master of architectural composition

Nature-Inspired Architecture: Integrating Termite Mounds and Windcatchers in Future UAE Dwellings

Università di Genova | DAD DIPARTIMENTO ARCHITETTURA E DESIGN

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ABSTRACT

This thesis explores an integrated architectural strategy for passive cooling in hot and humid climates, through the design of a sustainable residential prototype submitted to the "House of the Future" competition organized by the UAE government. The design merges vernacular Persian technologies, modern sustainable systems, and cultural traditions, responding to the environmental and social context of the Persian Gulf region.

A primary challenge addressed is the inefficiency of traditional windcatchers (badgirs) in humid climates, where high moisture content limits evaporative cooling and natural cross-ventilation. To overcome this, a hybrid system combining the windcatcher with a solar chimney is proposed, forming a convection-driven airflow loop that operates even in low-wind conditions.

Further inspiration is drawn from termite mounds, which use a central vertical shaft to facilitate convective cooling, maintaining interior climate stability in harsh external environments. This principle informs the integration of a vertical passive cooling core. The design also incorporates traditional concepts such as

The “Hobaneh” cooling jar, applied as double-walled lime-and-clay façades with insulating air gaps.

In alignment with the cultural guidelines of the competition, the project considers the Emirati social lifestyle, especially the inclusion of Majilis—a space historically dedicated to male gatherings—and emphasizes privacy and spatial segregation, critical to Gulf domestic architecture. The layout features a shaded courtyard, geometric canopy, and Shanashil-style balconies(in north of Africa called Mosharabiye), all arranged within an octagonal geometry, referencing sacred Islamic forms while optimizing airflow and cultural symbolism.

The result is a climate-adaptive, culturally rooted, and low-energy architectural prototype that bridges tradition and innovation, offering a replicable model for sustainable living in the Middle East.

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CHAPTER 1

CONTEXT & OBJECTIVES

1.1. Project background

The rapid urbanization of the United Arab Emirates (UAE), alongside its unique climate and rich cultural heritage, poses significant challenges for sustainable housing development. In response, the House of the Future Edition #2 – 2024/25 competition was launched to explore innovative residential designs that align with local environmental, cultural, and social contexts. This thesis was developed as a contribution to this competition, aiming to propose a future-proof housing prototype for Emirati citizens that integrates traditional architectural elements with modern sustainable technologies. Drawing inspiration from vernacular strategies in the Persian Gulf region, this research seeks to reimagine and adapt passive cooling systems for the hot and humid climate of the UAE.

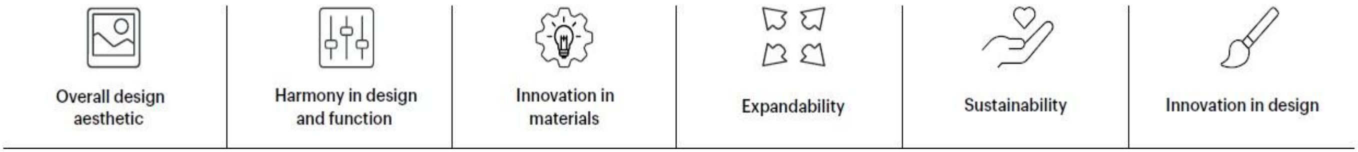
Poster of the house of the future compotation

Sky line of the UAE

The design responds directly to the competition brief, which called for a culturally rooted, innovative, and sustainable home for Emirati nationals. The key evaluation criteria are summarized in the diagram below.

The competition assignment

Design a home for Emirati nationals that can accommodate a family of 4 to 6 members. Submitted project will need to consider the following criteria:



The competition assignment which is exactly stated in the PDF related to the competition.

Emirati nationals’ culture

1.2. Problem Statement

The UAE's residential sector consumes a substantial amount of energy, primarily due to the high demand for mechanical cooling in response to extreme heat and humidity. Traditional passive cooling systems, such as windcatchers (bâdgirs), have proven effective in hot and dry climates but are less efficient in humid environments. Additionally, many modern housing designs in the region overlook cultural identity and climatic suitability in favor of universal styles and technologies. There is a clear need for innovative housing solutions that address both energy efficiency and cultural relevance in design.

1.3. Objectives

The main objectives of this research are as follows:

- To design a residential prototype for Emirati families that responds effectively to the hot and humid climate of the UAE.
- To integrate traditional architectural strategies, such as windcatchers and local cooling techniques, with modern sustainable technologies.
- To enhance thermal comfort while minimizing energy consumption through passive design.
- To reflect cultural identity and traditional spatial hierarchies in the architectural language of the house.
- To contribute a feasible and buildable proposal for the House of the Future competition.

1.4. Research Questions

- How can traditional passive cooling methods, such as windcatchers, be adapted or enhanced to perform effectively in hot and humid climates?
- What role can biomimicry (e.g., termite mounds) play in passive airflow design for residential architecture?
- How can local cultural values and architectural heritage be meaningfully embedded in contemporary housing design?
- What spatial configurations best support natural ventilation while respecting cultural privacy and usability norms?
- How can cost-effective and sustainable materials (e.g., lime, clay) be used to reduce heat gain and energy demand in housing?

1.5. Methodology Overview

This research employs a qualitative design-based methodology supported by case studies, climatic analysis, biomimicry research, and computational simulations. The process includes:

- Literature review on traditional Gulf architecture, passive cooling strategies, and sustainable housing design.
- Climate analysis of the UAE to understand environmental constraints.
- Evaluation of windcatcher and solar chimney systems through performance modeling.
- Exploration of termite mound ventilation principles for biomimetic application.
- Iterative architectural design process integrating climatic, cultural, and spatial considerations.
- Final design proposal presented according to competition submission guidelines.

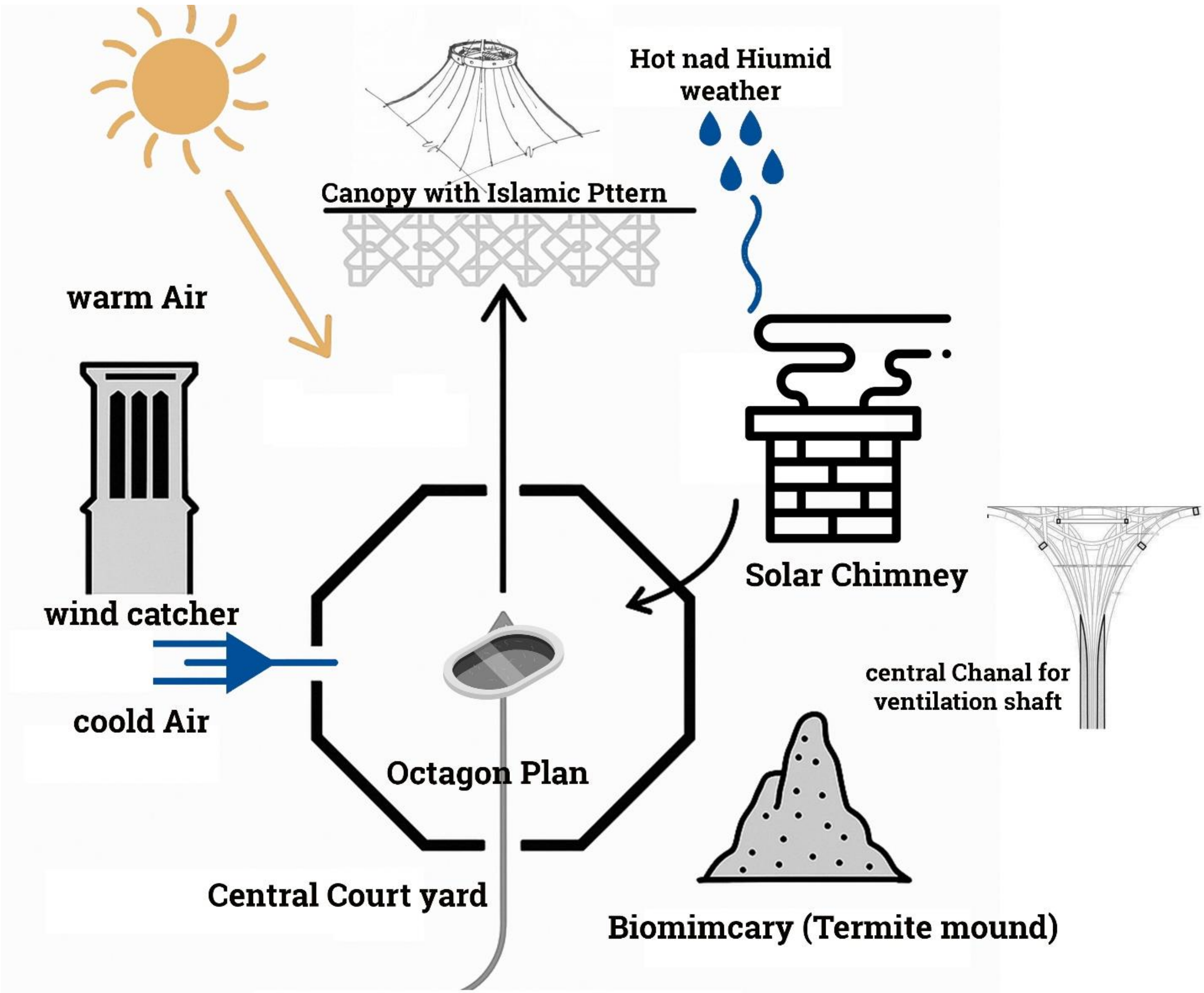


Diagram of conceptual Approach

1.6. Thesis Structure Overview

The thesis is structured into six main chapters:

1. Introduction – Outlining the background, problem, objectives, and methodology.
2. Contextual Stud (Climate, Culture & Traditional and wisdom) – Examining UAE's climate, culture, and architectural traditions.
3. Case studies: incorporates a series of targeted case studies that directly relate to the core concepts of the project—namely passive cooling strategies, biomimicry inspired by termite mounds, traditional windcatchers, and Islamic-Iranian architectural principles. These precedents have been carefully selected to guide and support the development of a culturally and climatically responsive residential design.
4. Design Process – Detailing the development of the architectural concept and iterations.
5. Final Design Proposal – Presenting the outcome with plans, sections, materials, and performance strategies.
6. Conclusion and Reflection – Discussing the findings, contributions, limitations, and future research direction.

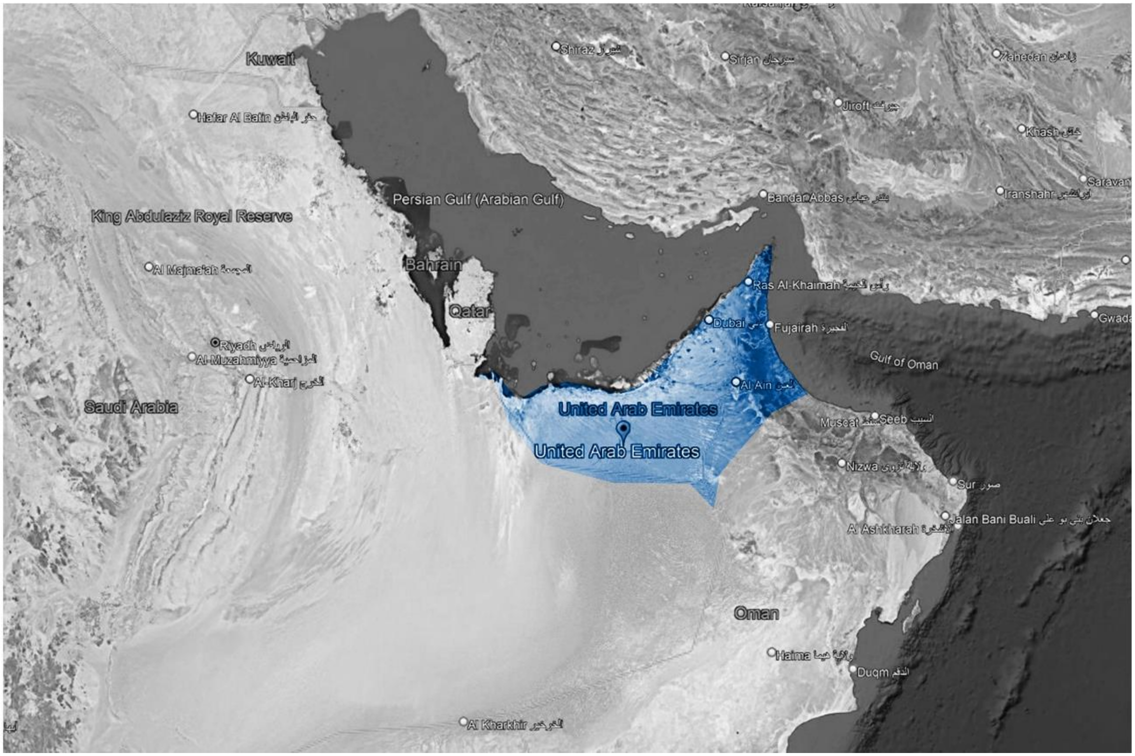
CHAPTER 2

Climate, Culture & Traditional Wisdom

2.1 Climate Analysis

2.1.1. Geography of UAE

United Arab Emirates located in the southeast of the Arabian Peninsula, the UAE is bordered by Saudi Arabia to the south and west, and Oman to the east. The country boasts a diverse landscape ranging from vast desert dunes to lush oases, rugged mountains, and pristine coastlines along the Persian Gulf.



2.1.2. climate overview of UAE

The climate of the United Arab Emirates is characterized by high Temperatures and low precipitation, posing unique challenges for architectural design, The country experiences two main seasons: summer and winter.

- Summer (Jun to September):

Temperatures can soar up to 50c, with a mean temperature ranging from 32c to 37.2c. This season is marked by intense heat and humidity.

- Winter (December to March):

The weather is milder, with mean temperatures ranging from 16.4c to 24c. Rainfall is rare, occurring primarily during the winter months, averaging about 25 days of rain per year.

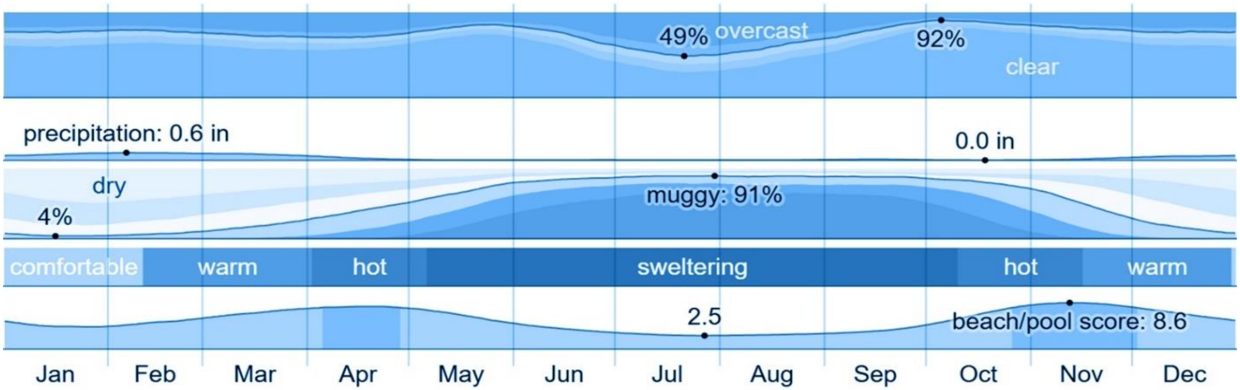
Sunshine: The UAE enjoys an average of 8 to 10 hours of sunshine daily, ensuring blue skies and warm to hot weather throughout the year.

