid overheating.

Table 4 : summary Technologies for temperature regulation, solar shading, and ventilation within smart domes

Finaly the development of dome architecture—starting from ancient Persian, Roman, and Byzantine marvels to future geodesic shapes—testifies to the enduring value and flexibility of this form. With respect to contemporary environmental challenges, smart domes represent a meeting of ages between historical ingenuity and present technological innovation.

Smart domes are not design gimmicks; they are functional solutions for living in the future. Through the integration of intelligent climate-control systems, passive ventilation, solar shading, and adaptive materials, domes can create self-adjusting, energy-aware environments that adapt to shifting climatic conditions. Spaces like the Montreal Dome, Reichstag Dome, and Sony Center illustrate how shape, symbolism, and intelligent systems can come together to create sustainable, multi-use spaces that are both ecologically responsive and socially innovative.

Along with this, the structural strength, energy efficiency, and acoustic properties inherent in the dome make it the ideal answer to modern needs—ranging from green housing and labs to museums and public spaces. With growing urban populations and climatic pressure, the intelligent dome becomes not just an architectural form, but a revolutionary model for adaptive, resilient, and regenerative living.

Fundamentally, the smart dome is not shelter—it's a system. A synergistic architectural solution combining form, function, and future into a single integrated, self-contained form

1.5.4 Overview of materials suited for sustainable building in arid climates:

Clay

The use of the clay is found a almost everywhere on the globe. Thecomposition of the soil mixture as well that its implementation may vary

Figure 76 clay / source: https://www.teaching.com.au/product/creatistics-air-dry-ceramic-clay-8211-grey-10kg

THE TORCHIS

torchis is a mixture of earth and of cut straw or lawns. This mixture is applied to a reinforcement made of vertical piles and of a braiding of branches. In this case, the earth only plays a role of filling. The trochis is also used without reinforcement for the construction of domes or attics. The trochis is still used as a covering plaster of bricklaying.

Figure 77 the torchis / source: https://fr.wikipedia.org/wiki/Torchis

THE STONE

In a general way is the rock that is used, either in the raw state with a mortar, either cut to a sharp joint. In earthen construction, the stone is often used for the foundation of the walls.

Figure 78 the stone / source: https://fr.pikbest.com/backgrounds/stone-texture-textured-fa%3F%3Fade-a-close-up-of-the-unrefined-used-in-house-construction_9972666.html

THE BALL OF LAND

The earthen ball or columbine is a mixture of earth and straw, kneaded a the hand, the walls are mounted in spiral by successive beds. This process is characteristic of the construction of Sahelian granaries.

Figure 79 the ball of land / source: https://sciendo-parsed.s3.eu-central-1.amazonaws.com

LIME

Lime is obtained by calcination of the lime stone. Mixed with sand and water, it forms mortars that harden at the "eau.la manufacture of lime is done handcrafted in the ovens rudimentary or the temperature n"is that"approximate.

Figure 80 lime / source: https://ru.made-in-china.com/co_limemanufactory/product_Dry-and Hygroscopic_ysguoehhey.html

THE WOOD OF PALM TREE

The palm tree is a structural wood commonly used but which does not last not very longtemps.sa low

bending strength conditions the organization of the plan and the scopes between the walls can not protrude three meter.

Figure 81 the wood of plam tree / source: https://moroccanwoodworking.com/palm/

THE BAMBOO AND THE REED

Bamboo and reed are grown for construction. They are used in continuous beds laid on the beams to retain the groomed earth constituents the floors of floors. They are also used for making of braided mats or panels ligatures of roofs in the regions hot

Figure 82 the bamboo and the reed / source: https://www.architonic.com/fr/p/reeds-or-bamboo-ku-6-10mm-20117399/

THE BRANCHES

Several branches linked together allow to realize elements of frame when of palm made default. The intermingled branches constitute elements of claustre in the regions wet.

Figure 83 the branches / source: https://www.saemereien.ch/blog-jardin/creer-un-tas-de-branches

Conclusion

In this chapter, we learned that housing is more than just a shelter; it is about making people's lives better through comfort and well-being. We discussed in detail different aspects of comfort, including thermal comfort (being warm or cool enough), visual comfort (having good lighting), acoustic comfort (reducing unwanted noise), and ergonomic comfort (designing spaces that suit human bodies). Good housing design must carefully consider all these elements to provide a healthy, comfortable, and enjoyable place to live. We also saw how traditional architecture in hot and dry climates uses passive or natural design techniques, such as thick walls, shading, and natural ventilation, to create comfortable indoor environments without relying on electricity or complicated systems. These traditional solutions are valuable because they are energy-efficient and well-adapted to their environment. By understanding these comfort concepts and traditional techniques, architects can design better houses today. This knowledge helps us meet modern housing needs while also protecting the environment and reducing energy use

2. Chapter 2 : Analytical study

Introduction

This chapter provides a detailed look at real-life examples of houses in the Souf region, an area known for its hot and dry climate. We will first describe the local environment, including its natural and urban characteristics, to understand the challenges that builders face. Then, we will analyze specific cases of traditional dome houses, explaining how their unique designs help manage heat, sunlight, and airflow to keep the inside comfortable. We will discuss what makes these houses successful in terms of comfort and energy efficiency, as well as identify areas where improvements are needed. By examining these examples closely, this chapter will highlight valuable lessons from traditional architecture. These lessons can guide architects in designing new and smarter housing solutions that combine traditional wisdom with modern technology to meet today's comfort and sustainability goals.

2.1 Examination of smart technologies in architecture

<u>Analysis of smart technologies implemented in residential projects in hot, dry regions:</u>

Project Info Gate Residence

Architects: Vincent Callebaut Architectures
Location: Cairo, Egypt
Local Architects: K&A Design, Injaz Development
Surface Area: 450 000 M²
Client: Abraj Misr, Urban Development, Cairo, Egypt
Program: 1000 Appartments, Offices and Shopping Mall
Green Certification: LEED Gold Plus
Year:2019
Type: Mixed use, Offices, Retail, Residential

Figure 84 Gate Residence/ source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-

1. Windcatchers (Malqaf)

Windcatchers, also known as "Malqaf" in Egyptian traditional architecture, were early passive cooling devices in the 19th Dynasty, as seen in Neb-Ammun's Pharaonic house (British Museum). They were reintroduced into modern Neo-Islamic architecture by Hassan Fathy and are utilized as a renewable means of natural ventilation.

Windcatchers operate in three main ways:
Downward airflow with direct wind entry.
Creating upward airflow using wind-assisted temperature gradients.
Creating upward airflow using solar-assisted temperature gradients.
In The Gate Project, the 9 mega trees serve as large-scale windcatchers. Their possible environmental benefits are:
Increased passive cooling on hot, still days.
Increased night-time rates of cooling.

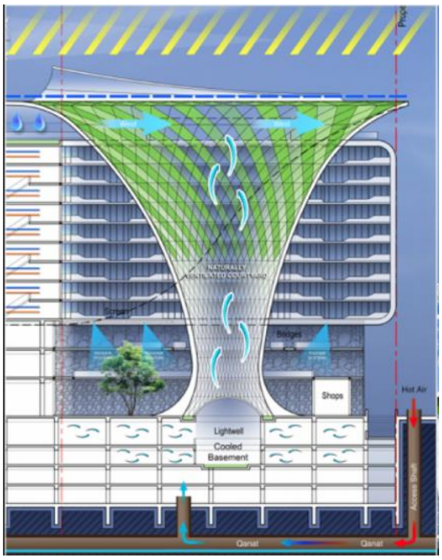


Figure 85 Windcatchers (Malqaf)/ source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette

Optimum use of thermal mass for temperature moderation.
Enhanced indoor comfort through more regulated airflow and reduced draughts.

2. Passive Geothermal Heating and Cooling

Passive cooling is concerned with heat gain and dissipation prevention using nature with minimal or no electrical power. A critical technique is the Canadian well system, where fresh air is circulated through ground pipes (2–3 meters deep), the earth's constant temperature being utilized to cool or heat air before it is supplied to a building.

In summer, the lower ground temperature reduces incoming air by 5–8°C, and in winter, pre-heats the air. The Gate Project proposes 1m² air shafts incorporated along building cores to naturally ventilate every apartment. Combined with geothermal heat pumps, this system provides sustainable climate control and hot water with very high energy efficiency.

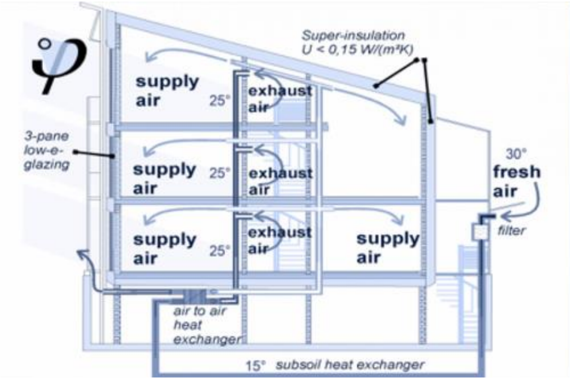


Figure 86 Passive Geothermal Heating and Cooling / source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette

3. Solar Photovoltaic Cells

Unlike conventional solar panels, innovative photovoltaic cells in The Gate Project also harvest ultraviolet light, enhancing energy harvesting capacity. Solar panels that can be walked upon will be used to cover the roof promenade, serving two functions:

Figure 87 Solar Photovoltaic Cells / source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette

Generating electricity. Providing shaded walkways and public spaces

Being part of a double-glazed setup for ensuring ease of maintenance, these cells will contribute immensely towards the energy independenc of the project.

4. Solar Water Heating Tubes

Solar hot water systems are a well-established and cost-effective renewable technology.

Solar-collecting glass-metal tubes will be installed on top of the elliptical roof enclosures above the mechanical rooms at each core. These systems will warm water for all of the bathrooms and kitchens for much of the year, reducing conventional heating.

Figure 88 : Solar Water Heating Tubes / source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette

5. Vertical-Axis Wind Turbines (VAWTs)

VAWTs feature ground-level generators and a vertical rotor shaft, which means they are very simple to maintain. New designs employ helical-twisted blades for smoother torque and reducing mechanical stress.

These turbines will be strategically located along the inner street of the roof, harnessing prevailing winds to generate electricity. In addition, a prototype called "The Phylolight"—a hybrid of an urban light pole and wind turbine—will be built along Nozha Street, showcasing an innovative energy-positive urban infrastructure solution.

Figure 89 Vertical-Axis Wind Turbines (VAWTs)/ source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette

6. Rooftop Community Gardens

Rooftop gardens enhance food security, social cohesion, and urban climate change resilience. They offer:

- Fresh leaves and fruit.
- Recreational and social spaces.
- Organic insulation and reduced heat island effect.
- The Gate Project envisions an active "garden in the sky" with:
- Food gardens and orchards.
- Playgrounds and sports courts.
- Social spaces for all residents.

This green layer not only compensates for the high density of the project but also provides thermal insulation and social coherence.

Figure 90 Rooftop Community Gardens / source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette

7. Green / Living Walls

Heat absorption and re-radiation by buildings aggravate urban heat islands. Living walls mitigate this by reducing surface temperatures by 4–5°C through transpiration by plants.
Other benefits are:

- Recycling of grey water by phytoremediation.
- Enhanced biodiversity and air quality.
- Less evaporation in dry climates.

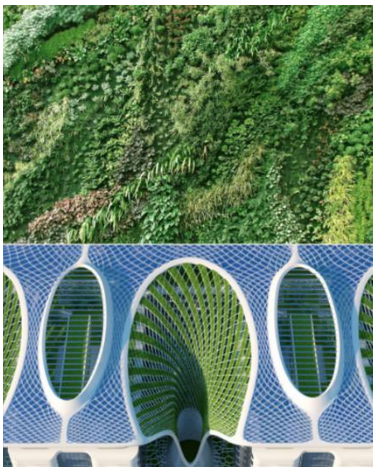


Figure 91 Green / Living Walls / source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette

In this project: 9 mega trees will be equipped with vertical vegetation. Green / Living Walls / source: https://www.arch2o.com/gate-heliopolis-vincent-callebaut-architectures/#google_vignette
Green walls will define building entrances on the inner street, uniting nature and architecture and improving conditions of microclimate.