- Humidity:

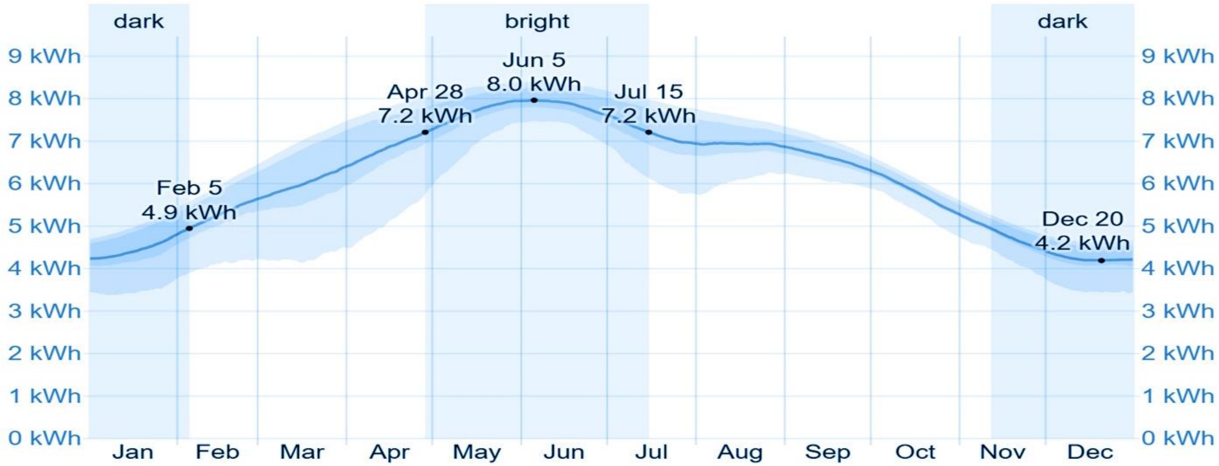
The humidity levels in the UAE can be particularly high, especially during the summer months, often exceeding 90%. This creates additional challenges for maintaining indoor comfort and preventing moisture-related issues.

2.1.3. Specific Climate and Geography of Abu Dhabi

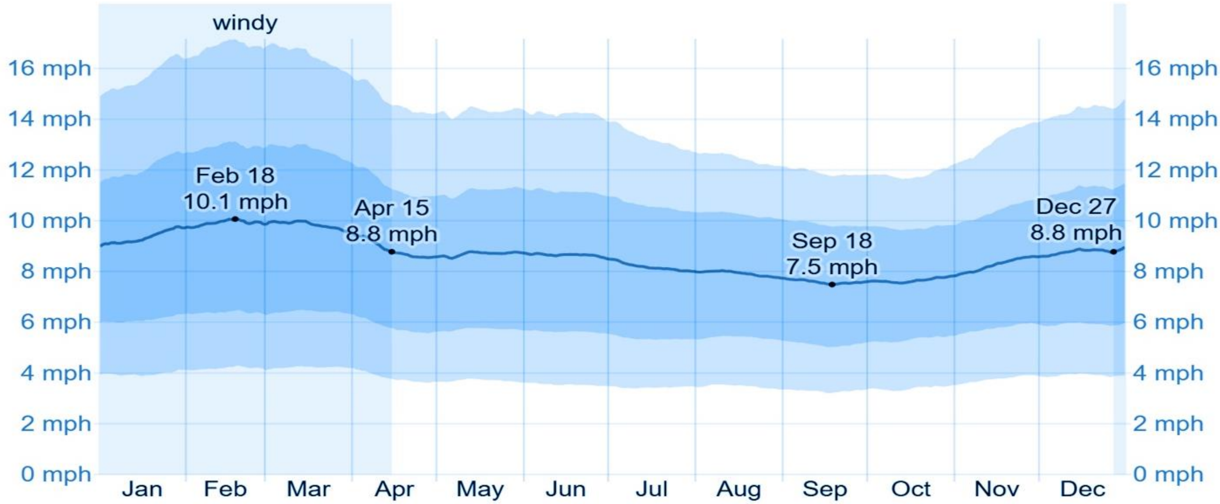
Abu Dhabi is located on the southeastern side of the Arabian Peninsula, adjoining the Persian Gulf, and is primarily situated on an island connected to the mainland by several bridges, including the Sheikh Zayed Bridge and Maqta Bridge. It has a hot desert climate (BWh), with extremely hot and humid summers from May to September, where temperatures often exceed 40 °C (104 °F), and cooler, milder weather from November to March. Sandstorms and high humidity are common in summer, while fog and occasional rain occur during the cooler months.



CLIMATE DIAGRAM



SOLAR DIAGRAM



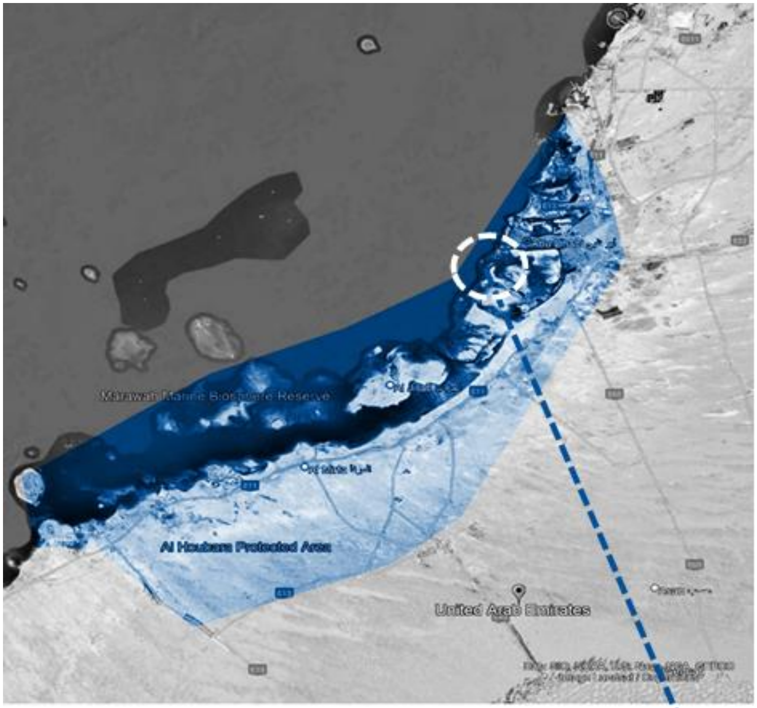
WIND DIAGRAM

2.1.4. Prevailing Winds in Abu Dhabi

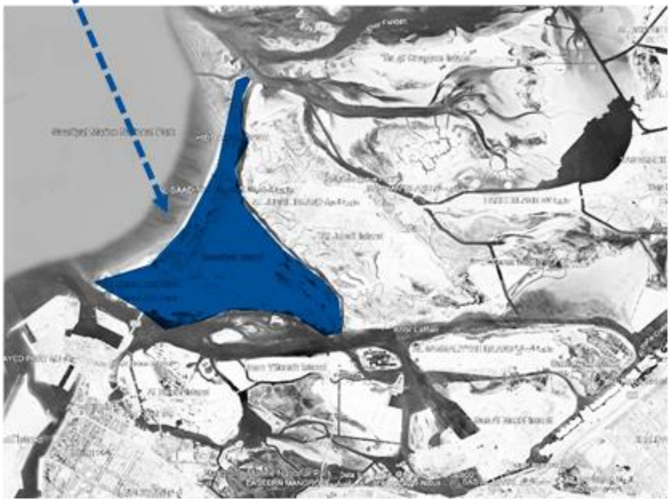
Abu Dhabi, located on the southeastern edge of the Arabian Peninsula along the Persian Gulf, experiences prevailing winds influenced by its desert climate and proximity to the sea. The main types of winds affecting the region are:

Prevailing Winds in Abu Dhabi

Wind type	Direction	Seasons	Characteristic	Effect on Abu Dhabi
Shamal (Northwesterly)	Northwest to Southeast	Winter to early summer (Dec-Jun)	Cold, dry, strong	Lowers temperature and humidity; reduces visibility; affects air quality
Sea of Breeze	Persian Gulf to Inland	Year round (specially summer)	Cool, moist air during day time, moderate speed	Natural cooling of coastal areas; improves urban air quality
Qaws/Qawsan	Inland desert to coastline	Summer (Jun-Sep)	Hot, Dry, Intense, can bring heat Waves	Raises temperature; lowers humidity; intensifies heat stress



ABU DHABI



SAADIYAT ISLAND

2.1.5. site analyses of project (Saadiyat island)

Saadiyat Island, a 27-square-kilometer area near central Abu Dhabi, is a major urban development project planned to house over 145,000 people. It will feature residential, cultural, and commercial zones, including landmarks like the Louvre Abu Dhabi and New York University Abu Dhabi. With natural beaches and views of the Persian Gulf, its location benefits from cooling sea breezes that enhance living conditions.

2.2 Cultural Context

To learn about Emirati culture, find an extensive description in the appendix, which provides insights into the nation's rich heritage and traditions. This appendix includes detailed information on key cultural values such as hospitality, generosity, and religious tolerance. It covers traditional practices, including the significance of Islamic customs, traditional attire, and the central role of family and language in Emirati society. Additionally, the appendix highlights the UAE's architectural heritage, traditional sports like falconry and camel racing, crafts such as Al-Sadu weaving, and the unique flavors of Emirati cuisine. This section serves as a valuable resource for understanding the cultural fabric that de8ines Emirati identity.

2.2.1. Majlis

The people of the United Arab Emirates have deeply preserved their Islamic and Arab cultural roots, and this preservation is clearly reflected in both the spatial organization and interior architecture of traditional and contemporary homes. A key element in these houses is the Majlisi (also known as *Diwaniyyah* among the Arab communities of southern Iran), which serves as a gathering space for men. In line with Islamic social and cultural values, the Majlisiyyah typically has a separate entrance and exit (Majaz[1]), designed in a way that ensures minimal interaction with other private and domestic spaces of the house. This arrangement respects the concept of privacy (Haram or Mahram), which is a cornerstone of Islamic domestic design.

Maintaining such spatial and social boundaries aligns with Islamic teachings and is often emphasized in traditional architecture throughout Islamic countries, including examples from Morocco, Egypt, Iran, and the Persian Gulf region. These designs prioritize privacy, hospitality, and community gathering—all while maintaining a clear division between public and private domains.

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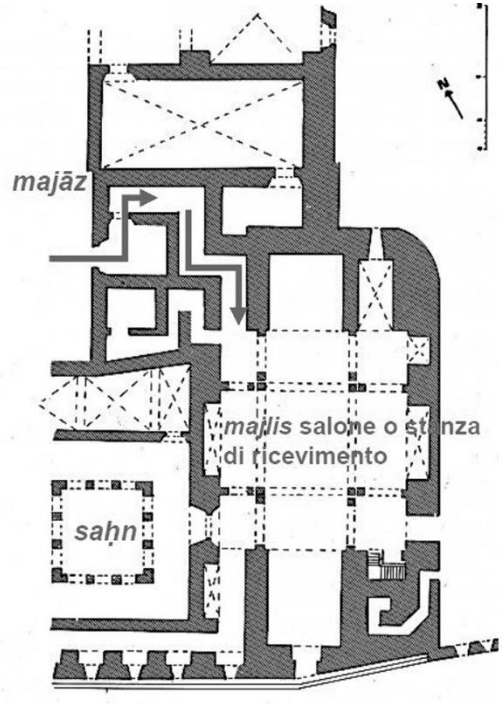
[1] Different entrance to House or indirectly entrance



Egypt- Sultan Malik palace- 1240 A.D.

Source: Typology article - Pro. A. Naser Eslami

Majlis of mans

2.3 Traditional Architectural Solutions

2.3.1. Wind catcher

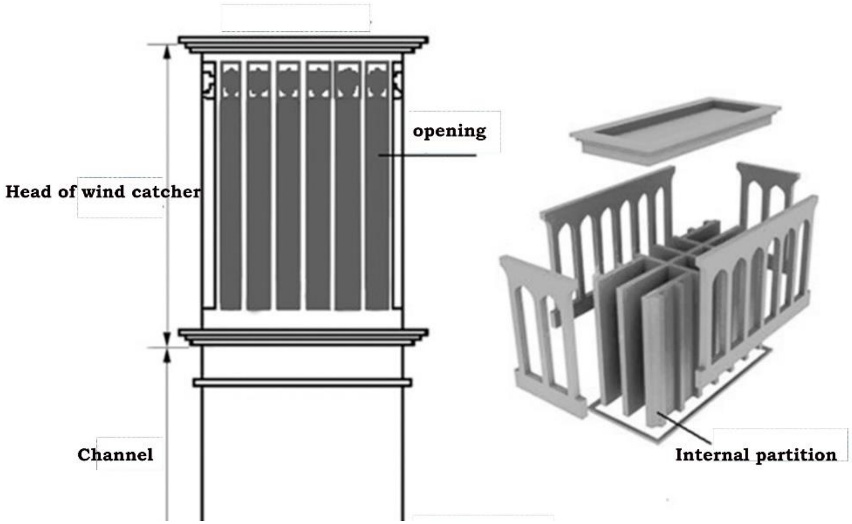
Brujerdi House- Kashan- Iran

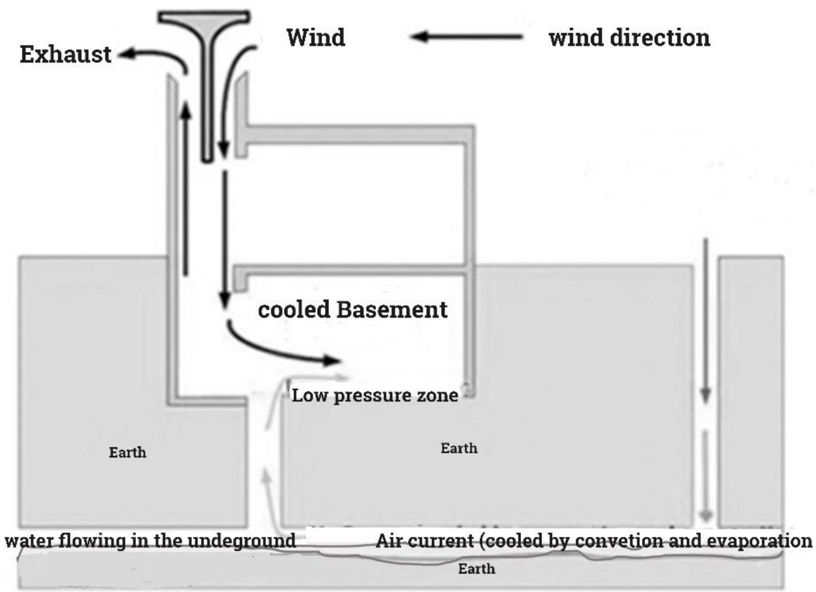
A windcatcher (Persian: *badgir*) is a traditional architectural feature primarily found in the hot and arid regions of Iran, such as Yazd, Kerman, and Kashan and hot and humidity regions of Iran like Bushehr, Hormoz Gan that these cities are located near Persian Gulf. Its main function is natural ventilation and passive cooling of buildings, achieved

without any electrical energy.