8. Smart Home – Home Automation

Smart technologies grant residents the authority to control and monitor their living environment. Certain features are:

Zonal control of temperature, lighting, and ventilation.

Multi-sensors detecting occupancy, motion, temperature, and daylight.

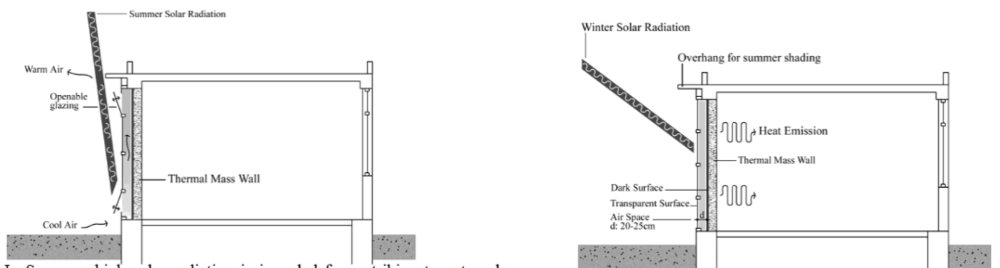
Auto HVAC adjustments based on ambient conditions.

Following the principles of bioclimatic design and integrating renewable energy systems, The Gate Project aims to minimize mechanical ventilation and artificial lighting reliance. The master plan is to transform the city into an ecosystem and reimagine the district as a forest, with nature and architecture harmonized.

2.2 Exploration of adaptive systems and materials that enhance sustainability.

Indirect Gain Systems

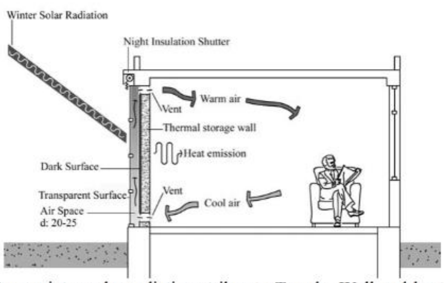
Indirect gain passive solar design varies from the immediate technique with one buffer that obstructs infiltration of solar beams into the consumed space straightforwardly. There are some indirect gain systems parts; Paul (1979) characterizes them as thermal mass walls, trombe walls, water walls, and sunspaces isolated from principal space by a thermal wall, roof ponds , and convective air circle system. These are all indirect gain systems that combine the collection, storage, and distribution of solar heat in the building's envelope , which covers the space to be heated (The European Detached Sunlight basedHandbook, 1992).
In this systems , solar beams are gathered first, then consumed by a Thermal mass, and afterward a portion of the gathered energy is delivered to heat the space by normal convection, the others are conducted through the thermal mass to heat the space by radiation at non-solar time. Joining of these systems inside the structure is related with resistance to the natural flow of heat.
A portion of the systems utilized are set in the consumed space, rest of them are set remote given that convection happens normally. Following is brief clarifications of the parts to be utilized in indirect gain Passive Solar Design:



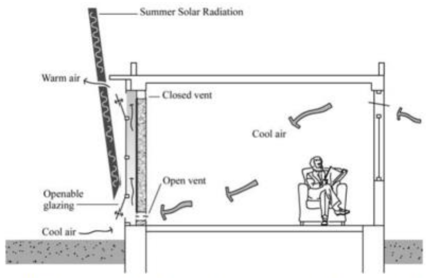
: In Summer, high solar radiation is impeded from striking to external surface of thermal mass wall by shading devices or vegetation. So, the sun doesn't heat the mass wall, and mass of the wall is cooled by convection opening the vents top and bottom of the glazing.

In Winter, solar radiation strikes to external surface of thermal mass wall due to low sun altitude, and heats up the mass during the day. At nights, stored heat is emitted to occupied space by radiation.

Figure 92 thermal mass wall / source: Passive Solar Design Strategies for Buildings: A Case Study on Improvement of an Existing Residential Building's Thermal Performance By Passive Solar Design Tools By



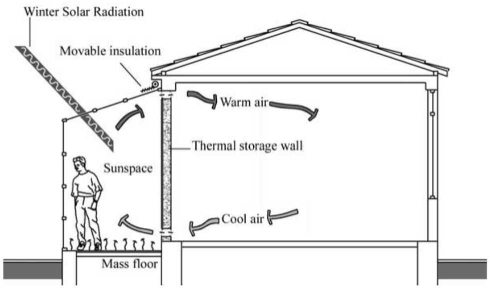
: Low winter solar radiation strikes to Trombe Wall and heats the air. Heated air becomes buoyant then starts to rise up making circulation between space air and trombe wall air via vents during the day.
At winter nights, vents and glazing insulation ought to be closed to prevent the air from reverse circulation that will otherwise cause to lost of heat to cool night sky.



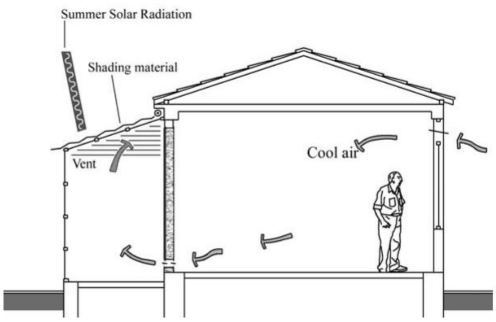
High summer solar radiation doesn't strike to Trombe Wall due to shading devices. The air in between gets warmer because of ambient reflecting radiation then starts to rise up making circulation between trombe wall air and outer cool air via open glazing vents during the day. Space ventilation can be achieved opening the upper glazing vent and bottom Trombe Wall vent so that space air can be sucked by stack effect.

Figure 93 trombe wall / source: Passive Solar Design Strategies for Buildings: A Case Study on Improvement of an Existing Residential Building's Thermal Performance By Passive Solar Design Tools BybSerkan BİLGİÇ

Water Wall: The water wall is like thethermal mass and trombe wall System with the exception of that contained water replaces the strong wall



Thermal storage materials in the sunspace collect heat during the day, and collected heat is distributed to occupied space by vents and openings on the common wall.
At winter nights, all vents and openings ought to be closed to prevent heat losses through the glazing of sunspace.

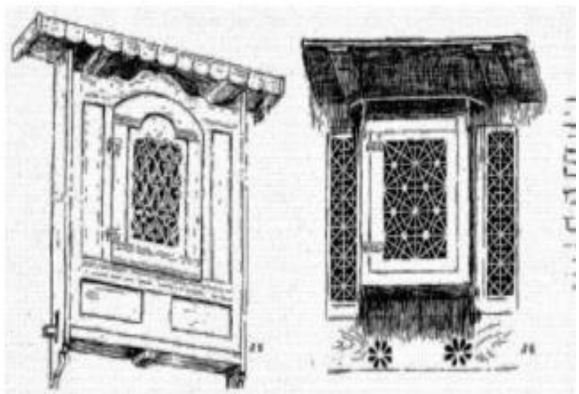


: In summers, sunspace ought to be impeded from direct solar beams by using shading devices and ventilated by opening some part of the glazing of sunspace as far as possible.

Musharabieh:

it is an architectural element traditionally made of turned wood assembled, it is a natural ventilation device through its perforated patterns which allows the passage of air throughout the day , invented by the inhabitants of hot countries . It is used to bring areas of shadows and freshness in spaces often exposed to the sun and high temperatures as well as the reduction of the surface produced by the mesh of the musharabiah accelerates the passage of the wind.

Figure 94 Musharabieh / source: https://books.openedition.org/iremam/3166



Promoting Ventilation

Cooling towers "el Malquaf" :

Among the Egyptians and badgir among the Iranians, or "tower of wind" is a traditional element of architecture of Persian origin used to create ventilation natural in buildings.

The towers are designed and oriented in such a way as to take advantage of the prevailing winds at the roofs and to direct the flows towards the interior of the building.

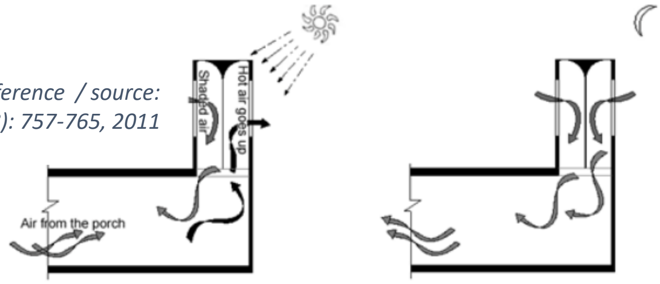


Figure 95 Function according to the temperature difference / source: Australian Journal of Basic and Applied Sciences, 5(8): 757-765, 2011 ISSN 1991-

Solar Chimney:

Thermal chimneys are designed to expel hot air from the interior of a building by taking advantage of natural convection. They are typically constructed narrow and vertical in design—very similar to a regular chimney—and often feature a black metal absorber that is easily heated by sunlight.

To function effectively, the thermal chimney must extend above the building's roof to allow for a sufficient pressure gradient to drive the warm air upwards. At the top of the chimney is a rotating metallic scoop that facilitates the exhaust of the warm air, enhancing ventilation and airflow efficiency in general.

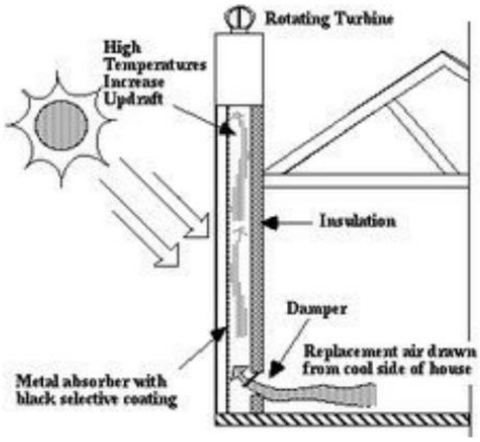


Figure 96 Thermal chimney / source: BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI Publicat de Universitatea Tehnică „Gheorghe Asachi" din Iaşi Volumul 67(71), Numărul 2, 2021 Secţia CONSTRUCŢII. ARHITECTURĂ DOI: 10.2478/bipca-2021-0013

Promote Radiant Cooling:

Radiative cooling is the exchange of intensity from a hotter surface to a cooler encompassing surface. Any item discharges energy by electromagnetic radiation.

If two components at various temperatures are confronting each other, a net brilliant intensity shortfall from the more sizzling component will happen. What's more, in the event that the coldest component is kept at a proper temperature,the other component will chill off to arrive at harmony with the colder component.

This actual guideline shapes the premise of radiative cooling (The European Aloof Sun powered Handbook, 1992).

Roof as Radiant Cooling Surface

As the portion of the building with the maximum surface area open to the sky, the roof provides the ideal location for application of long-wave radiative cooling. The ideal method is to use the roof itself as a radiator.

Movable Roof Covers One good way is:

A movable roof cover may be employed to shade the structure from solar gain during the daytime.

Rolling back or bringing back the covers at night to leave the whole roof open to the sky, realizing a very high degree of radiant cooling.

Maintaining a gap of a few millimeters between the cover and the roof to allow for day convection.