2.3.1.1. How Windcatchers Work

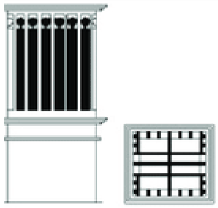
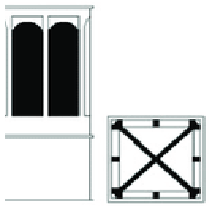
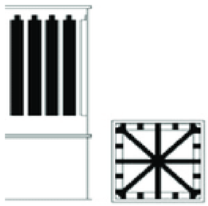
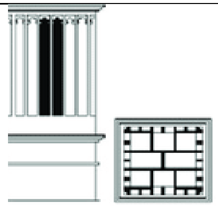
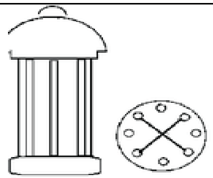
Windcatchers capture cool breezes from above and channel them into the interior of buildings. In some designs, air passes over water sources (like pools or qanats) to become cooler before entering the living spaces. Even when there's no wind, the temperature difference between inside and outside creates a convection current that circulates air.


opening
Head of wind catcher
Channel
Internal partition


Exhaust
Wind
wind direction
cooled Basement
Low pressure zone
Earth
Earth
water flowing in the undeground
Air current (cooled by convetion and evaporation
Earth

2.3.1.2. Types of Windcatchers

- One-sided windcatcher: Open only in one direction, usually facing the prevailing wind.
- Two-sided windcatcher: Has two openings to catch wind from two different directions.
- Four-sided windcatcher: The most common design, especially in cities like Yazd, capturing wind from all four cardinal directions.
- Multi-sided windcatcher: Often hexagonal or octagonal, found in more elaborate or prestigious buildings.
- Composite windcatcher: Integrates wind catching with other cooling methods like qanats or water reservoirs to enhance cooling efficiency

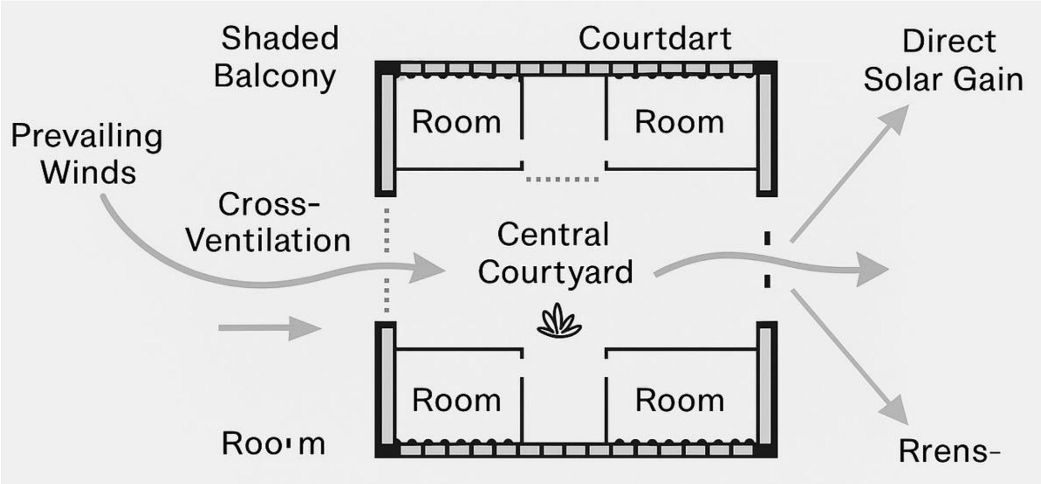
Schematic Drwings	Design Criteria
	Elevation and plan of (I) blade four-sided wind catcher at square plan, commonly used in Iran
	Elevation and plan of (χ) blade four-sided wind catcher at square plan. Commonly used in Iran & GCC countries
	Elevation and plan of (K) blade multiple sides wind catcher at square plan. Commonly used in Iran & GCC countries.
	Elevation and plan of (H) blade four sides wind catcher at square plan, commonly used in Iran.
	Elevation and plan of multi sides (X) blade wind catcher, over circular plan and dome supported by cylindrical columns. A decorative wind catcher used in Yazd, Iran and Sharjah, UAE

2.3.2. Central Courtyard Design in Hot and Humid Climates

In hot and humid climates, the central courtyard acts as a thermal and spatial regulator. By organizing rooms around a shaded open-air void, the design encourages cross-ventilation and reduces indoor humidity levels. The courtyard also provides a microclimate that can cool the surrounding rooms through evaporative cooling, especially when combined with vegetation or water features.

2.3.3. Openings and Orientation

Openings in such climates must be carefully oriented to capture prevailing winds while minimizing direct solar gain. Strategically placed windows, shaded balconies (such as *shanasheel*), and mashrabiya-style screens allow for controlled airflow and filtered light. The goal is to create a breathable envelope that protects from heat while allowing natural ventilation to occur effectively



Central Courtyard Design in the hot
and humid climate

Bait Al Naboodah museum .Sharje- UAE- 1845
Source: https://www.arabianbusiness.com/gallery/396130-look-inside-sharjahs-newly-restored-bait-al-naboodah-museum

2.3.4. Shanashil (شناشیل)

The shanasil (or as the locals in Bushehr call it, “shanashir” or “shanashin”) is a prominent element in the traditional architecture of southern Iran, especially in cities such as Bushehr, Bandar Abbas, and other coastal areas of the Persian Gulf. These structures, which are designed in the form of latticed windows and are often made of wood, have both a functional and decorative role. Now let’s get into the details of the construction and structure of the shanasil:

2.3.4.1. Material:

The shanasil is usually made of wood, as wood is more resistant to moisture and the humid climate conditions of the south (of course, with proper maintenance). Woods such as teak or walnut, which have good resistance to moisture, were common options.

Sometimes in less expensive areas, brick or pottery were also used for parts of the shanasil, but wood was more common due to its carving ability and flexibility in design.

2.3.4.2. Double-shell or single-shell construction

Shingles are usually designed as two shells:

- Outer shell: This is a latticed section and is carved with geometric patterns or Islamic motifs. These lattices both filter light and allow air to flow, while maintaining privacy inside the house.
- Inner shell: There is usually a wooden or glass layer (in more aristocratic houses) that can be opened and closed. This layer acts as a door or window and is closed when more protection is needed (for example, against storms or rain).

This double-shell construction helps regulate temperature and light, the outer shell blocks direct sunlight, and the inner shell allows air flow to be controlled.

2.3.4.3. Lattice design

The lattice patterns of the Shenashils are usually hand-carved and include geometric designs (such as stars, squares, and diamonds) or plant motifs (aslimi). These patterns are not only beautiful, but also help with natural ventilation.

The lattices are designed to limit the view from the outside to the inside, but to provide good visibility from the inside to the outside. This feature was very important for maintaining privacy, especially for women in traditional houses.

2.3.4.4. Dimensions and location

The Shenashils are usually located on the upper floors of houses (second or third floor) and are designed as small balconies or large windows protruding from the wall.

This protrusion (sometimes up to a meter from the main wall) creates more shade on the lower walls and reduces the temperature inside the house.

2.3.4.5. Connections and Strength

To build a Shenashil, wooden pieces were connected using traditional connections such as kond and kob (wooden joints without nails) or wooden nails. This method made the structure more resistant to moisture and temperature changes.

Sometimes, wooden or metal columns were used to support protruding parts for greater strength.

2.3.4.6. Structural Benefits of a Shenashil

- Natural Ventilation: Lattices help with air flow, and in hot and humid areas, this ventilation is vital to keeping the house cool.
- Light and Heat Control: Lattice patterns diffuse sunlight and prevent direct heat from entering.
- Privacy: The design of a Shenashil allows residents to view the outside without being seen.

2.3.4.7. Aesthetics

Shinashils give the facades of houses a special and artistic look and are part of the architectural identity of southern Iran.

2.3.4.8. Challenges in construction

- · Humidity and wear: In humid areas, the wood of shinashils is subject to decay over time. For this reason, regular maintenance and painting (often with natural oils) are essential.
- · Cost and time: The intricate and precise carvings of shinashils require a lot of skill and time, which is why their construction was expensive and was mostly seen in aristocratic houses.

2.3.4.9. Historical examples

Shinashils are well seen in historical houses in Bushehr, such as the Dehdashti Mansion or the Ghazi House. These houses, often built during the Qajar period, are beautiful examples of double-shell shinashils with delicate carvings.

Shanashil (Moshrabie)- Tunes

Shanashil- Bushehr- Iran

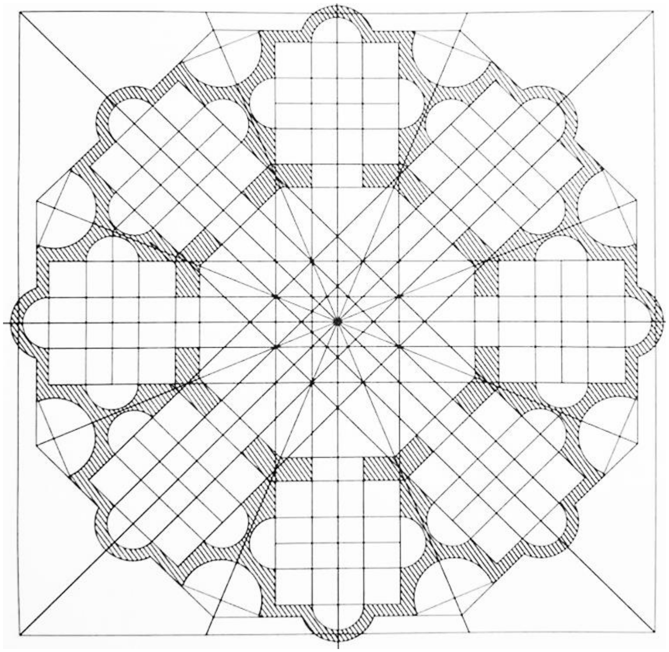
2.3.5. Islamic pattern and design

Islamic architecture is renowned for its intricate geometric patterns and highly symbolic design elements that reflect spiritual, philosophical, and cultural values. Unlike figurative art, which is generally avoided in Islamic contexts, Islamic design emphasizes abstraction through repeated motifs, symmetry, and complexity. These patterns are not merely decorative—they serve to represent the infinite nature of creation and the unity of God (Tawhid) through the repetition and harmony of forms.

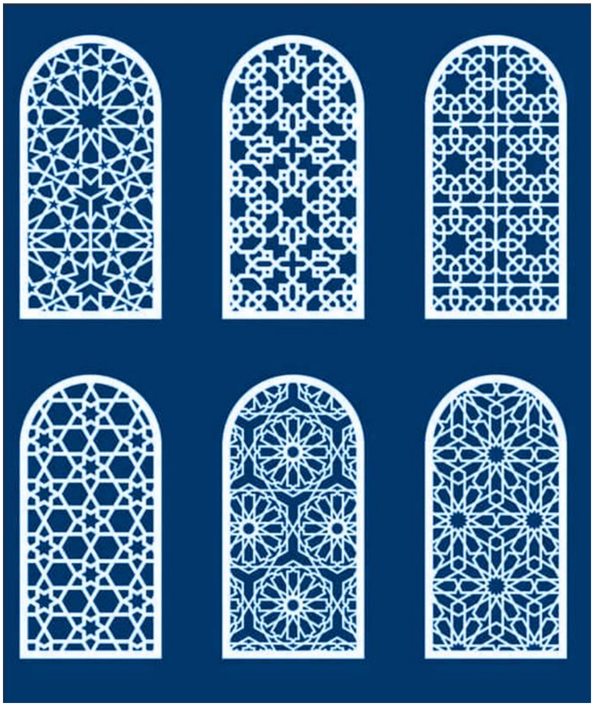
One of the most iconic features is the use of geometric tessellations, such as the eight-pointed star, hexagons, and arabesque motifs, which are derived from mathematical principles and often represent the concept of infinity. These patterns appear in various architectural elements including screens (mashrabiya), windows, wall carvings, tilework (zellige), and ceilings.

Calligraphy is another integral component of Islamic design, frequently used to inscribe verses from the Qur’an or to decorate architectural surfaces with flowing script. Together, these design strategies create an atmosphere of spiritual contemplation, visual harmony, and cultural identity.

In contemporary architectural projects inspired by Islamic tradition, these patterns continue to offer inspiration—not only aesthetically, but also functionally. They are often used to filter light, regulate privacy, and enhance ventilation, connecting the past with the future through timeless design logic.



Eight-pointed star- HOLY Geometry



Islamic pattern on window

2.3.6. Cultural Origins of the Tent Form in Arab Architecture

The traditional tents used by Arab Bedouins—known as *bayt al-sha'ar* (house of hair)—are one of the earliest and most resilient forms of mobile architecture in the hot and arid regions of the Arabian Peninsula. These tents were made from woven goat or camel hair, offering both shade and breathability, and were crucial in providing shelter against extreme heat during the day and cold at night.

Symbolically, the tent represents hospitality, community gathering, and adaptation to nature. Its light, modular, and open structure has influenced many architectural elements in the Gulf region, particularly in public spaces and shading systems.

In this project, the central canopy structure takes formal inspiration from these traditional Arab tents, reinterpreted through a modern lens. The octagonal Islamic patterns embedded into the canopy face material not only evoke cultural identity but also modulate sunlight and cast patterned shadows, enhancing both environmental performance and spatial richness.

This reinterpretation bridges the gap between vernacular wisdom and contemporary sustainable design—a core aim of the proposal.

Traditional Arab Tent

Pattern in canopy and celling

2.3.7. Hobaneh (حبانه) Traditional Clay Pot Cooling Technique)

In the southern regions of Iran—particularly in Khuzestan, Bushehr, Hormozgan and GCC Countries—traditional clay pots known as *habbābah*, *safali pots*, or *gelleh* have long been used to cool and store drinking water and food. These pots are a remarkable example of vernacular passive cooling systems, developed in response to the region’s hot and Humid climate.

2.3.7.1. Material & Structure

- Clay (Terracotta): The pots are made from locally available clay, shaped by hand and fired in kilns. The porous nature of terracotta allows for natural evaporation.
- Porous Walls: The micro-pores in the clay walls enable small amounts of water to seep outward, supporting the cooling effect through evaporation.