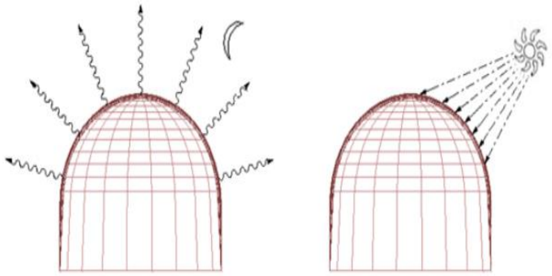


Figure 97 : Low radiant heating during the day and high radiant cooling at the nigh / source: Australian Journal of Basic and Applied Sciences, 5(8): 757-765, 2011 ISSN 1991-8178

Integration with Solar Panels

These mobile covers can also be provided with solar panels that collect the sun's energy during the day and use it to power the cover mechanisms—thus making the system energy-efficient and autonomous

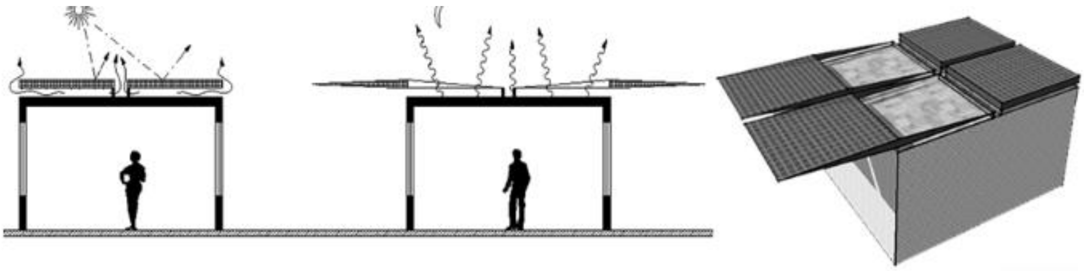


Figure 98 Movable cover on the roof can reduce radiant heating and increase radiant cooling source: Australian Journal of Basic and Applied Sciences, 5(8): 757-765, 2011 ISSN 1991-8178

Promote Evaporation:

Evaporation is a process of mass transfer that plays a significant part in the functional building design and exerts a profound influence on psychological comfort. Evaporative cooling is a natural phenomenon whereby sensible cooling occurs when moving air passes over a wetted surface or a water body—such as a fountain, river, sea, or shower. As water evaporates, it draws heat from the air close to it, resulting in a sensation of cooling.

Evaporative cooling is especially effective in arid climates as a method of indoor temperature reduction (Jan et al., 1994).

The wind catcher, one of the traditional methods that can be re-designed to function as an evaporative cooling system, can be transformed into such a system by introducing a fan and a pump I at the entrance duct. The fan increases the volume of air entering the building, and the pump adds water to the incoming dry air, cooling it in the process.

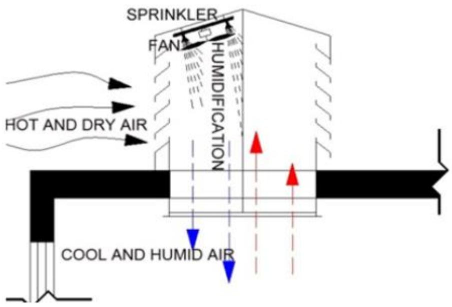


Figure 99 Adding moisturizing element into traditional wind catcher / source: Australian Journal of Basic and Applied Sciences, 5(8): 757-765, 2011 ISSN 1991-8178

Roof-based systems can also enhance evaporation. Sprinklers and a small pool on the roof, for example, can be used to keep the surface continuously wet. The roof is inclined slightly to allow water to run into the pool, which acts as a continuous water source. The water runs from the pool down into the courtyard through a solid surface designed to prevent the entry of water into the building walls. The water eventually collects in a central pool in the courtyard. In this process, water is constantly being converted to vapor. The energy required to convert water to vapor is drawn from the surrounding air, and this results in decreased ambient temperatures and increased humidity .

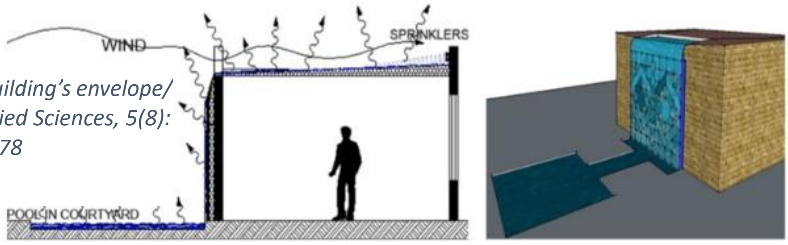


Figure 100 Promote evaporation over the building's envelope/ source: Australian Journal of Basic and Applied Sciences, 5(8): 757-765, 2011 ISSN 1991-8178

Constructional material

The materials that surround the occupants of a building play a significant role in protecting them from cold and heat. Therefore, careful consideration must be placed on wall and roof materials and their thickness to obtain optimum thermal performance.

The significant physical properties to be considered are:

- Thermal Conductivity – the ability of the material to conduct heat.
- Thermal Resistivity – the resistance of the material to the flow of heat, the inverse of conductivity.
- Thermal Transmittance (U-value) – the quantity of heat passing through the material per unit time.
- Optical Reflectivity – the capacity of the material to reflect solar radiation and minimize absorption of heat.

Through the selection of suitable materials according to these properties, indoor temperatures can be controlled effectively by designers, energy use lowered, and occupant comfort levels increased under different climatic conditions.

Material	Thermal conductivity (W/mK)
Aluminum	214
Steel (carbon 1%)*	43
Concrete, dense	1.30
Bricks	0.73
Water (20°C)	0.60
Sand (dry)	0.30
Wood (oak)*	0.17
Glass fiber quilt	0.035
Air*	0.024

Source: (Anon, 1988; http://www.engineeringtoolbox.com)*

Table 2: Thicknesses of walls of different material that give coefficients of thermal transmittance of approximately 1.1 kcal/hm²C°

Wall Material	Wall Thickness (m)	Thermal Transmittance (kcal/ hm²C°)
Hollow brick block	0.30	1.10
Double-wall brick with holes and 8-cm cavity	2 x 0.12	1.12
Brick wall with holes	0.38	1.03
Sand-lime brick	0.51	1.25
Hollow block sand-lime brick	0.51	1.16
Lime	0.51	1.10-1.35
Concrete	1.00	1.20

Source: (Hassan Fathy, 1986)

Figure 101 thermal conductivity of some materials/ source: Australian Journal of Basic and Applied Sciences, 5(8): 757-765, 2011 ISSN 1991-8178

Conclusion : The integration of intelligent technologies with dwelling architecture in the hot dry environment of Cairo and the broader Sahara has proven to be a credible path to sustainable, energy-efficient, and climate-responsive habitation. The Gate Project in Cairo is a seminal example of such an integration that combines traditional passive cooling techniques like windcatchers (Malqaf) and mashrabiya with advanced renewable technologies such as solar photovoltaic panels, geothermal systems, and vertical-axis wind turbines.

The project illustrates how bioclimatic design, when combined with smart automation systems and sensitive building materials, can significantly reduce the need for mechanical systems and artificial energy sources. Passive strategies—like thermal mass exploitation, evaporative and radiant cooling, green roofs, and living walls—highlight the importance of nature-integrated design in reducing the impact of extreme climatic conditions while enhancing indoor comfort and urban microclimates.

Additionally, indirect gain systems, solar chimneys, removable roof covers, and construction materials with specifically designed thermal properties improve the resilience of built environments in resisting extreme desert conditions. All these systems contribute to energy conservation, reduced carbon footprints, and improved thermal performance.

Essentially, this analytical study demands an integrated design strategy—a strategy that bridges vernacular know-how and modern innovation. By learning from vernacular architecture and supplementing its lessons with smart, responsive technologies, architects and urban planners can create sustainable urban ecosystems that not only react to their environment, but positively regenerate it. Projects like The Gate provide a blueprint for the future of construction in the desert, where resilience, sustainability, and livability are no longer separate goals, but inseparable imperatives.

2.3 Analysis of existing dome housing projects

Everite dome, Brackenfell

- Vital Statistics and Working Drawings of Prototype Dome

Geometry: -frequency, 5/8-sphere, icosa-alternate
breakdown, vertex zenith
Diameter:
. of sphere: 6,800 m
. of floor: 6,680 m
Floor Area: 35 m
Height at Apex: 4,000 m
Type of Structure: 'Panel' dome - complete shell, with four
standard windows, one standard door,

Figure 102 Everite dome, Brackenfell / source: a techno-economic evaluation of the geodesic dome as a possible form of low- income house in southern africa

a ventilation flue/hood and a paved floor; no ceiling, no electricity, no plumbing, no internal partitions.

- The Foundations

He first operation is to clear and roughly level the site. The area cleared is almost 80 m 2 defining a circle 10 m in diameter - this provides a working space of 1,6 m around the outside of the proposed structure.

To set-out the foundations, a metal stake is driven into the ground at point O, the center of the circle (see Figure). By means of a piece of inelastic string or nylon chord, a circle of radius 3,350 m (OA) is set-out from center 0.

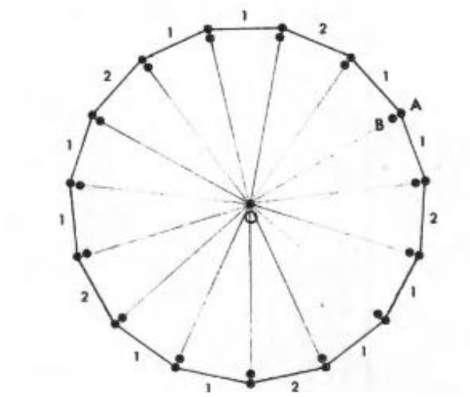


Figure 103 The Foundations / source: a techno-economic evaluation of the geodesic dome as a possible form of low- income house in southern africa

- The Superstructure

The geodesic dome can either be employed as a complete structure or a roof with "riser walls" for support—resulting in either a clean dome or a dome-on-cylinder configuration. Dome A accommodates a gross floor area of 35 m² without riser walls. Its superstructure is attached and anchored directly to the foundation.

The construction of the dome is divided into two principal phases:

- Manufacture
- Erection (Assembly)

Since a panel dome, as such, involves the bulk of its construction taking place in manufacture, precision of creating the pre-assembled panels primarily determines success and ease of assembly. Performed under the controlled factory conditions—experienced personnel, quality equipment, and efficient supervision—the process is quite precise. Such precision is one

of the principal advantages over the more laborious, specialist on-site labor used in traditional brick riser-wall construction.

Alternatively, riser walls can be manufactured off-site, as in the case of conventional timber-framed housing methods. All the same, to achieve this goes against the very principle of geodesic construction.

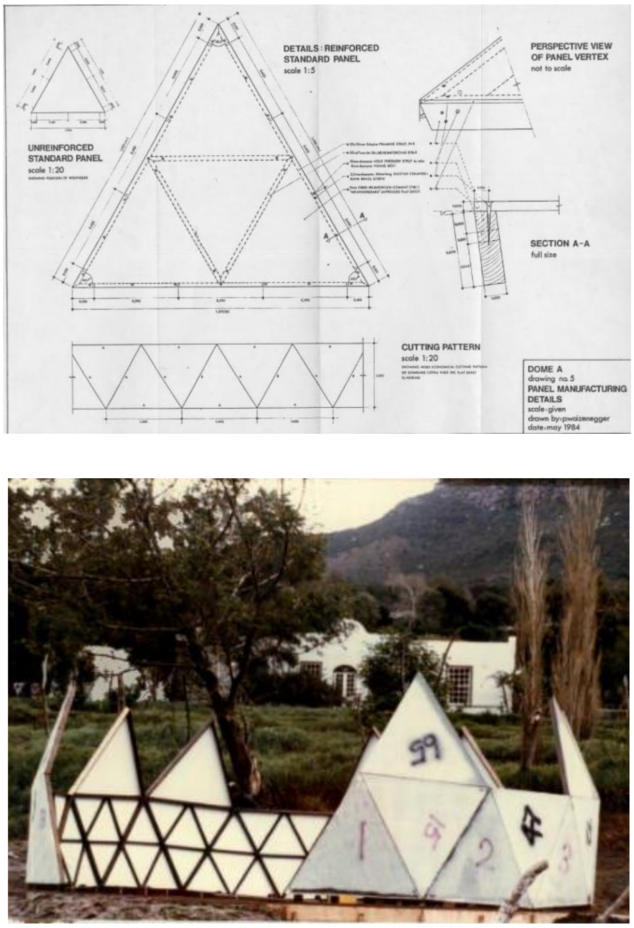


Figure 104 The superstructure / source: a techno-economic evaluation of the geodesic dome as a possible form of low-income house in southern africa

- Special Panels
- Closure Panels

These panels are used to fill gaps at the
.