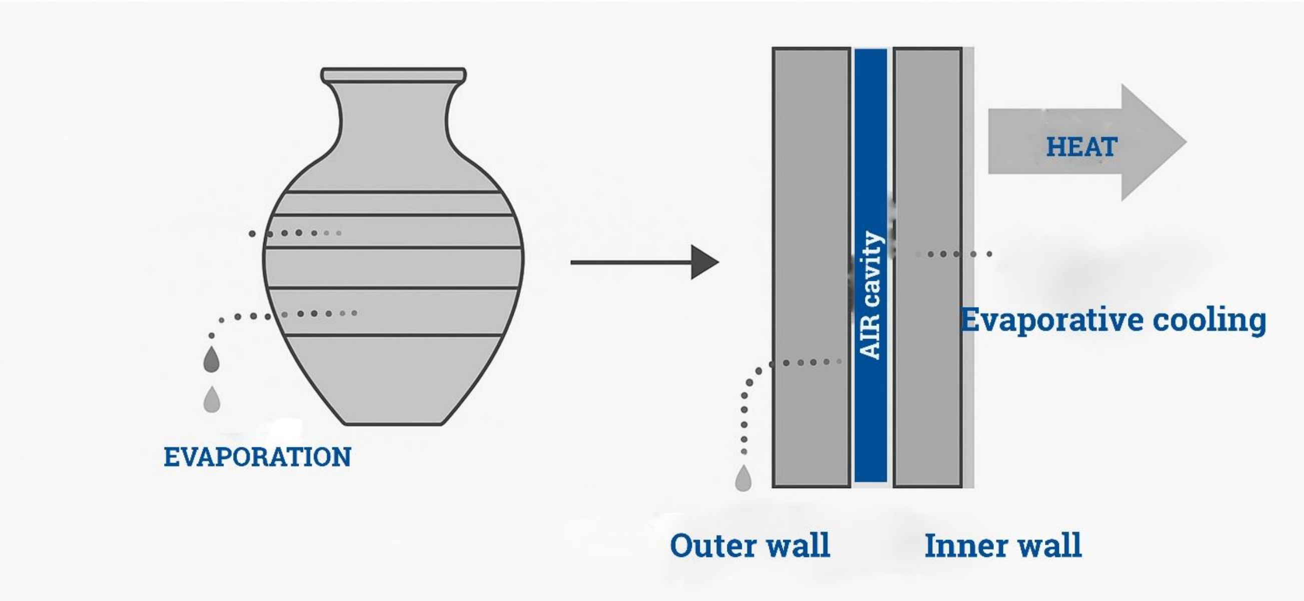
2.3.7.2. Cooling Mechanism

- When filled with water, a thin layer seeps to the outer surface of the pot.
- Exposure to dry air initiates evaporative cooling, absorbing heat from the pot and reducing the internal temperature of the water or food inside.
- Pots are often placed in shaded or ventilated areas to enhance the effect.

2.3.7.3.Features & Benefits

- Energy-Free Cooling: No electricity or mechanical systems are needed.
- Eco-Friendly: Made from biodegradable and locally sourced materials.
- Functional Design: Their rounded or cylindrical forms with narrow necks minimize evaporation and contamination.

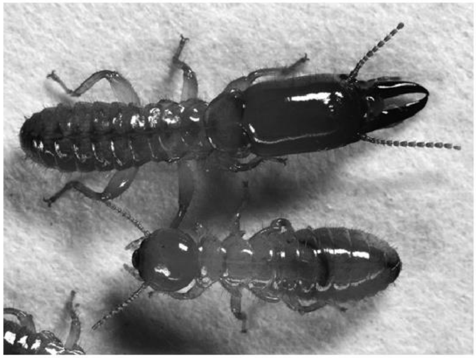
This natural method reflects the indigenous wisdom of adapting to harsh environments and serves as inspiration for modern bioclimatic design. In this architectural project, the habbābah concept has been reinterpreted in the form of double-layered lime and clay walls with an air cavity, using the same principles of evaporative cooling for thermal comfort in hot climates.



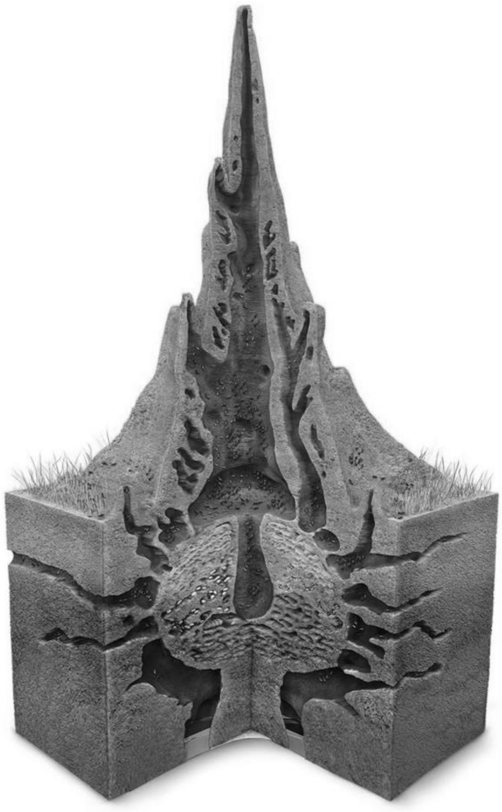
Hobbane – inspired Evaporative cooling – Double Wall

2.4. Lessons from Nature (Natural patterns - biomimicry)

Termites of the Macrotermes species, such as Macrotermes michaelseni, build large, complex mounds that have natural ventilation systems. These regulate the internal airflow by taking advantage of the day-night cycle and the specific structure of the mounds. During the day, the sun's heat warms the outside of the mound, and warm air rises, while cooler air sinks. This process helps to naturally control the amount of carbon dioxide inside the mound.



Macroterms Termite

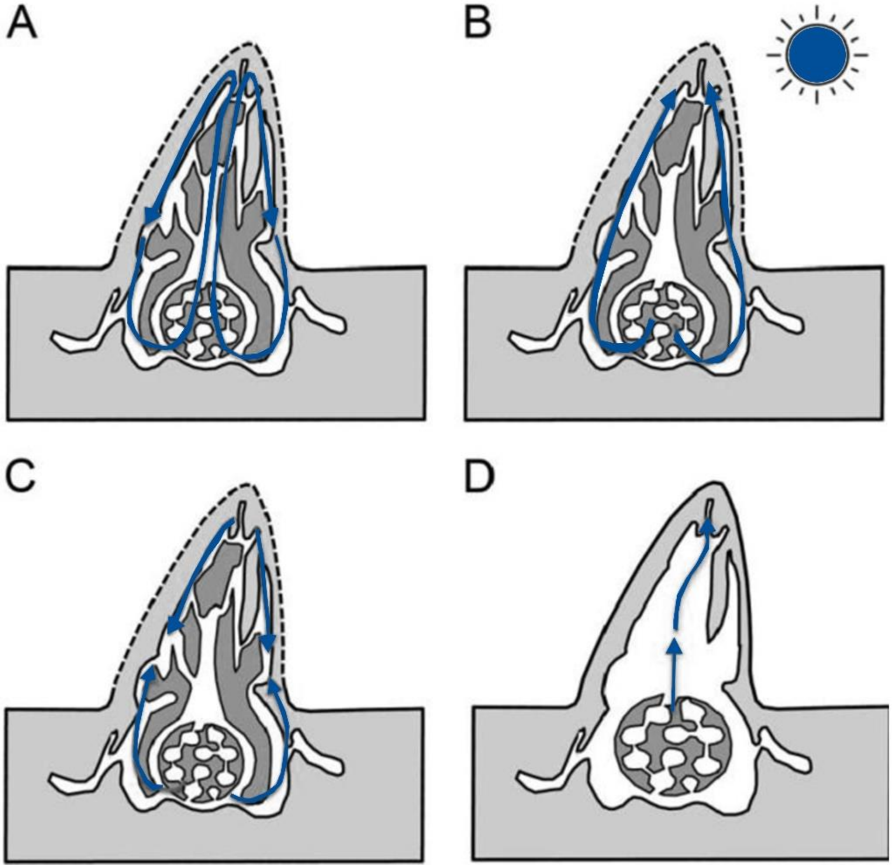


Termite mound

2.4.1. Termite Mound Ventilation

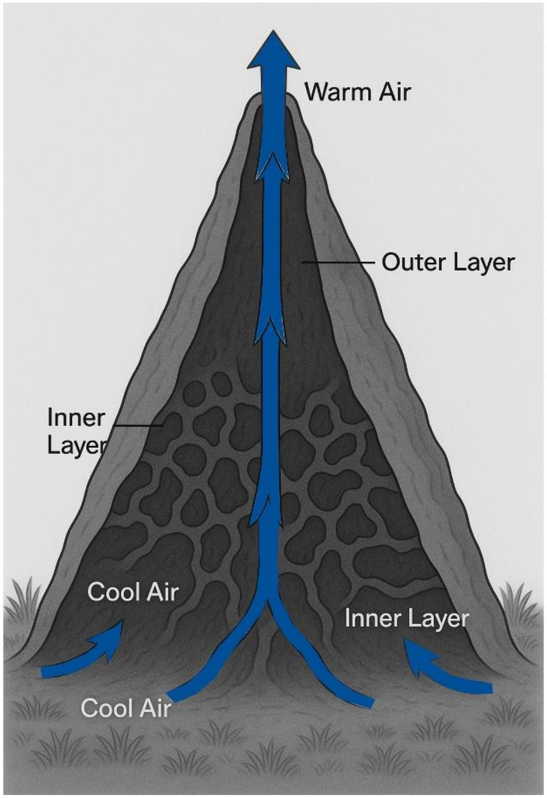
Termite mounds exhibit a sophisticated natural ventilation system that maintains stable internal conditions despite fluctuating external temperatures. This passive ventilation is primarily driven by temperature gradients and structural design. The diagram illustrates four key airflow patterns within the mound:

- Panel A: During cooler periods, such as nighttime, external air enters through peripheral flutes, descends, and then rises through the central chimney. This creates a convective loop that facilitates air exchange.
- Panel B: Under daytime solar heating, the outer walls of the mound warm up. The heated air rises along the outer channels and escapes through the top, generating a suction effect that draws cooler air into the base.
- Panel C: Air circulates laterally through multiple side channels, enabling multidirectional ventilation. This supports a consistent internal microclimate and enhances the efficiency of gas exchange.
- Panel D: In simplified conditions or when some passages are blocked, air flows directly upward through the central shaft and exits at the summit, allowing for basic yet functional ventilation.



Ventilation Mechanism of Termite Mounds

This natural ventilation system supports the mound's internal ecosystem, particularly by regulating temperature and humidity essential for the termites' fungal cultivation. It also ensures adequate oxygen supply and removal of carbon dioxide, functioning entirely without mechanical aid.



Cooling system based on convection current in termite mound

2.5. Synthesis of Vernacular Wisdom and Cultural Heritage

The environmental, cultural, and material strategies explored in this chapter reflect a deep understanding of how traditional societies in the Gulf region adapted their architecture to extreme climates. From the evaporative cooling of HOBBANE pots to the convective airflow systems inspired by *termite mounds*, and from the social spatiality of *Majlis* to the symbolic form of the Bedouin tent canopy—each element contributes to a design language that is both climatically responsive and culturally rooted.

These insights form the foundation for the innovative design strategies developed in the next chapters, where vernacular wisdom meets contemporary sustainability

Vernacular Element	Function	Cultural Value	Integration in Project
Windcatcher (Badgir)	Natural Ventilation	Regional Identity	Combined with solar Chimney
Hobbane	Evaporative cooling	Material Tradition	Applied in Double layered Walls
Termite Mound	Convective Flow	Biomimicry	Inspiration for vertical ventilation core
Bedouin Tent	Shade + Mobility	Symbol of Community	Influenced Canopy Geometry and structure
Majlis	Spatial Separation	Social Customs	Included in Layout planning

Synthesis of Vernacular Wisdom and Cultural Heritage

CHAPTER 3

CASE STUDIES

3. Case Studies – Learning from Contextual & Climatic Wisdom

This section presents a series of architectural case studies that serve as foundational references for the development of this master's thesis project. The aim of the thesis is to design a sustainable and culturally grounded residential space in response to the *House of the Future* competition in the UAE.

The selected case studies are drawn from regions with similar climatic conditions—such as the hot and humid coastal areas of the Persian Gulf and North Africa—and share architectural strategies that emphasize passive cooling, spatial privacy, cultural symbolism, and material wisdom. Each example is analyzed in terms of its climate response, spatial organization, and potential relevance to the thesis design process.

By extracting lessons from these precedents, the thesis seeks to merge traditional knowledge with modern innovation in a meaningful and context-sensitive architectural proposal.

3.1. Burtinle Hospital

3D view of the Hospital

Project Title: Hospital

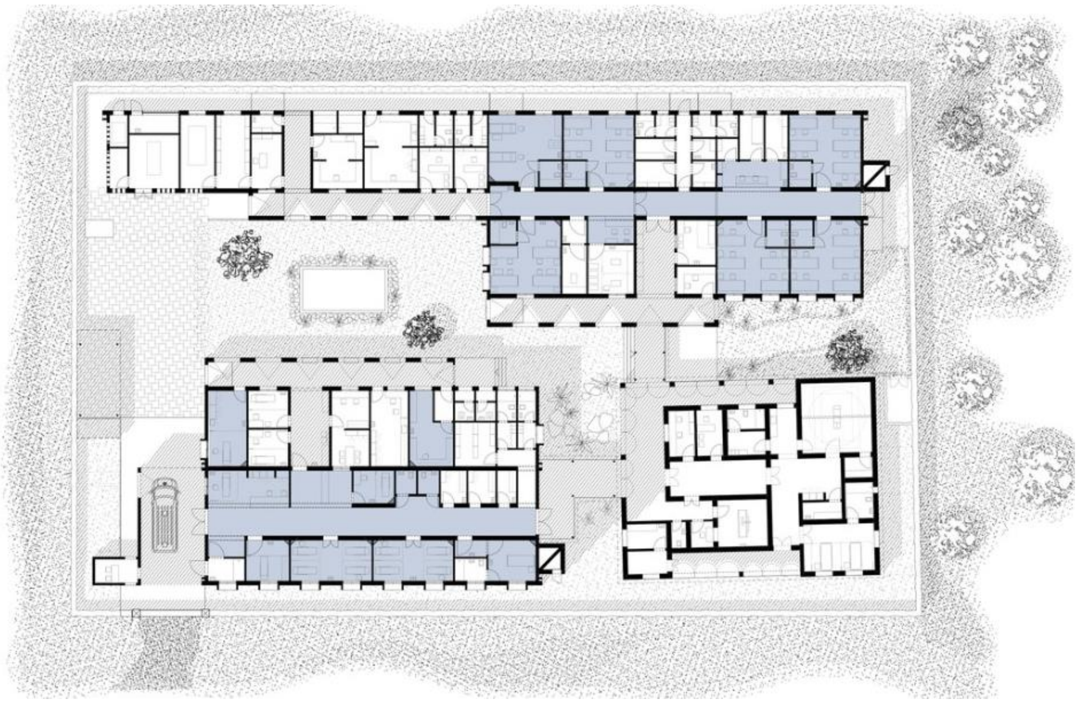
Location: Hospital: Burtinle, Somalia

Climate Type: Hot and Arid Climate

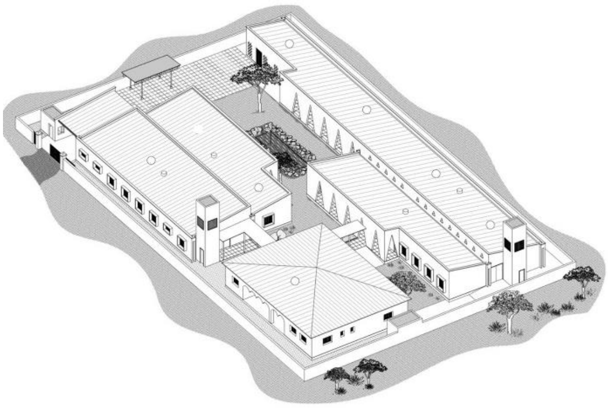
Architect name / Date: Architectural Pioneering Consultants- 2023

Key Architecture Features: Windcatcher

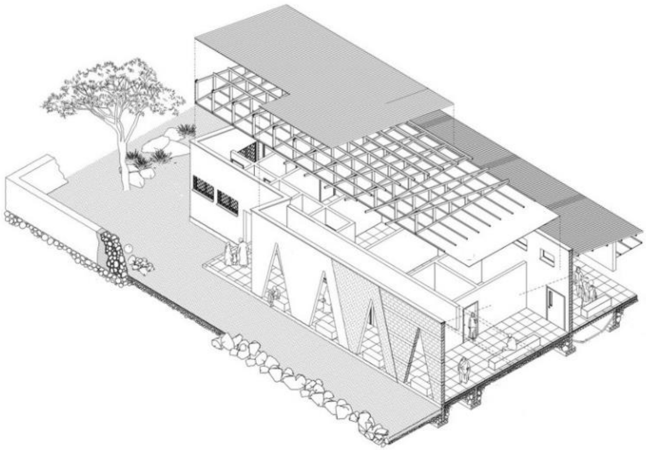
Passive cooling strategies: Windcatcher



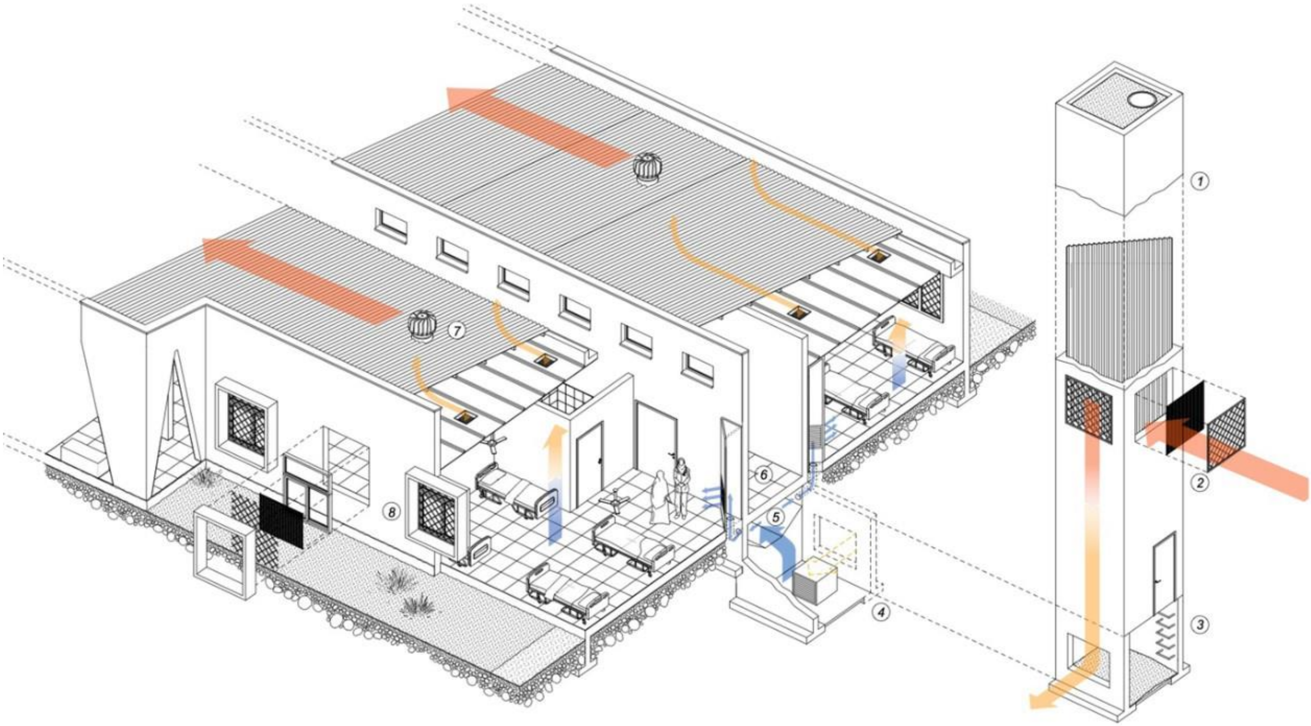
Plan of the Hospital of



Birdview of the Hospital



3D section of the Hospital



Passive cooling mechanism working

1. Wind tower
2. Wind catcher: Intake of dry and sandy desert wind
3. Sand Filter
4. Humidification
5. Earth cooling
6. Ducting to selected rooms
7. Vent and warm air Extraction
8. Supplementary Air Exchange and regulation via window opening

Hospital of Somali

3.2. The Eastgate Center

Project Title: The Eastgate Centre

Location: Hospital: Harare, Zimbabwe

Climate Type: Moderate and dry

Architect name / Date: Mick Pearce- 1996

Key Architecture Features: Biomimicry Inspiration (Termite mound), natural ventilation

Passive cooling strategies: shaft ventilation

3.2.1. Design Concept

- Inspiration: Termite mounds maintain internal temperatures between 28–31°C, even when the outside temperatures vary from 35°C in the day to 10°C at night. They achieve this through a series of vents and channels that allow natural convection and passive airflow.
- Objective: Reduce the energy required for heating, ventilation, and air conditioning (HVAC) in a commercial building.

3.2.2. Key Design Features

- Passive cooling system:

  The building has no conventional air conditioning. Instead, it uses a combination of natural ventilation, thermal mass, and strategic openings to regulate temperature.

- Thermal mass:

  Concrete slabs absorb heat during the day and release it at night, smoothing out temperature fluctuations.

- Ventilation shafts:

  Inspired by the mound's tunnels, a series of vertical shafts draw cool air in and push warm air out through the roof.

- Night purging:

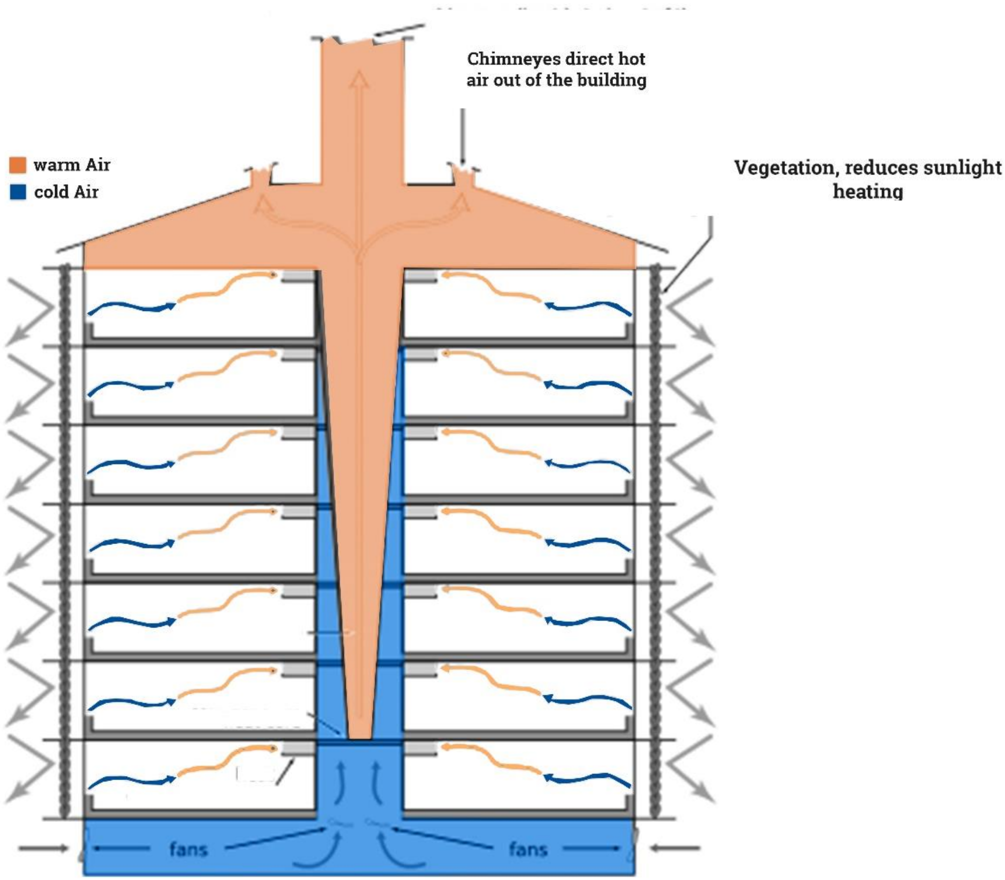
  Cool night air is pulled through the building to remove heat stored during the day.

3.2.3. Performance Results

- Energy savings: The building uses ~10% of the energy compared to a conventional air-conditioned building of similar size.
- Cost savings: Saved around $3.5 million in initial air conditioning costs.
- Environmental impact: Dramatically reduced carbon footprint and running costs

The Eastgate center

Termite Mound



Natural ventilation in Highrise building (Termite Mound system)

3.3. The Borujerdi House (خانه بروجردی ها)

Brojerdi house court yard

Project Title: The Brojerdi House

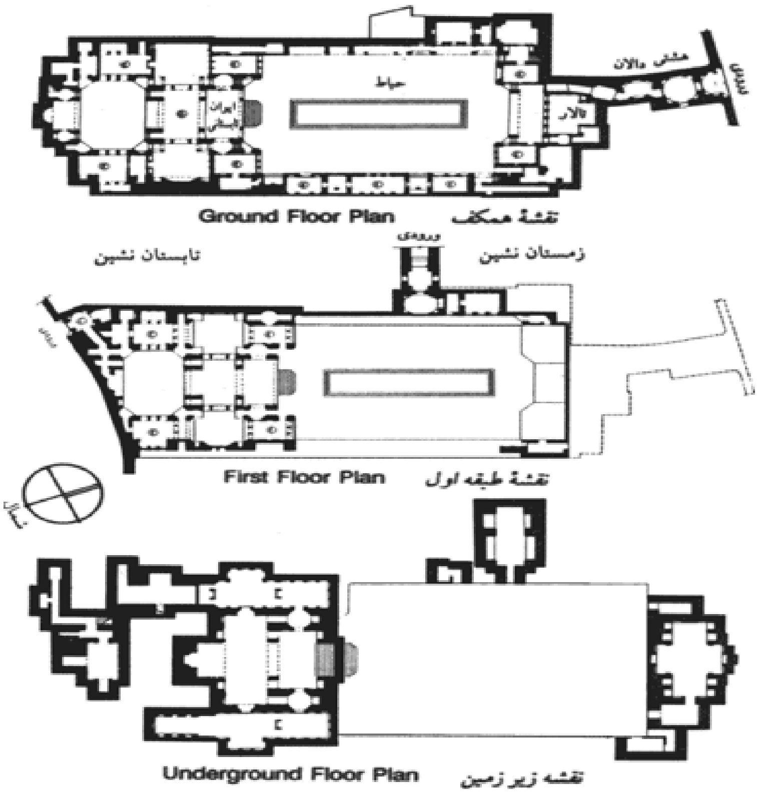
Location: Hospital: Kashan, Iran

Climate Type: Hot and Arid Climate

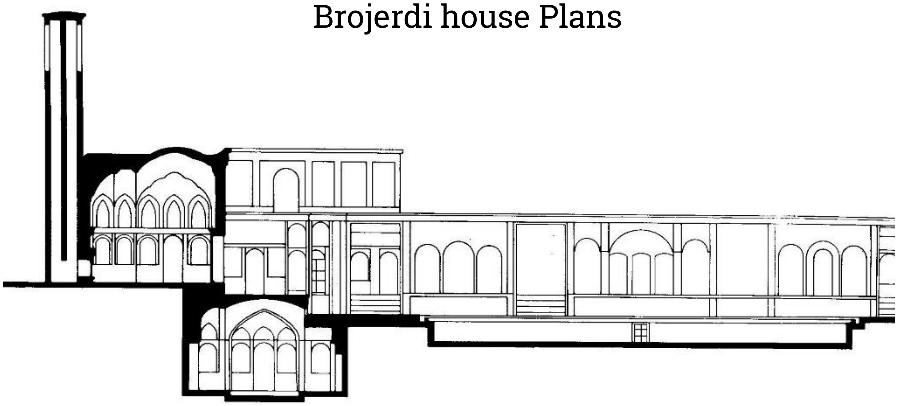
Architect name / Date: -Ustad Ali Maryam ,1857

Key Architecture Features: Windcatcher system- Central court yard- Islamic pattern- privacy layers-

Passive cooling strategies: Windcatcher



Brojerdi house Plans



Brojerdi house section

Brojerdi house section

Brojerdi house

The Borujerdi House is a historical residential building located in Kashan, Iran, built in the mid-19th century during the Qajar era. It is renowned for its elegant Persian architecture, featuring a central courtyard, tall windcatchers (badgirs), and intricate stucco and mirror work.

One of its most distinctive elements is its advanced passive cooling system, which includes windcatchers combined with a subterranean reservoir (howzkhaneh) to naturally cool interior spaces. The house exemplifies how traditional Iranian architecture adapted to the hot and arid climate using sustainable techniques.

Architecturally, the house reflects cultural values of privacy and separation of public and private spaces, with designated areas for men (biruni) and family (andaruni). Its ornamental details, from the geometric plasterwork to the richly painted ceilings, also highlight the aesthetics of Persian craftsmanship.