In the prototype, timber framing for every window-set was built in situ and then clad with FRC panels. However, it is recommended that all window-sets be manufactured as prefabricated units. This includes factory framing and cladding and simple and quick on-site installation by bolting of the units to neighboring standard shell panels. Waterproofing of all (jambs, head, sill) would be carried out at the factory to avoid complex and lengthy on-site work.

Although different dormer window designs are utilized, their on-site installation is the same—only manufacturing details vary.

Figure 105 Window Panels / source: a techno-economic evaluation of the geodesic dome as a possible form of low-income house in southern africa

- Door Panels

The door-set manufactured can consist of either:

- A Woodlyte DFH 38 timber frame (used in the original Dome A prototype), or

A Woodlyte S54 frame (used in the newer prototype). bottom of the dome, where the vertical panels don't meet flush with the sole plate There are three variations in panel shape required: one is common to both left- and right-handed versions.

- Window Panels

In Dome A, the standard geodesic shell has six pentagonal windows. Four of these are adapted to have windows. Various window-set designs can be fitte.

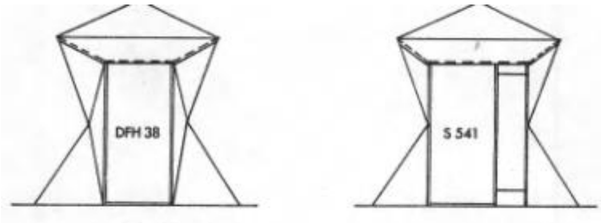
One of the most common solutions is the dormer window design that allows a standard Woodlyte N43FX frame to be fitted vertically between custom window panels. One of the Dome A prototypes featured a window consisting of five fixed triangular glass panes, bent to fit the dome's curvature.

- While this design provides ample natural light, it does not provide ventilation and has waterproofing problems due to the high angle of installation

The frame is inserted between next-door special door panels during production so that all the waterproof detail can be sorted out in the factory.

There in place, the door-set is simply secured to neighboring standard shell panels. There is a sloping-hood extending outward over the door to allow rainwater to run off. So water won't be falling directly on individuals entering the dome, a varying hood shape can be employed—one that allows water to eject ut sideways.

Figure 106 doorPanels / source: a techno-economic evaluation of the geodesic dome as a possible form of low-income house in southern africa



➢ Ventilation Panels

The pentagonal aperture on top of the dome serves to provide ventilation within. There are many ways this can be done, but perhaps the simplest is as follows:

- Adding five identical triangular panels to form a seal.
- Securing in place a 100 mm diameter vent pipe of FRC via one of the panels.
- The vent pipe is approximately 100 mm below the internal ceiling and 600 mm above the panel.
- A Bidim bandage, bituminous rubber sealed, is used as flashing around the pipe where it exits the panel.
- A commercially available rotating cowl can be fitted over the flue to prevent rainwater

<u>Alternative Ventilation Options</u>

Two other designs are proposed:

1 *Umbrella Hood Ventilation*

- Five identical triangular panels are raised vertically above the dome surface using five 200 mm-tall perforated rectangular airflow panels.
- These panels allow warm air to escape, reducing the risk of condensation and heat buildup at the dome's apex.
- The hood's triangular panels project 200 mm beyond the vertical panels as an overhang, allowing rainwater to drip off.
- A wire mesh or screen will have to be fitted behind the perforations, similar to that of air bricks.

2 *Louvered System*

- More complex, a later version replaces the perforated panels with adjustable vertical louvers.
- This configuration allows the ventilation to be closed off when idle, improving the thermal control.

➢ Supplementary Ventilation

In order to improve airflow in closed windows, low-level ventilation openings near the bottom of the building are also advisable. This can be accomplished by using vertical louvers. The warmer the climate, the more essential low-level ventilation becomes to maintain a comfortable interior temperature.

Other Methods for Climate Control

<u>External Treatments:</u>

- Black paint on the dome can be employed to regulate temperature according to climate.
- Shading windows and north-facing facades reduces solar heat gain.

Translucent Hood Option:

- Replacing the opaque ventilation hood with a translucent one allows natural light to enter the dome interior.
- Alternatively, a solar-heated hood may be provided, which matches the dome's philosophy of panel-based, passive building

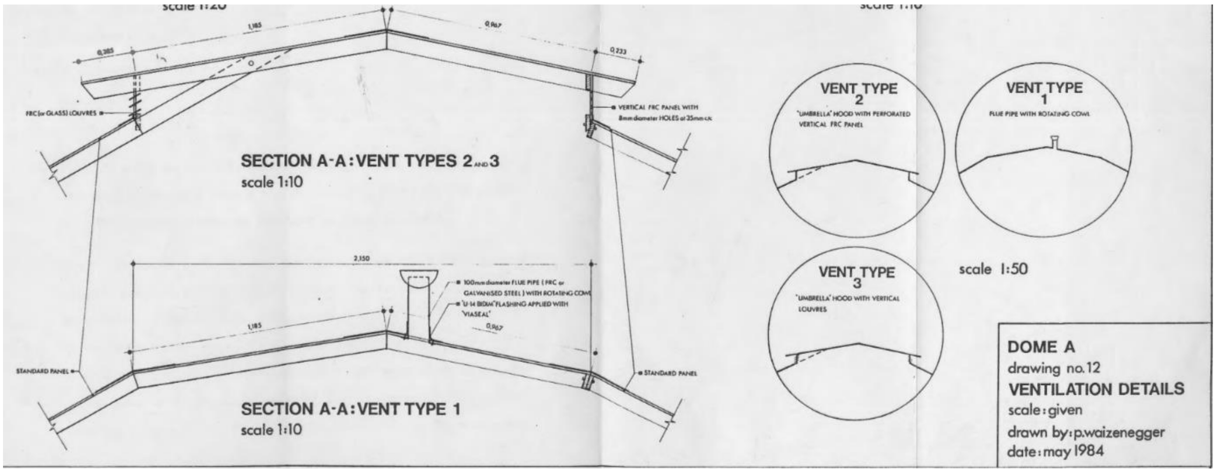


Figure 107 ventilation details / source: a techno-economic evaluation of the geodesic dome as a possible form of low- income house in southern africa

2.4 vernacular house

The house is located at Taghzout 14 km to the North from El oued on the road national N°48

➢ The organigram

The entree and skifa: The entrance Raised from the ground is extended by a wide corridor called (skifa) who gives in the yard.

- Dar skifa : The guests can access this room without switch to the yard.
- El hawch : This is the space central which manages the house All spaces converge to him Seeing that he is open ,it includes in general a well and a palm tree.
- The rooms : are gone again around the course in the EAST side.
- Summer sabat : it is a space located south of the haouch ,open to the north; protected from the sun throughout the year used in summer for rest and the nap.

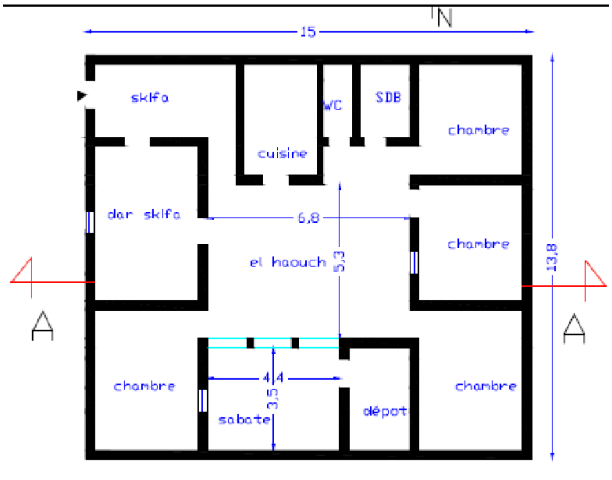


Figure 108 plan of a vernacular house located at Taghzout / source: 4.720.283.pdf

- The kitchen: will be in a room to the north, at the interior of the cooking on find the chimney.

It includes an internal courtyard, around from which are distributed the rooms. Each room has a , two or three domes, the ground is sand , sometimes in plaster, rarely in tiling. In front of the northern and from the south are often found sabat or women settle down. In the summer, she works under the north arcades, in winter. the entrance is by skifa chicane so that strangers cannot see what is happening part of the house.

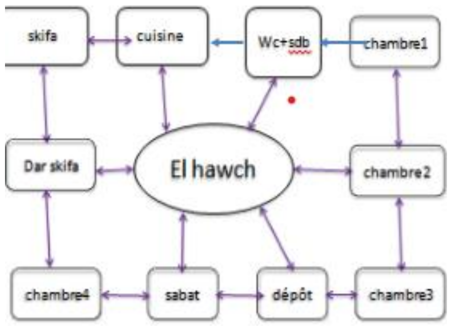


Figure 109 : organisation spatial / source: 4.720.283.pdf

- the domes -It avoids stagnation sand on the terrace.It reflects the sun radiation.

The barrel vaults - She plays the same role from the dome .She is used in large parts

Figure 110 the domes / source: 4.720.283.pdf

- The facade

The arcs :

the semicircular arch in the openings of the doors.

The houses of the Souf are present with walls blind, as a kind of an enclosed place.A small window with a door very discreet unique

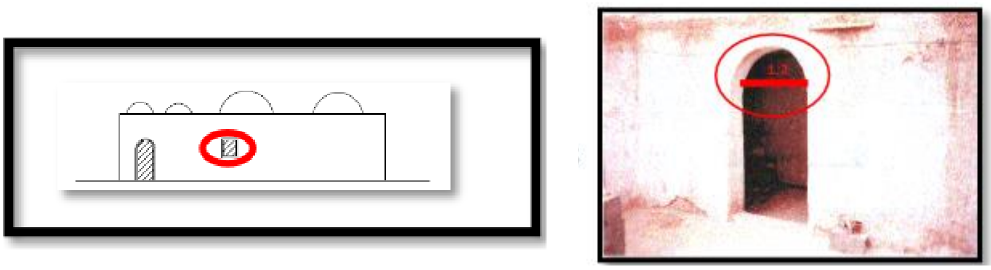


Figure 111 the facade / source: 4.720.283.pdf

Projet: 216

the 216-housing project comes from the housing program which consists of creating new housing areas it is programmed at the urban pole level in the west ZHUN commune of biskra.

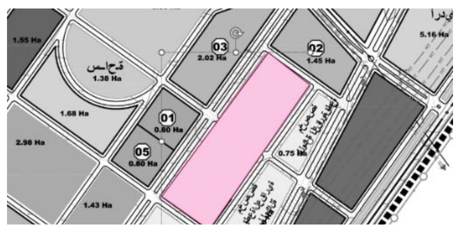


Figure 112 : the situation of the project / source: AWGRFU BISKRA

Technical information :

Project	216-housing
type	Individual promotional housing F5
Maitre d'ouvre	Wilaya Agency For Urban Land Management & Regulation AWGRFU BISKRA
Nombre of housing	216-housing
Level	R+1 LOGTS TYPE F5 R+1 N°52 LOGTS TYPE F5 R+1 N°112 R+2 LOGTS TYPE F5 R+2 N°52 phase 2

- immediate environment

the 112-housing phase is surrounded by individual dwellings and several equipment (administrative educational security service)

this aspect could as well be considered as an advantage as a disadvantage indeed it causescongestion and nuisance for the inhabitants .