3.4. Dowlatabad Garden

Project Title: Dowlatabad Garden

Location: Hospital: Yazd, Iran

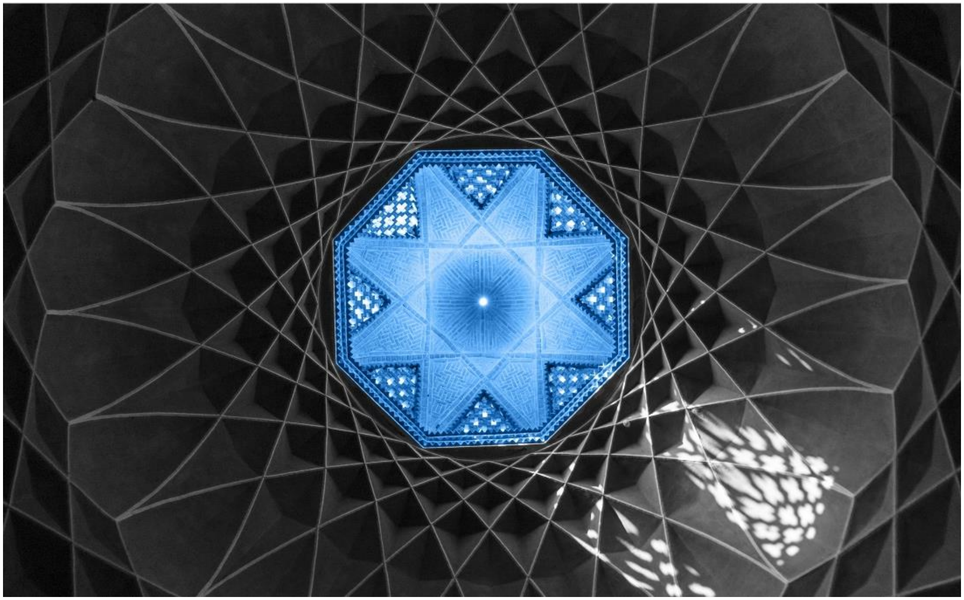
Climate Type: Hot and Arid Climate

Architect name / Date: Mohammad Taghi Khan Bafqi - 1747

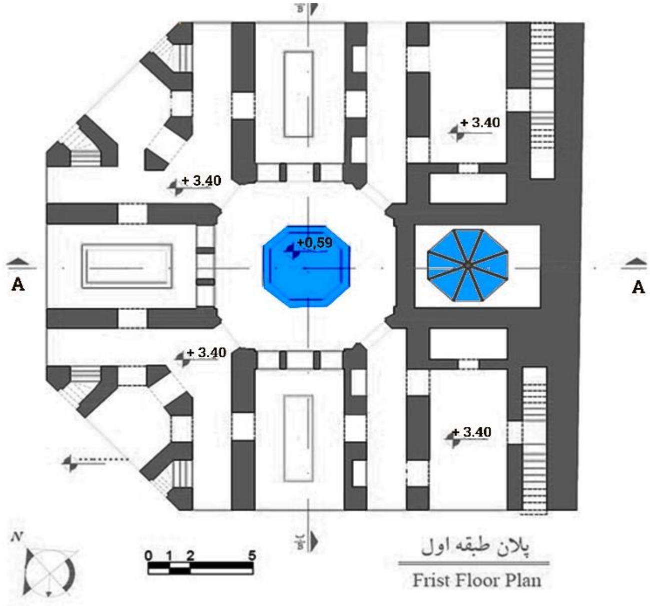
Key Architecture Features: Windcatcher, Octagon plan, Islamic pattern, symmetric design

Passive cooling strategies: Windcatcher

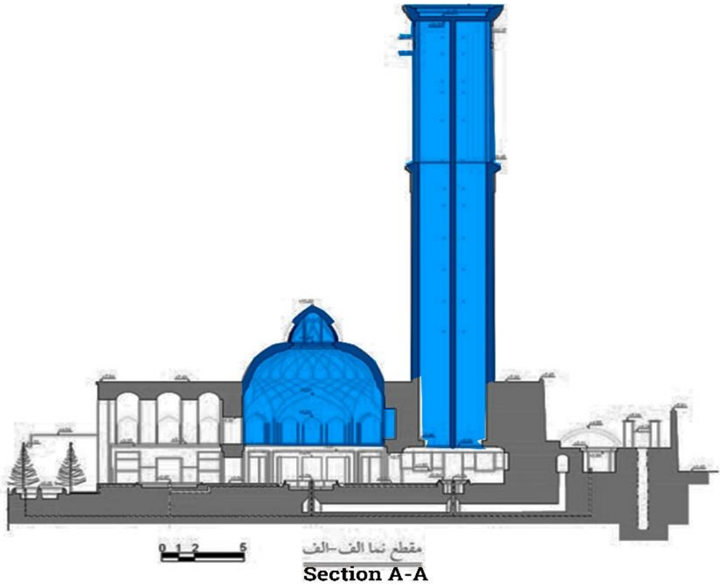
Dolat Abad Garden in Yazd, Iran, is a prime example of traditional Persian garden design adapted to a hot, arid climate. Built in the 18th century, it features the world's tallest adobe windcatcher (badgir), an ingenious element for natural cooling and ventilation. The garden's symmetrical layout, central water channels, and use of native plants demonstrate sustainable landscape design deeply rooted in local environmental conditions—making it an ideal case study for research on climate-responsive architecture and historical sustainability practices.



Octagon star (Holy Geometry) in the celling of the Dome of the Dowlatabd garden

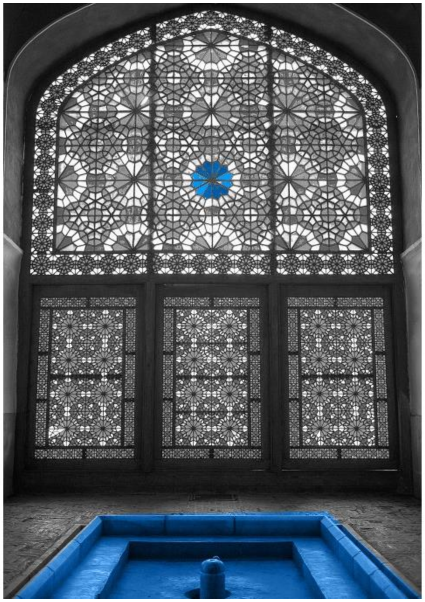


First Floor plan OF DOWLAT ABAD



Section A-A OF DOWLAT ABAD

Open space (balcony) in the Dowlatabad Garden



Glass of the window with the pattern in the Dowlatabad

3.5. Emarate Sabz (Green Mansion)

Project Title: Emarate Sabz (Green Mansion)

Location: Hospital: Bushehr- Iran

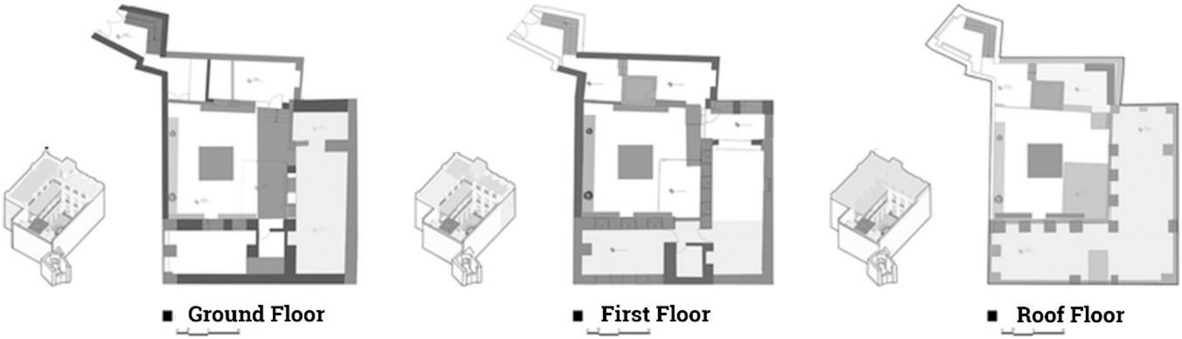
Climate Type: Hot and Humid Climate

Architect name / Date: Mojtaba Naghi Zade Mangili, Nastaran Tavakoli- Restoration 2020

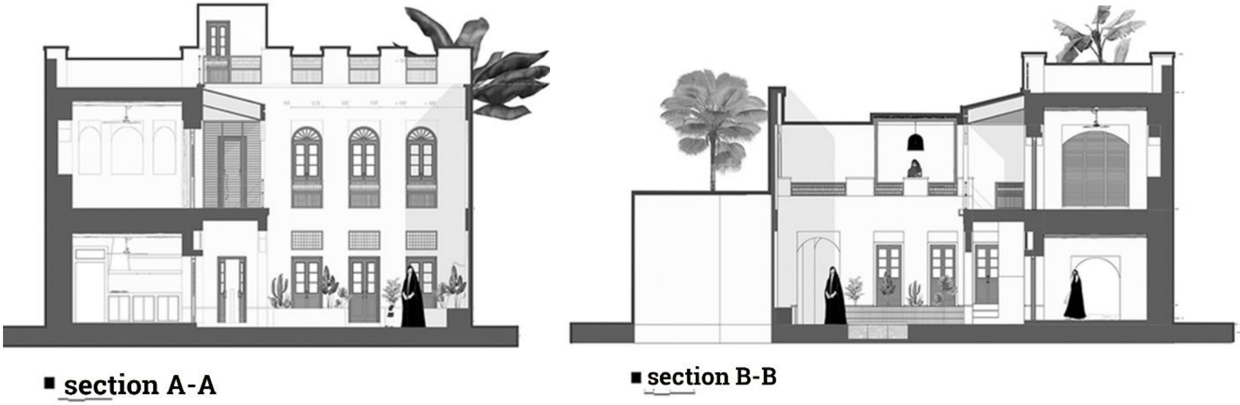
Key Architecture Features: Shanashil-style wooden balconies, Central courtyard with reflecting pool, Local materials and patterns

Passive cooling strategies: Including cross-ventilation, shaded openings, and light-colored surfaces to reduce heat gain.

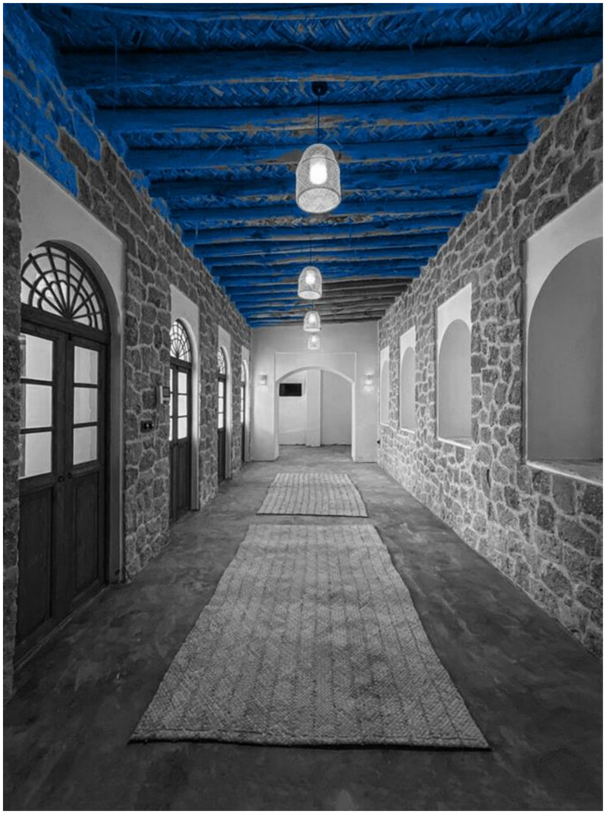
The Green Mansion in Bushehr, a 2020–21 restoration by Ev.Design, transformed a fragmented and improperly expanded historic residence into a coherent, context-sensitive home using a clear four-phase methodology. Through detailed site and structural assessment, removal of incongruous additions, reinforcement of original masonry, and the reintroduction of coastal vernacular elements—such as shanashil wooden balconies, a central courtyard pool, woven-patterned tile flooring, enhanced fenestration, and a restored entrance hall—the project not only revived the building's architectural integrity but also exemplified sustainable, climate-responsive renovation grounded in local materials.



Green Mansion plans



Green Mansion sections



CHAPTER 4

Design Innovation & Passive Cooling Strategies

4.1. Design concept and innovation

The design incorporates a combined passive cooling strategy by integrating windcatchers, a solar chimney, and a central vertical shaft inspired by the convective ventilation of termite mounds. Together, these elements enable continuous airflow throughout the building, especially effective during periods of low wind or intense heat.

To complement this, Shanashil (projected balconies) and a lightweight canopy—inspired by desert tents and Islamic patterns—provide shade, reducing direct solar exposure and enhancing thermal comfort.

On the following page, a circulation diagram illustrates how these elements work together to create a natural ventilation system and maintain indoor comfort in a hot and humid environment.

1 Wind catcher
Cold air enters from the north and northwest vents and hot air exits from the south and southeast vents.

2 solar chimney
Creating warm air through mirrored panels to absorb warm air and ultimately circulate air in hot and humid weather.

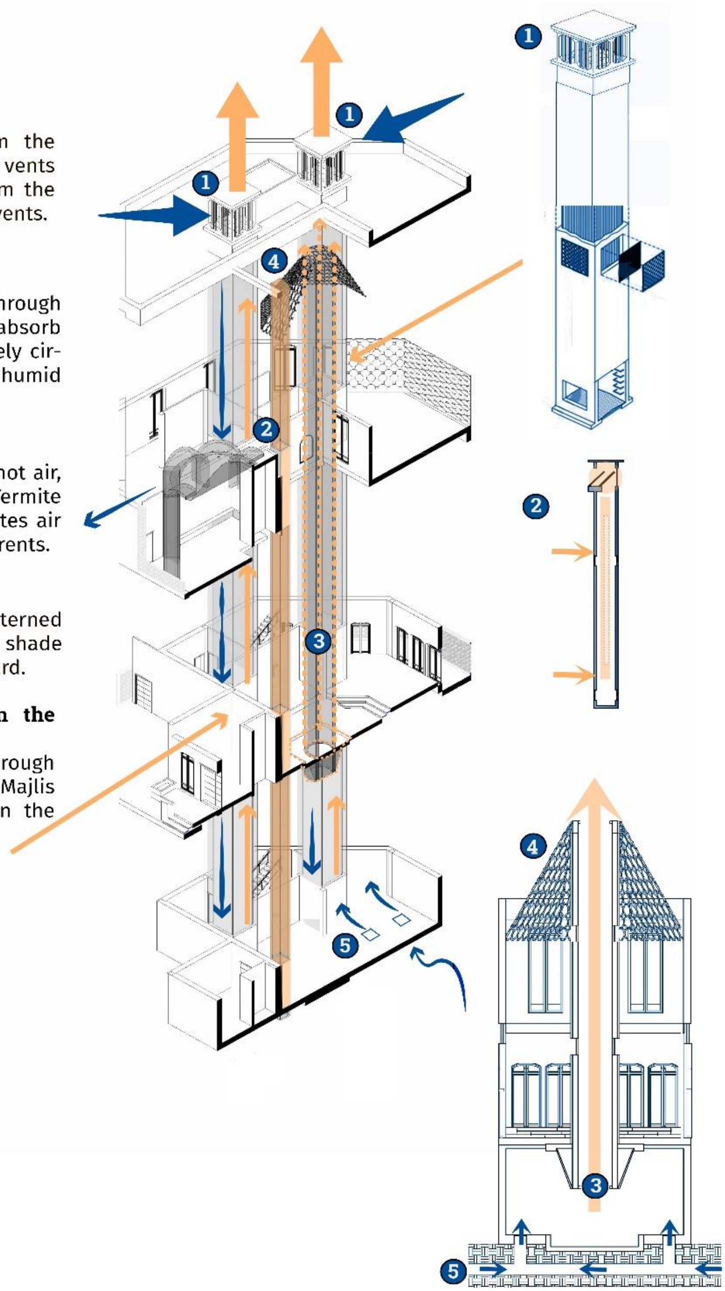
3 Central Channel
The vertical shaft of hot air, derived from the Termite house system, circulates air due to convection currents.