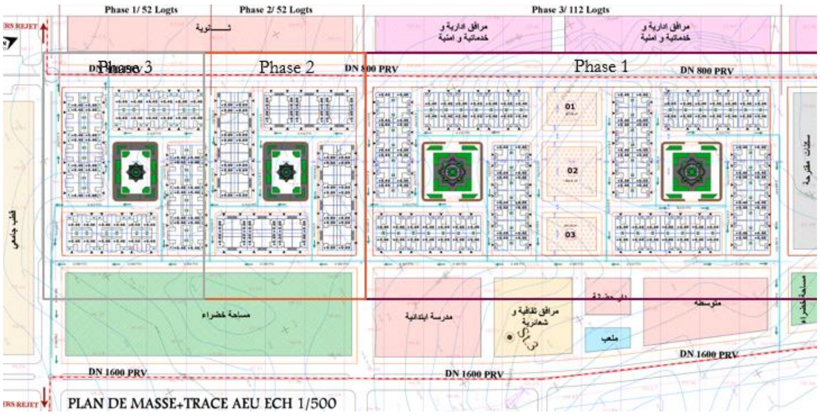


Figure 113 immediate environment / source: AWGRFU BISKRA

- Accessibility

mechanical access

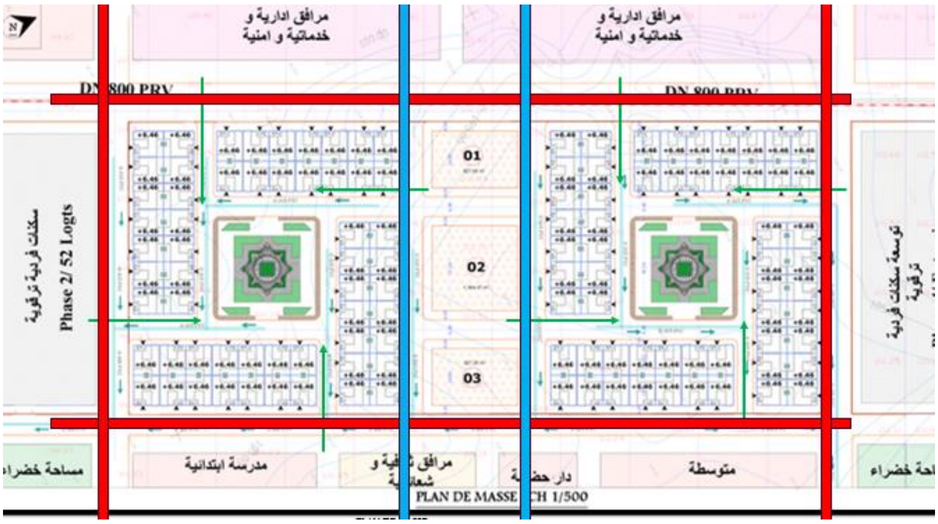


Figure 114 accessibility / source: AWGRFU BISKRA

112 is accessible by 6 lanes (4 main lanes (red) 2 secondary lanes (bleau)) the tertiary roads (green) lead directly to the parking

piteon access it takes place on sidewalks arranged parallel to the mechanical tracks giving directly to the housing

it takes place on sidewalks arranged parallel to the mechanical tracks giving directly to the housingThe

- organigram

The design was distributed to the inner courtyard, where the latter is considered the starting center for the home spaces, as it was based on the idea of privacy, as the first floor was adopted for private spaces and the ground floor for public spaces Water areas on the north-east side and dry areas on the south side The house enjoys an accessible roof

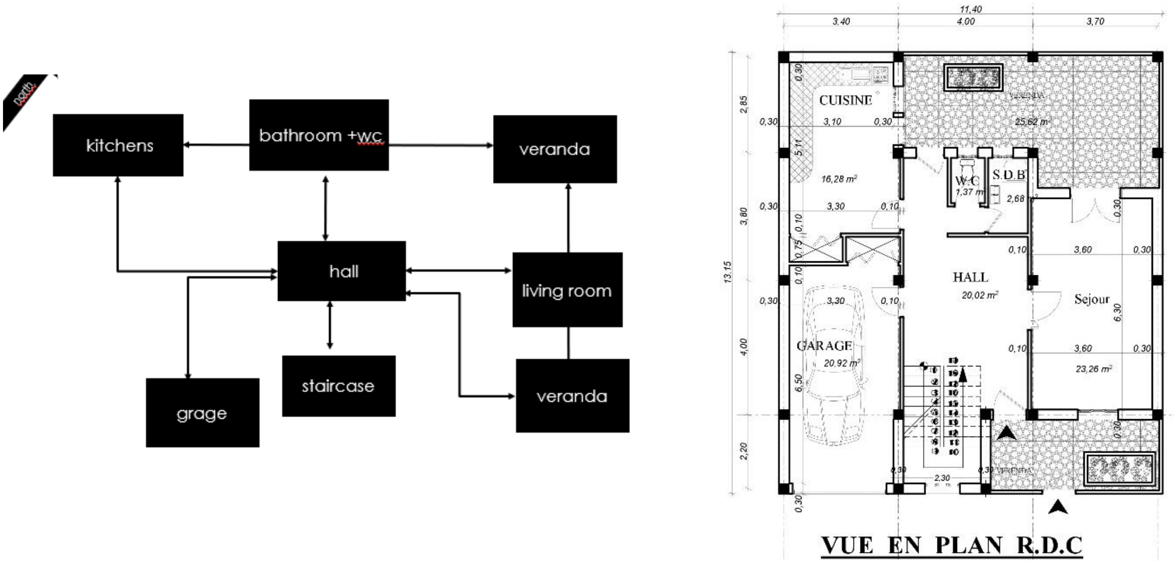
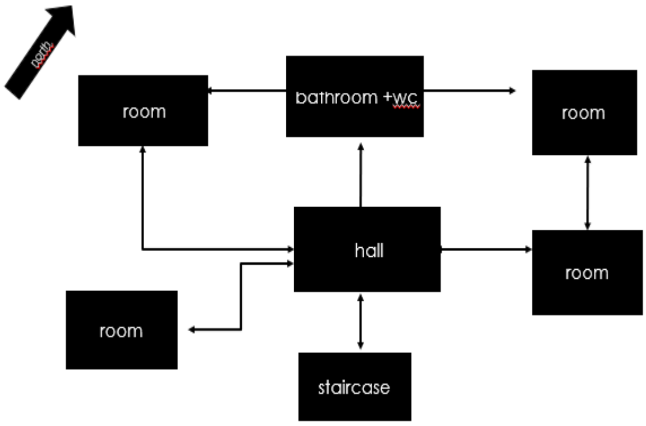


Figure 115 organigram spatial of ground floor   / source: AWGRFU BISKRA



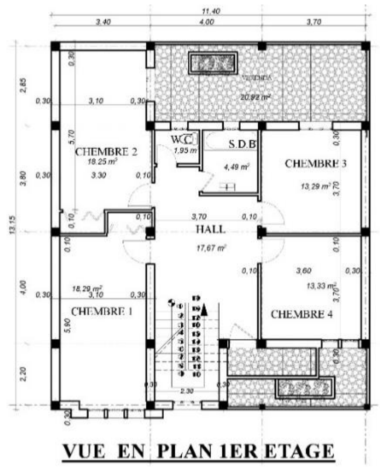


Figure 116 organigram spatial of first floor / source: AWGRFU BISKRA ground

facade

are treated in a uniform way The desert colors characteristic of the area were adopted, there are longitudinal openings at the facade level to break the idea of a transverse facade décor

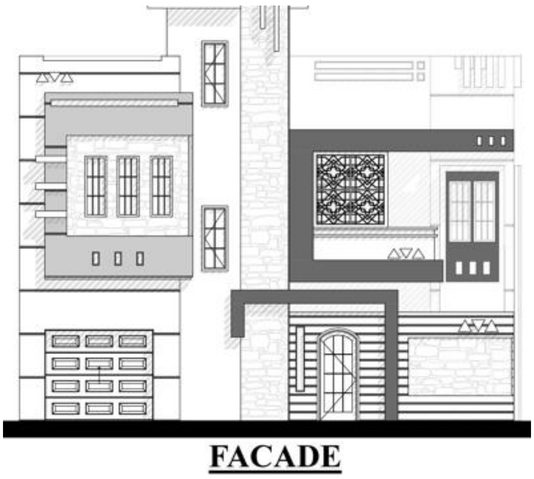


Figure 117 facade of one house / source: AWGRFU BISKRA

Analytical Study: 400 Housing Units Project – El Oued, Algeria

1. Project Overview

Architects: Hani and Abdel Rahman El-Miniawy (El Miniawy Brothers)

Client: Governorate of El Oued (formerly Biskra)

Completion: 1986–1992

Scale: 402 units on 40,000 m²

Figure 118 400 Housing Units Project – El Oued, Algeria / source: by Ashraf Salama

Purpose: Public housing for middle-income families within a hostile Saharan climate.

Figure114 : 400 Housing Units Project – El Oued, Algeria / source: by Ashraf Salama

2001 Technical Review Summary 400 Units Housing Project El Oued, Algerie

2. Climatic & Environmental Response

Climate: Very hot, arid desert; summer temperatures up to 45°C; winter as low as -5°C; rare seasonal sandstorms

Thermal Strategy:

Double roof utilization: tufla brick domes over flat concrete slabs to minimize heat gain and facilitate cross-ventilation

Narrow and low opening windows in order to restrict solar radiation

Staggered massing of buildings for shaded walks and reduction of solar exposure

Inclusion of natural ventilation in design; air conditioning essentially unnecessary *

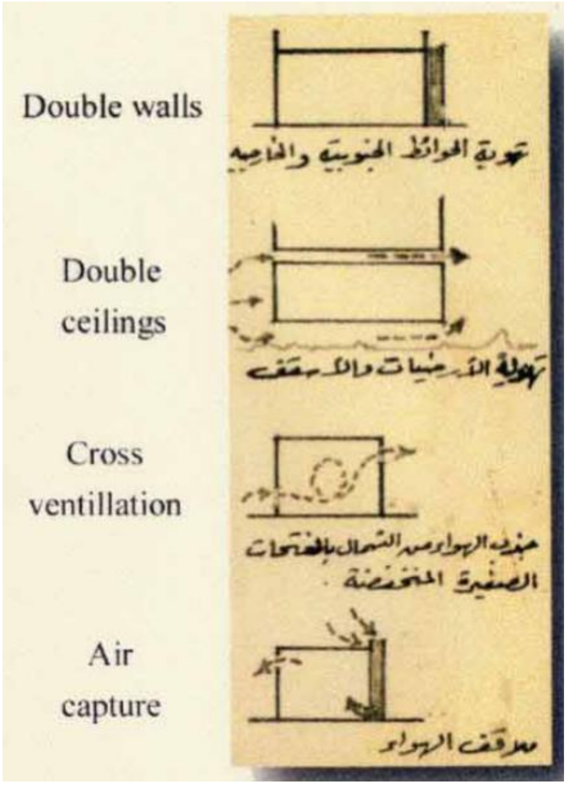


Figure 119 Thermal Strategy of 400 Housing Units Project – El Oued, Algeria / source: by Ashraf Salama 2001 Technical Review Summary 400 Units Housing Project El Oued, Algerie

3. Urban Design & Form

Cluster-based layout: Cubic volumes organized around shared outdoor areas

Public space planning:

Semi-covered play areas and shaded communal walkways

Commercial spine integrated into the ground floor

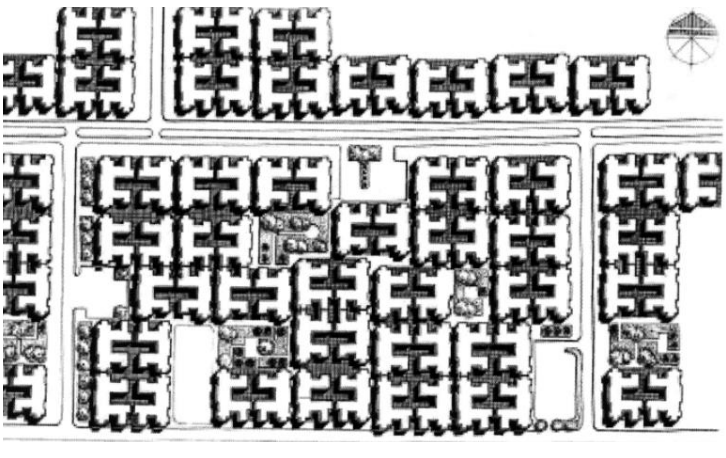


Figure 120 Urban Design & Form of 400 Housing Units Project – El Oued, Algeria / source: by Ashraf Salama 2001 Technical Review Summary 400 Units Housing Project El Oued, Algerie

4. Color & Materials:

Originally warm yellow gypsum matching desert tones (later painted white, which caused glare issues)
Locally sourced tufla bricks and fired gypsum textures
Long-lasting cement and rough tile finishes for sidewalks

Figure 121 Color & Materials of 400 Housing Units Project – El Oued, Algeria / source: by Ashraf Salama 2001 Technical Review Summary 400 Units Housing Project El Oued, Algerie

5. Functional & Spatial Performance

Apartment Types: F2 to F5 (based on room count), ranging from ~57 m² to ~115 m²

Patios increase usable area and climate control

Ground floor: Originally for play/commercial use, now frequently modified to government and residential purposes
Functional strengths: Privacy, natural light, social areas
Weaknesses: Inconsistent maintenance, minor water damage noted, white paint glare

Figure 122 Functional & Spatial Performance of 400 Housing Units Project – El Oued, Algeria / source: by Ashraf Salama 2001 Technical Review Summary 400 Units Housing Project El Oued, Algerie

Significance and Legacy

Pioneering Role: One of the earliest large-scale public housing initiatives in the Saharan south

Cultural Continuity: Successfully echoes and revitalizes traditional local architectural forms (dome, vault, courtyard)

Replicability: Elements have been reinterpreted in later regional housing schemes

Recognition: Identified by Aga Khan Award for Architecture as a model of culturally responsive, climatically appropriate design

2.5 Comparative Study of Comparable Climate Projects – Arid Regions: Lessons to Be Learned

1. Climatic Adaptation and Site Integration

➢ Vernacular House – Taghzout (El Oued)

This desert dwelling exhibits exceptional climatic sensitivity. The courtyard (El Hawch) regulates airflow and light, and domed and vaulted roofs reflect sunlight and keep sand from accumulating. Local materials are used, and spatial planning offers privacy and thermal insulation.

Lesson: Courtyard-based designs, natural ventilation, and earth materials remain very effective in resisting intense heat and dust storms in arid climates.

2. Structural Innovation and Thermal Performance

➢ Everite Dome – Brackenfell

This low-mass geodesic dome building is noted for its prefabricated panels and small geometry. Although it has quick assembly and cost-effectiveness, its thermal mass is low, and insulation layers and careful ventilation design are needed to control internal temperatures.

Lesson: Light structures in dry climates need to be coupled with high-performing insulation, ventilation strategies, and solar protection schemes (e.g., shading devices, reflective finishes) in an attempt to deliver comfort and energy efficiency.

➢ 216-Housing Project – Biskra

Being situated in a desert city, the project incorporates desert-colored facades, longitudinal window openings, and terrace accessibility to blend with the environment. While functional in design, the high-density configuration near existing infrastructure results in congestion and environmental discomfort.

Lesson: Urban housing in arid regions must prioritize spatial breathing space, green buffers, and passive cooling systems. Over-congestion disrupts climatic responsiveness and livability.

2.6 Key Takeaways for Arid Zone Housing Design

- Thermal Comfort

Utilization of domes and vaults (Taghzout), insulation layers (Everite Dome), and reflective surfaces.

- Ventilation

Central courtyards (Taghzout), louvered vents and air gaps (Everite Dome),

- Solar Control , north-facing sabats (Taghzout), overhangs and leafy trees (Everite Dome).
- Material Use

Earth-based materials (Taghzout), prefabricated insulated panels (Everite Dome), Social Interaction

- Aesthetic Integration

Color scheme attuned to local setting (Biskra, Taghzout),

2.7 Site analysis and contextual study

2.7.1 Site selection and context

Justification for selecting a specific arid region for the project:

In southern Algeria, their conventional settlements are an instant reaction to the material, religious, and cultural needs of their inhabitants. And inasmuch as they have been so, they have also been astonishingly successful in reacting to one of the harshest climates on earth. One of the most illustrative examples is in Souf region's vernacular housing, which embodies principles now widely regarded as sustainable architecture.

These traditional structures blend innovative cooling methods that show deep understanding of the activities of the occupants, environmental adaptation, and the efficient use of local technology and materials. As such, they offer valuable lessons and learning opportunities in addressing the climatic challenges of contemporary buildings in desert climates.

2.7.2 Description of the site's geographical, climatic, and social context:

geogrphical:

The wilaya of El Oued is located in the south-eastern part of the national territory, it is located at an altitude of 80m, on longitude 6o, 52 East and an altitude of 33o, 22 North, and se counts among the five wilayas borders with Tunisia.

It is 650km away from the capital (ALGIERS), 650 Km from Annaba, and 220km from BISKRA.It extends over a vast sandy tablecloth total from 19610 ha.

It is limited by :

Located In The North East: the wilaya of Tebessa.

Located In The North-west: the wilaya of Biskra.

Further South: the wilaya of Ouargla.

Located at East: the Tunisian borders.

Located on the West: the wilaya of Biskra

Climatic:

The Souf is a Saharan region in southeastern Algeria. It lies within the arid Grand Erg Oriental Basin, located in the northeastern Sahara Desert. According to the Köppen climate classification system, the Souf corresponds to the BWh type, a hot desert climate.

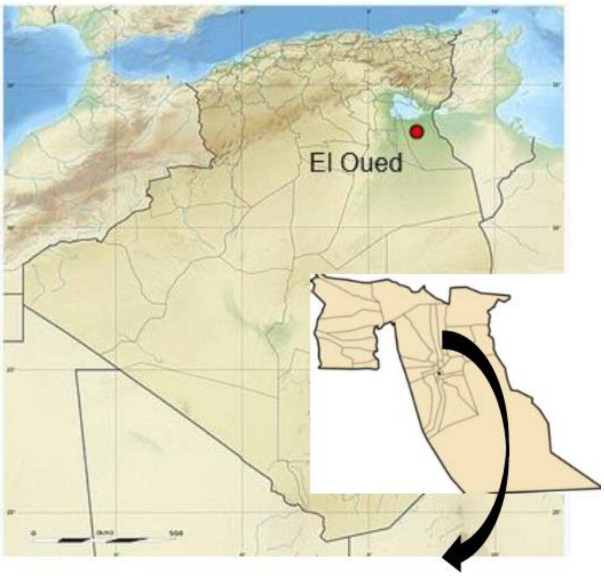


Figure 123 : situation of The wilaya of El Oued source: https://fr.wikipedia.org/wiki/El_Oued

This region is characterized as having extremely dry conditions. Summer is typically hot, dry, and sunny, and winter is cold, dry, and typically sunny as well. The yearly temperature range is from 5.5°C to 40.5°C in the Souf, with occasional extremes dropping below 2°C or rising above 45°C. The highest recorded temperature is 49.0°C in August.

Rain is scarce and unpredictable, and annual precipitation between 80 and 100 mm occurs mainly from October to February. The summers are particularly dry, contributing to the severity of the climate in the Souf.

In addition, the Sirocco, a hot, dry wind, regularly heads to the area, sometimes preceded and followed by sandstorms that last days or even weeks, further contributing to the challenging climate of the Souf.

social context:

As a region in the Saharan area, the Souf possesses an architectural heritage that developed over time based on the material, religious, and cultural needs of its inhabitants. The region is particularly renowned for the peculiarity of its dwellings, especially the employment of domes (gouba) and vaults in such a manner as to form curved shapes for its roofs.

These architectural elements have grown to be typical Souf landmarks in the urban setting, so much so that they represent the main expression of the vernacular identity. Not only do the domed structures respond well to the tough desert climate but also hold center stage as cultural icons, profoundly rooted in the local culture.

2.7.3 Climate-specific considertion

Detailed bioclimatic analysis, including temperature, solar exposure, wind, and precipitation data

Site analysis:

The site is located in the state of Wadi suf, where it occupies space for the expansion of housing.

With an estimated area of 3 hectares

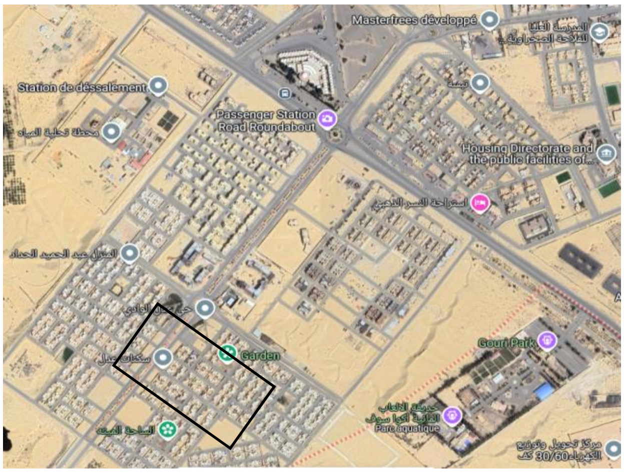


Figure 124 situation of the site   /   source: googlemap

Figure 125 immediate environment /   source: source:

2.7.4 Bioclimatic study:

- insolation:

The maximum duration of insulation is 350.30 hours/ in the month of July, which

results 6 hours for each day.

revailing Winds:

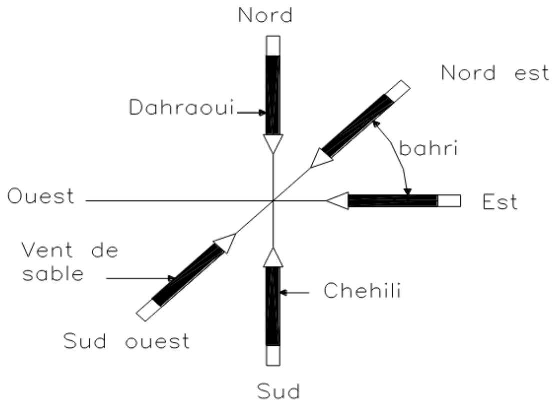


Figure 126 the prevailing winds

The winds are classified into four types:

- **Sand Wind:**
  Occurs from February to April, with peak intensity in March.
  Predominantly blows from the southwest, especially frequent in spring.
- **Hot Wind (Chéhili or Sirocco):**
  Originates from the south and prevails throughout summer, causing plant drought and soil dehydration.
- **Fresh Wind (Dahraoui):**
  Comes from the north, lasting from February until October.
- **Fresh Wind (Bahri):**
  A northeasterly wind, frequently occurring from late August to the end of October.
  Based on the analysis:

3 **Insolation:**

- The low density of adjacent urban areas makes the ground more vulnerable to insolation.

4 **Prevailing Winds:**

- The low density of neighboring urban areas increases vulnerability to both hot and cold winds.

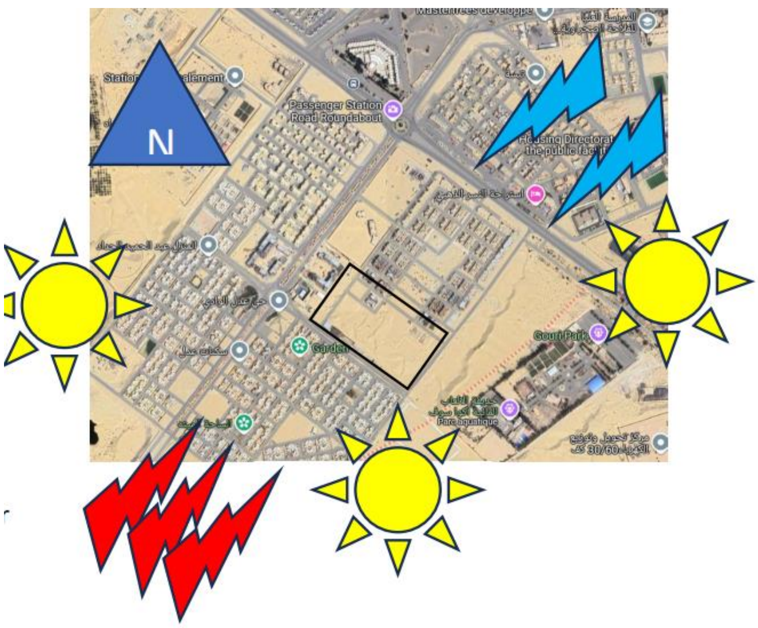


Figure 127 insolation and The prevailing winds / source: ww.google.com/maps

4.1.1 Implications of these factors for housing design in the selected area.

1. Building Orientation and Form

Both building orientation and form must be addressed to create effective climate-responsive architecture. This is particularly true in hot and dry conditions like in Wadi Souf, where precise orientation minimizes solar heat gain and achieves maximum natural ventilation.

Key Strategies:

Orient the building on a north-south axis to minimize east-west exposure and lower heat gain.

ake a streamlined form to reduce winter heat loss and pick up in summer.

Minimize building depth to optimize daylight penetration and permit natural ventilation throughout the building.

Plan layouts that are narrow permit air to circulate more easily through interior spaces.

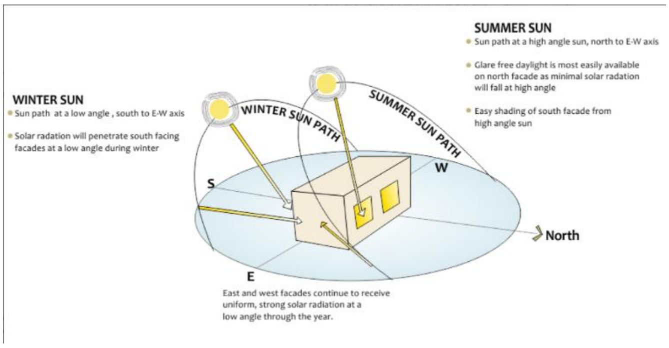


Figure 128 building orientation and form / Source https://nzeb.in/knowledge-centre/passive-design/form-orientation/

2. Ventilation and Openings

Effective design of ventilation in new buildings can typically eliminate the need for mechanical measures. Accurate placement and sizing of openings facilitate air flow and reduce internal heat gain.

Main Strategies:

Locate high-level windows as exhaust outlets and have openings on all four exterior walls to permit cross-ventilation.

Don't have west-facing windows; substitute with south-facing windows with horizontal louvers for solar control.

Install windows facing the north to admit diffused daylight with low heat.

Subsize window area, orientation, and shading based on each space's function and exposure.

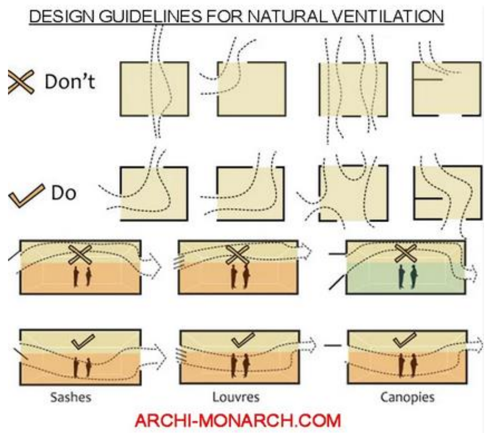


Figure 129 ventilation and openings Source: https://www.arsitur.com/2017/07/tips-mengatasi-rumah-yang-panas.html

3. Daylighting and Shading

In daylight-predominant climates, control of daylight is necessary to prevent glare and overheating while reducing energy consumption for lighting.

Key Strategies:

Use pergolas, louvers, and screens to control the amount of natural light into the building.

Position windows toward the ceiling to enhance daylight distribution.

Use Jaali walls, perforated roofs, semi-open pergolas, and partially shaded patios to balance daylight with shade.

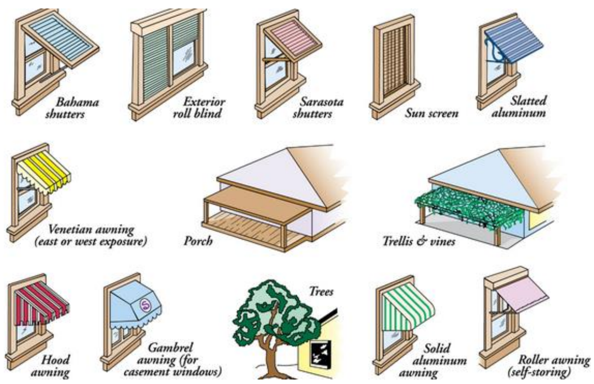


Figure 130 daylighting and shading Source: https://basc.pnnl.gov/resource-guides/shading-and-solar-control-windows-and-skylights

4. Walls

Walls are a fundamental component in the management of indoor temperatures in hot, dry climates. Proper materials and finishes significantly reduce heat transmission and moisture storage.

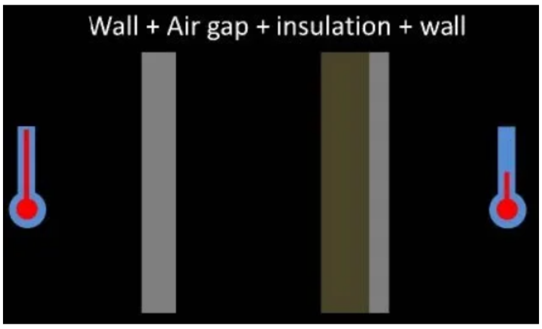


Figure 131 walls isolation / Source: https://archi-monarch.com/heat-transfer-in-building/

Key Strategies:

Choose light-colored external finishes to reflect sssolar radiation.

Use ventilated cladding systems that encourage airflow behind facades to remove moisture.

Employ thermal insulation to ensure airtightness and mold resistance.

Design walls to provide outdoor shading by using the sun path as a reference.

5. Roofing

Roofs are major contributors of heat gain. In passive design, they must be treated with materials and systems that restrict absorption and enhance ventilation.

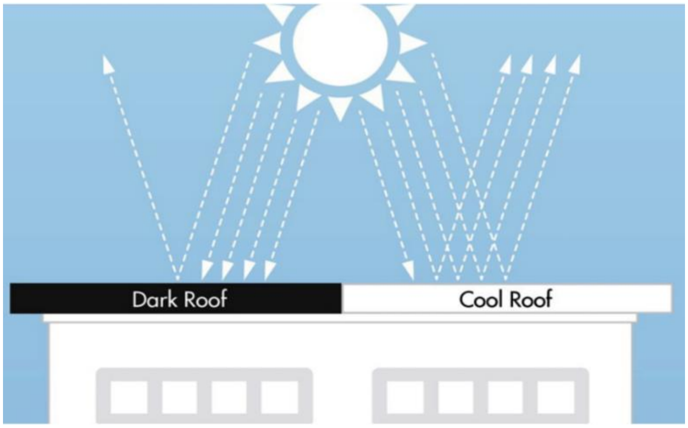


Figure 132 roofing / Source: https://www.roofingcontractor.com/articles/98549-city-of-austin-undertakes-study-of-cool-roofing-to-mitigate-urban-heat

Key Strategies:

Use light-colored, reflective roofing materials such as clay, terra cotta, metal, or slate.

Incorporate green roofs, which provide thermal insulation and reduce solar heat gain.

Incorporate ventilation systems like ridge vents, turbines, or passive stack ventilation to promote comfort.

the significance of incorporating open air into protected living spaces in desert design.

6. landscaping

In desert environments, landscaping is an aesthetic and functional solution that cools microclimates and enhances user comfort.

Significant Strategies:

Plant courtyards with gardens to stimulate natural ground cooling.

Provide rooftop or vertical gardens to insulate roofs and shadow surfaces.

Use plants as natural windbreaks and for moisture regulation.

Conclusion

The choice of Wadi Souf as the location for this project is not only explained by its intense climatic conditions, but also by its rich and varied architectural heritage, which provides profound insights into desert sustainability. The region's traditional settlements have for centuries proven resilient by vernacular means such as domed roofs, solid forms, shaded courtyards, and astute use of local materials—features that are still highly pertinent today in climate-responsive design.

The distant terrain, dry desert climate, and solid cultural identity of El Oued offer the ideal context in which to redefine passive design principles of modern architecture. The bioclimatic parameters of extreme solar radiation, hot climate, fluctuating winds, and scarce rainfall are unique obstacles that can be turned into advantages by wise architectural interventions.

The site's exposure to solar gain, wind streams, and low city density requires careful consideration in orientation, form, materiality, and ventilation. Adaptive strategies such as north-south orientation, cross-ventilation, light-colored finishes, insulation, and green roofs are required to counteract environmental stresses. Additionally, the integration of landscape elements such as rooftop gardens and courtyard vegetation can maximize thermal performance and user health.

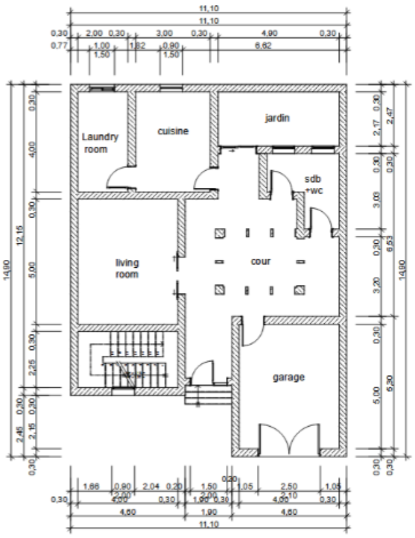
Finally, the proposed Wadi Souf housing development aims not only to resist climatic conditions, but also to respect the cultural heritage of the area. By integrating traditional wisdom and modern sustainable technologies, the scheme is a prototype for human-scale, resilient design in desert environments—unifying heritage, performance, and innovation.