4 Canoppy
A canopy with a patterned texture that provides shade in the central courtyard.

5 Cold air inlet from the floor
Cold Air passing through the soil enters the Majlis through the vents in the basement floor.

Cold Air

Warm Air



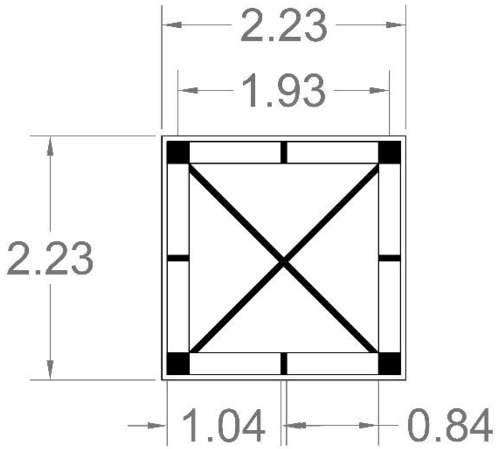
4.2. Passive Cooling Systems

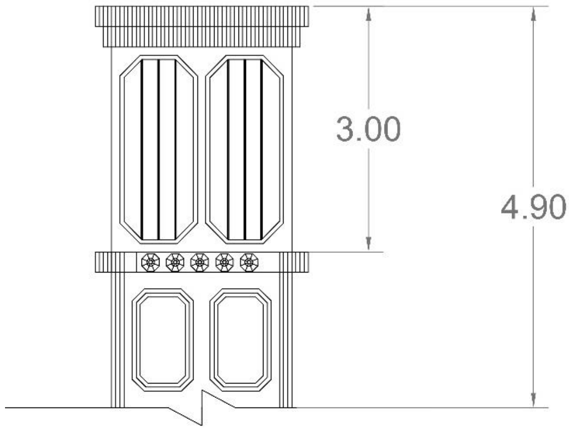
4.2.1. Wind catchers and solar Chimney

4.2.1.1. wind catcher

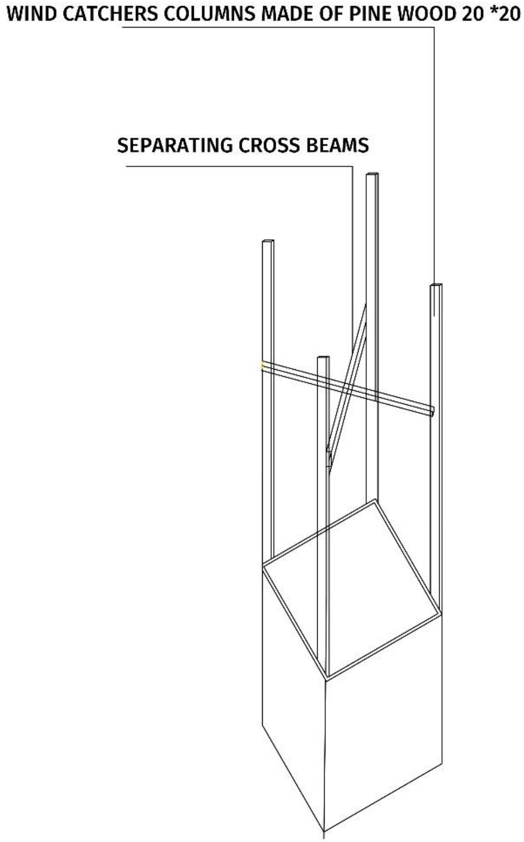
Wind catchers, also known as windbreaks, are traditional passive cooling systems that have long been used to enhance natural ventilation and indoor thermal comfort. Their structural shape varies across climates and are commonly found in rectangular, square, circular, rhombic, and sometimes triangular shapes. An important aspect of their performance lies in the orientation of their openings – which are strategically aligned with the prevailing wind direction to facilitate effective air entry, while the opposite sides are designed to allow hot air to escape.

The number and orientation of these openings are directly influenced by regional wind speed and direction and atmospheric conditions. For example, in hot, dry climates, wind deflectors may have a single opening, while in hot, humid environments, it is more common to see two-way or four-way configurations to increase airflow and cross-ventilation.





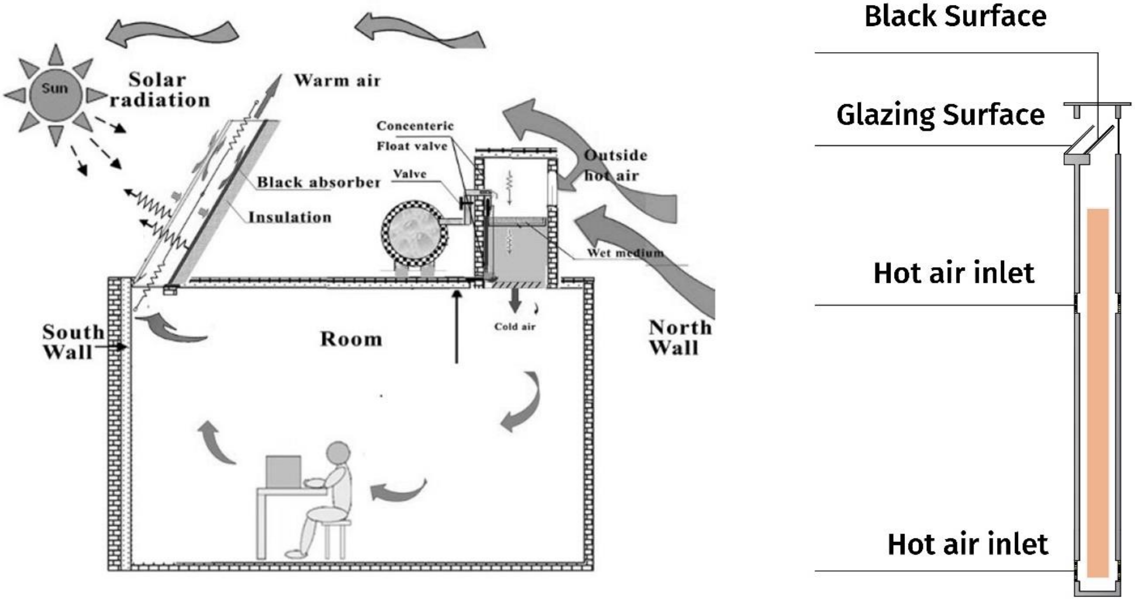
Elevation, SC: 1/25



Details of wind catcher in this project

4.2.1.2. solar chimney

The solar chimney, heated further by the mirrored surface, draws hot air upward, while the windcatcher brings in cooler air—this temperature and pressure difference creates a continuous airflow that reduces humidity and lowers indoor temperature.



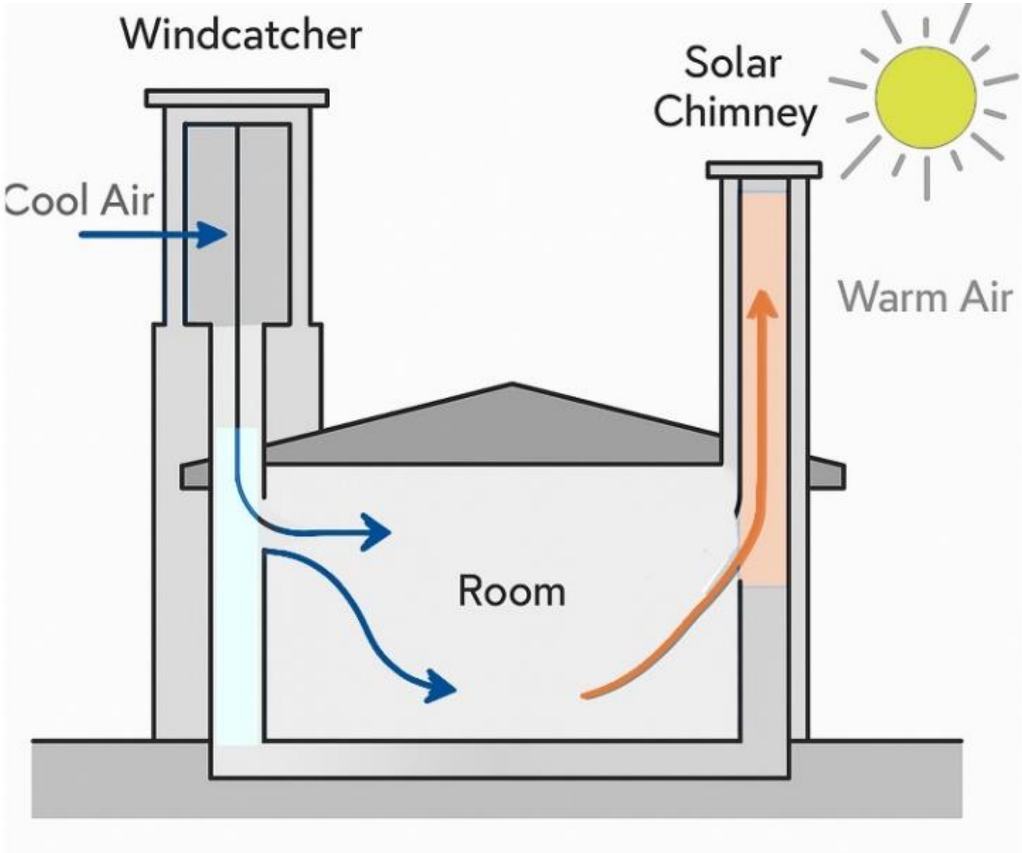
Solar Chimney

4.2.1.3. Combination Windcatchers and solar chimney

Despite their widespread use, wind Catchers are more efficient in dry climates and often face performance challenges in humid conditions due to the high humidity, especially in the Persian Gulf region. This climatic constraint presents a significant design challenge for wind Catcher applications in hot and humid regions, such as the context of this thesis project.

Based on current research and environmental analysis, it has been determined that a combined approach is needed to optimize passive cooling in such climates. Among the various combinations tested, integrating a wind catcher with a solar chimney has been the most effective method. This system increases natural air circulation by creating upward thermal pressure, thereby enhancing the performance of the wind catcher and achieving improved indoor comfort with minimal energy consumption.

The combined system of windcatcher and solar chimney promotes airflow even in hot and humid conditions, enhancing natural ventilation



Schematic diagram of how to work solar
chimney and wind catcher together

4.2.2. Thermal and Humidity Control via Solar Chimney and Windcatcher Design

- The windcatcher is a four-sided structure with a square plan.
- Openings are present on all four sides, separated by a cross-shaped blade.
- The site is rotated 45 degrees relative to cardinal directions.
- North and northwest openings face the prevailing wind direction.
- South and southeast openings function as hot air outlets.
- Windcatchers are located in the shaded central courtyard.
- The solar chimney is placed on the south side of the courtyard.
- A mirrored surface is also used to further increase sunlight absorption.
- The chimney acts like a vacuum, drawing in surrounding warm air.

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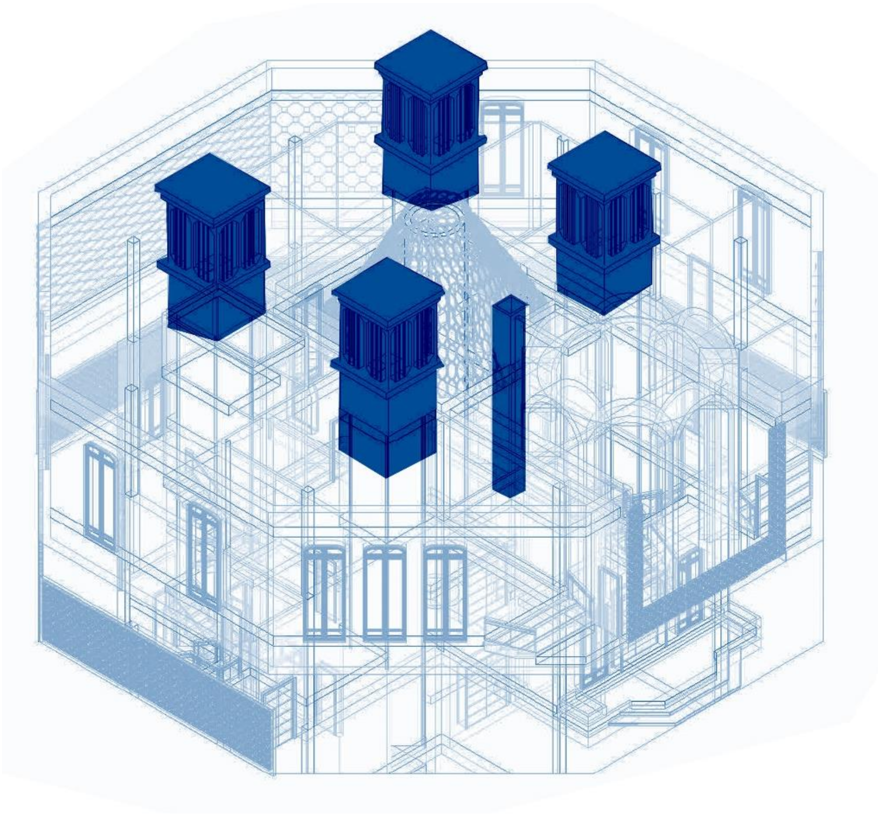