Chapter 3 : Conceptual approach to the housing project

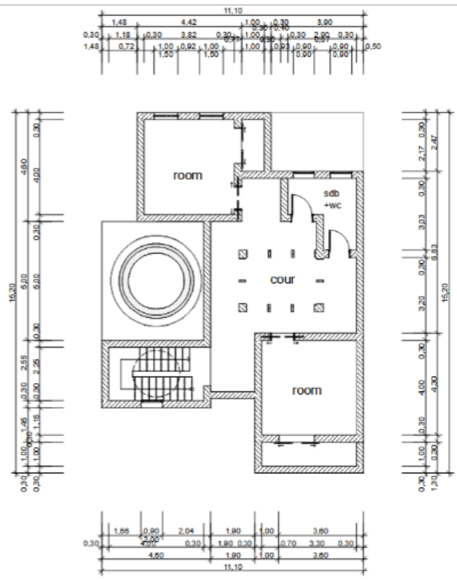
The final program

F3	F4	F5
Room1 16m²	Room1 18m²	Room1 18m²
Room2 14m²	Room2 15m²	Room2 18m²
	Room3 15m²	Room3 18m²
		Room4 18m²
Living room 20m²	Living room 22m²	Living room 25m²
Bath room 6m²	Bath room 6m²	Bath room 6m²
kitchen 12m²	kitchen 14m²	kitchen 16m²
Courtyard 6m²	Courtyard 10,72m²	Courtyard 12m²
garden 10,63m²	garden 11,96m²	garden 8m²
Landury room 8m²	Landury room 9m²	Landury room 8m²
Garage 20m²	Garage 20m²	Garage 20m²
Floor area	Floor area	Floor area
152m²	141,86m²	167m²

ground floor

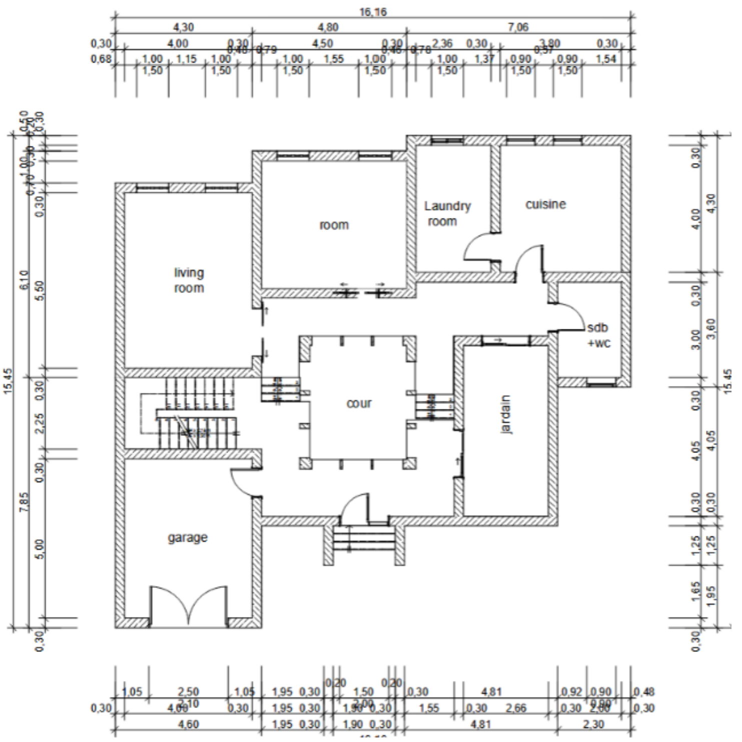


first floor

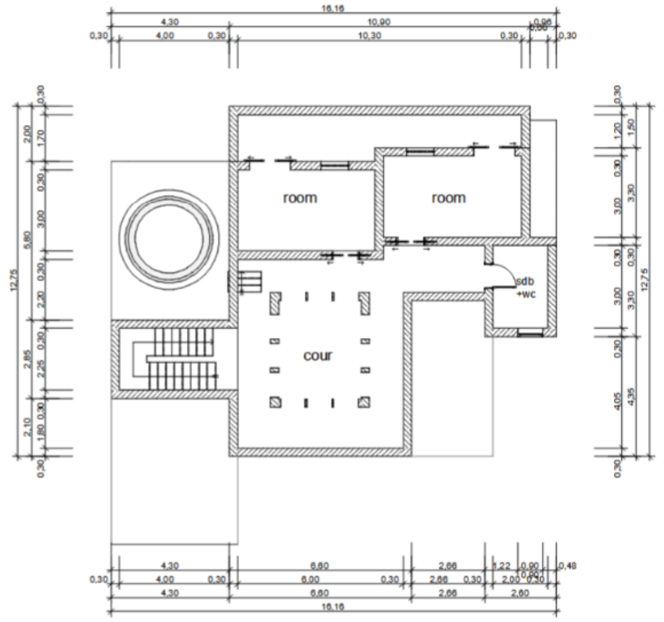


type f3

ground floor

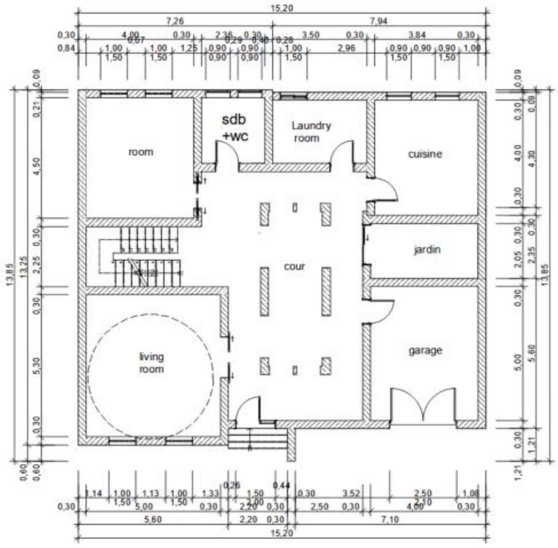


first floor

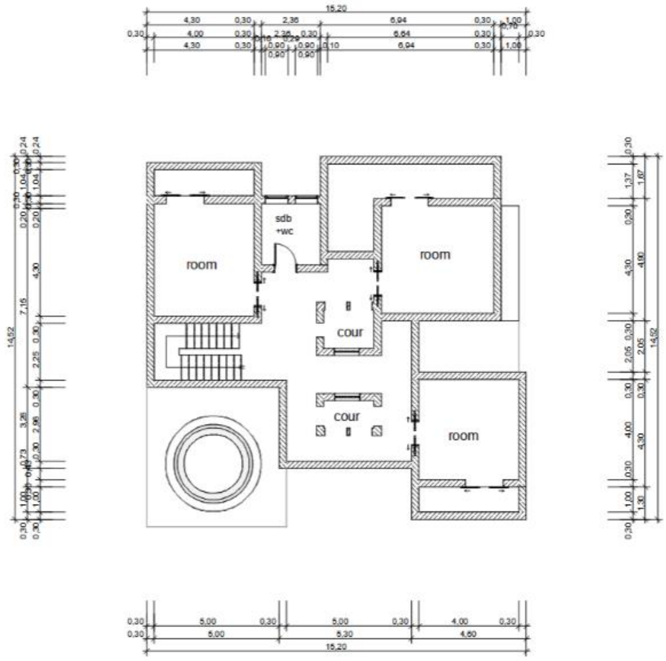


type f4

ground floor

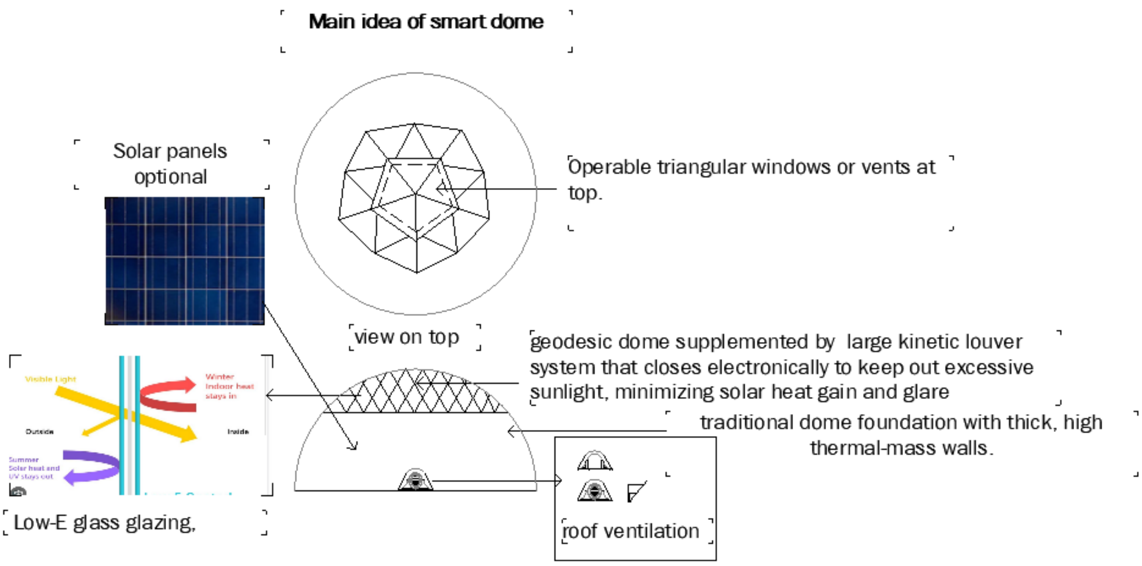


first floor



type f5

urban planning scheme for a the project



general Conclusion

Housing is far more than a physical shelter—it is a central expression of how humanity adapts to its environment, reflects its culture, and aspires to comfort, resilience, and sustainability. In regions characterized by harsh climates, such as hot-arid zones, this challenge becomes even more acute. The built environment must respond intelligently not only to environmental constraints but also to socio-cultural expectations and emerging technological opportunities. This thesis has taken up this challenge by exploring the revalorization of vernacular domes through the design of smart, sustainable housing prototypes tailored to arid regions, particularly focusing on the case of Oued Souf in Algeria.

The research was motivated by the recognition that modern construction practices often neglect centuries-old wisdom embedded in vernacular architecture. These traditional forms, developed through generations of empirical adaptation, are naturally suited to their climatic contexts. Among them, the dome stands out not only for its symbolic and cultural richness, but also for its environmental performance: thermal stability, resistance to wind and sandstorms, and minimized surface area exposed to solar gain. However, despite these advantages, traditional domes also face limitations when judged by modern standards of indoor comfort, energy efficiency, and adaptability to contemporary lifestyles.

To address this gap, the thesis is structured around three main parts: a theoretical framework, an analytical study of case examples, and a design proposal.

In the first part, the study investigates the fundamental concepts of comfort—thermal, acoustic, visual, and ergonomic—while also discussing the specific climatic characteristics of arid zones. It explains the relevance of passive architectural strategies such as orientation, compact volumes, thermal inertia, and natural ventilation in maintaining comfortable indoor environments with minimal energy use. The theoretical foundation further delves into vernacular architecture, particularly in the Souf region, where traditional domes demonstrate an intrinsic harmony between form, climate, and local identity.

The second part of the thesis presents a detailed case study analysis, focusing on dome-based architecture in southern Algeria. It analyzes the environmental behavior of traditional housing, especially its responses to extreme temperatures and limited resources. This section highlights how local building materials, spatial organization (courtyards, high thermal mass walls), and techniques such as wind capture and shading have evolved to optimize comfort. The analysis reveals the strengths and weaknesses of these traditional approaches and lays the groundwork for future integration with modern technologies.

The final part of the thesis proposes an innovative architectural design for a “smart dome”, combining the best of traditional and modern approaches. The proposed housing unit—based on a twin-dome configuration—employs passive techniques (natural shading, ventilation, insulation) alongside smart environmental systems for temperature control, water management, and energy efficiency. The design is supported by an evaluation of its performance in terms of thermal, visual, acoustic, and ergonomic comfort, aiming to create spaces that are not only functional but also emotionally and culturally fulfilling.

Thus, this research does not merely revive an old architectural form; it reimagines the dome as a platform for innovation, capable of hosting new technologies while preserving ecological intelligence. The smart dome represents a fusion between ancestral wisdom and contemporary performance criteria, providing a housing model that is adaptable, resilient, and attuned to its environment.

This work has shown that sustainability is not a concept opposed to tradition. On the contrary, when tradition is critically examined and innovatively adapted, it becomes a powerful engine for sustainable design. By proposing a holistic model that integrates cultural continuity, environmental responsibility, and technological advancement, this thesis contributes to a growing body of work seeking to humanize the green transition in architecture.

In conclusion, this study confirms that smart domes can serve as viable, energy-efficient, and culturally relevant housing solutions for arid zones. It also emphasizes the importance of a multidisciplinary approach, involving architecture, environmental engineering, and human-centered design. Future research could further explore simulation tools, real-world prototyping, and social acceptability studies to validate and implement such models at scale.

As urbanization and climate change continue to reshape our environments, rethinking traditional forms in light of contemporary needs becomes not only a design opportunity but also a social and ecological necessity.

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