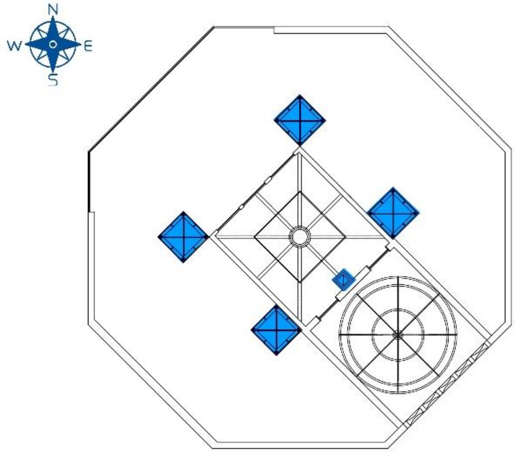
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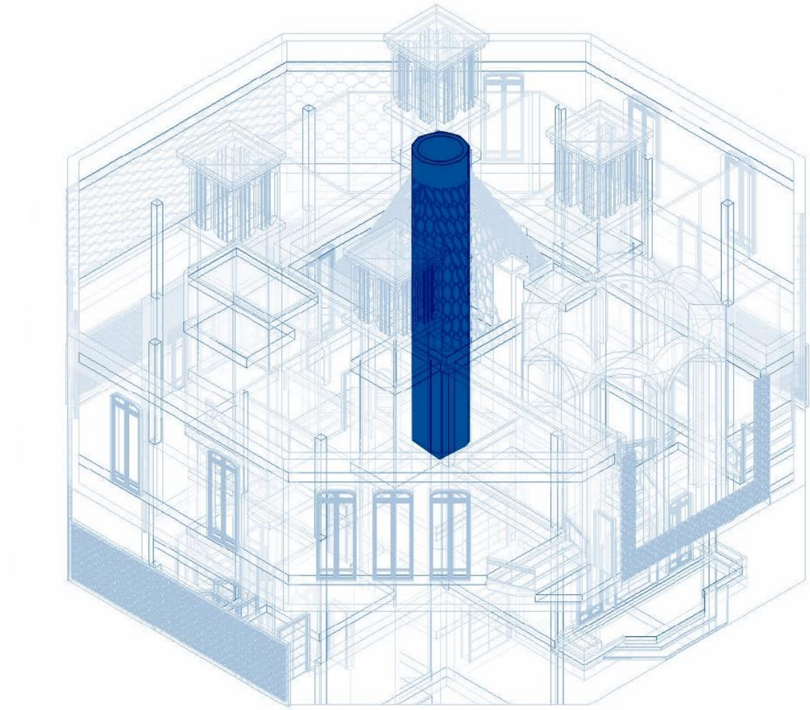
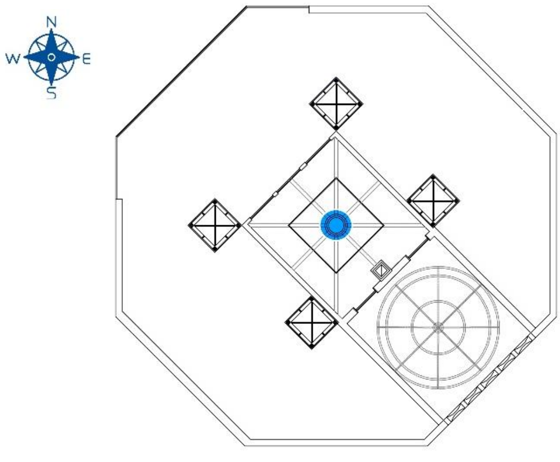
4.2.2.1. "Central Ventilation Shaft: A Biomimetic Strategy Inspired by Termite Mounds

In this project, the central ventilation shaft, inspired by the internal structure of termite mounds, functions as a biomimetic solution for passive cooling. It operates based on the principle of natural convection, where hot air inside the building rises through the vertical shaft and exits from the top, creating a low-pressure zone that pulls in cooler air from lower openings such as the windcatchers. This airflow cycle continues without the need for mechanical systems. The central shaft becomes especially effective during periods of low wind availability or extremely hot and humid conditions, where traditional windcatchers may lose efficiency. Its integration ensures a continuous and energy-free air circulation system that enhances indoor thermal comfort.

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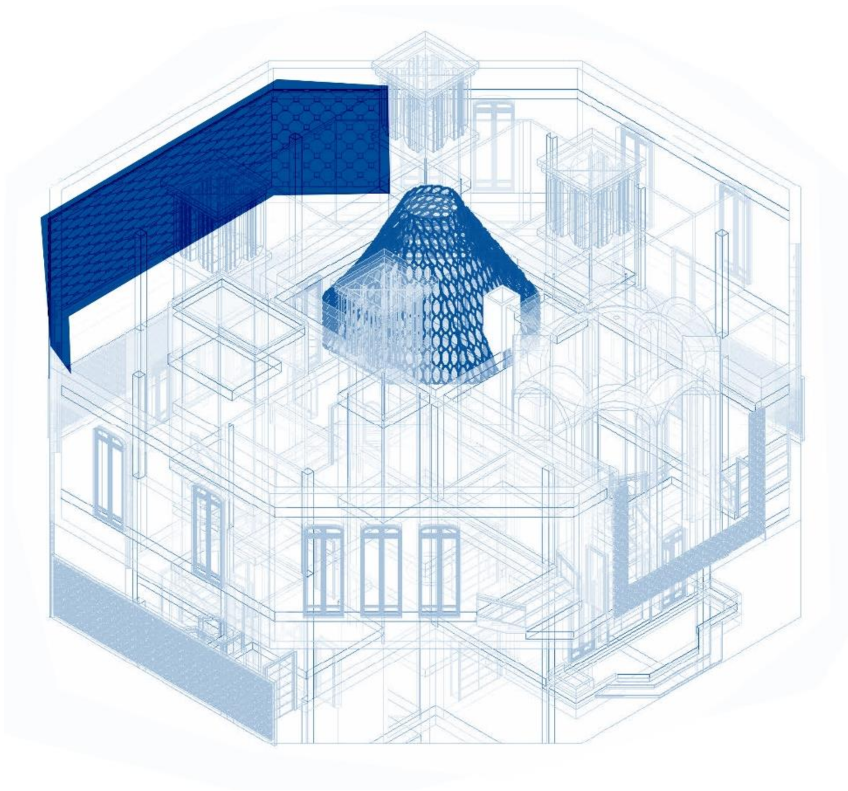
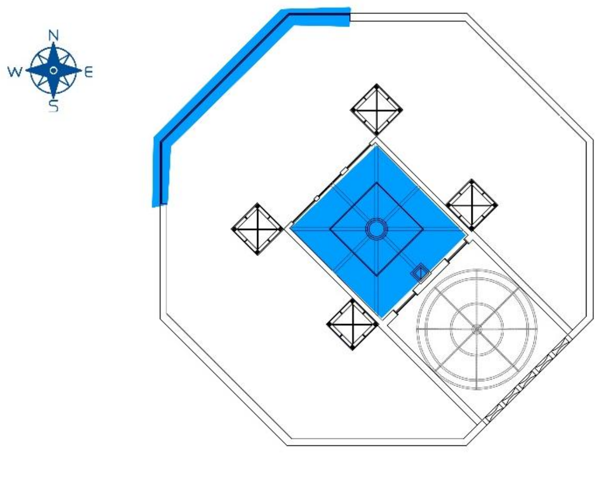
4.2.3. Traditional Shading Strategies

To enhance passive shading and cultural integration, the project incorporates traditional “Shanashil” elements and a canopy structure inspired by the tent forms of desert nomads. The Shanashil, with their deep wooden latticework, reduce solar heat gain and provide shaded semi-open spaces along the façade. The central canopy, shaped like a traditional tent and adorned with Islamic eightfold geometric patterns, creates a strong cultural and spatial identity while casting filtered shade over the courtyard. This form reduces direct solar radiation, softens light penetration, and improves thermal comfort. Together, these elements serve as effective passive cooling strategies, especially relevant in hot-humid climates, where controlling solar exposure is essential for energy efficiency and comfort.

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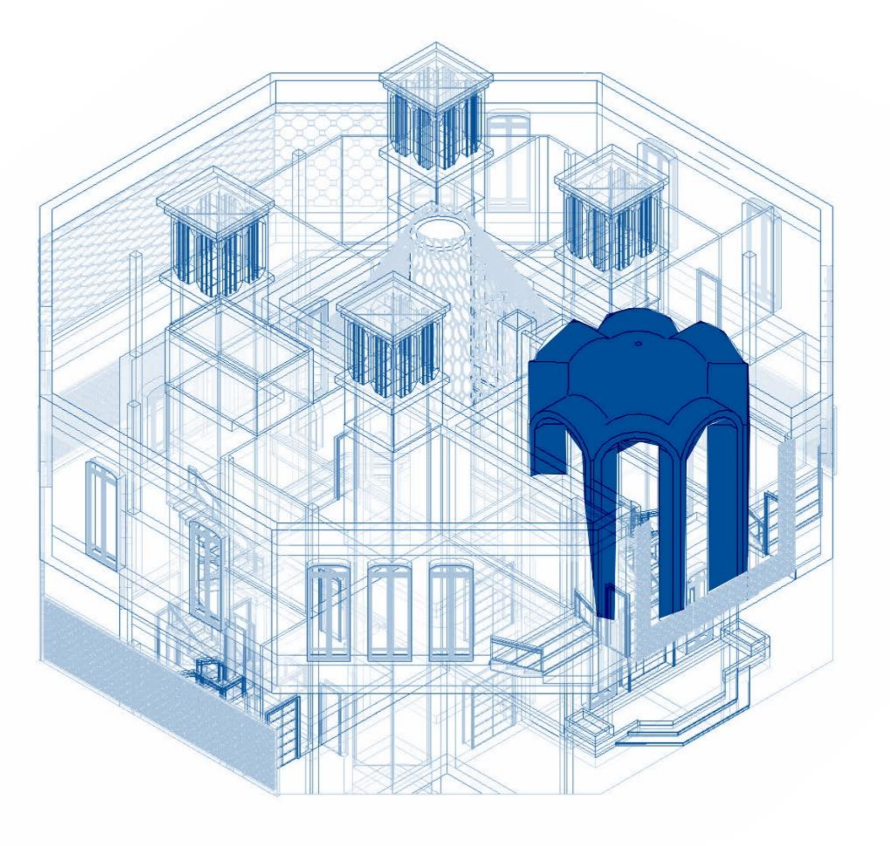
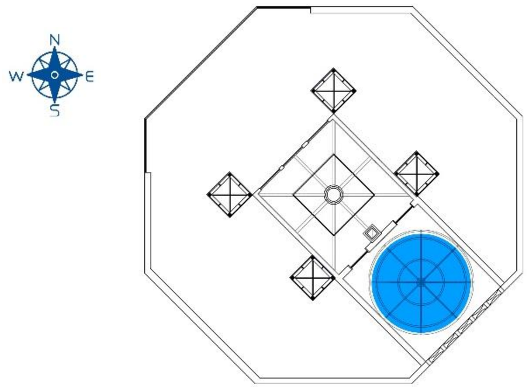
4.2.4. Dome

The dome located on the southern part of the project functions not only as a cultural and symbolic architectural feature, but also as an effective passive thermal strategy. Due to its curved and elevated geometry, the dome facilitates natural convective airflow by allowing warm indoor air to rise and accumulate at its apex. This vertical movement of hot air creates a stack effect, which encourages cooler air to flow in from lower openings. As a result, the dome acts as a thermal buffer zone, reducing heat accumulation in occupied spaces below and enhancing ventilation. This passive principle, rooted in traditional Middle Eastern architecture, contributes to improved indoor climate control—especially valuable in hot and humid conditions.

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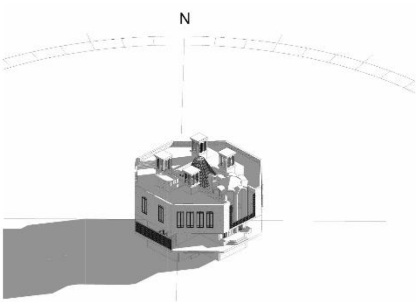
4.2.5. Solar-Oriented Design and Passive Shading

The architectural elements of the project have been thoughtfully oriented in response to solar exposure. The southern placement of the dome and solar chimneys maximizes their thermal performance by harnessing sunlight during peak hours to enhance natural ventilation and hot air extraction. Additionally, the upper floor overhangs have been designed to create self-shading for the lower levels, reducing direct solar gain on the façades and openings. These passive strategies, aligned with sun path analysis, contribute to improved thermal comfort, lower energy consumption, and an environmentally responsive design.



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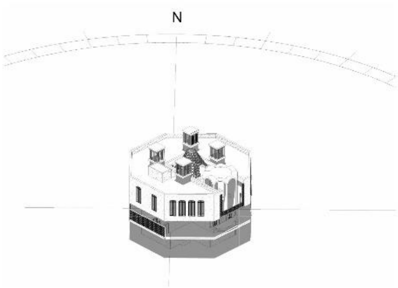
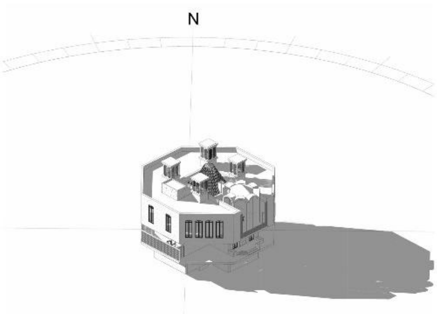
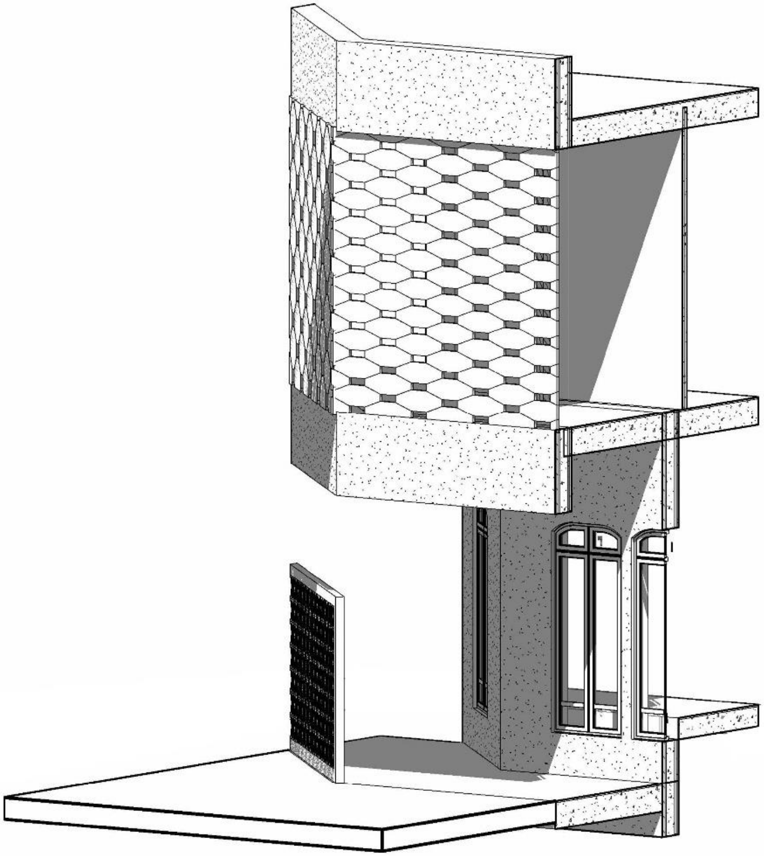


13 PM- July



7 PM- July

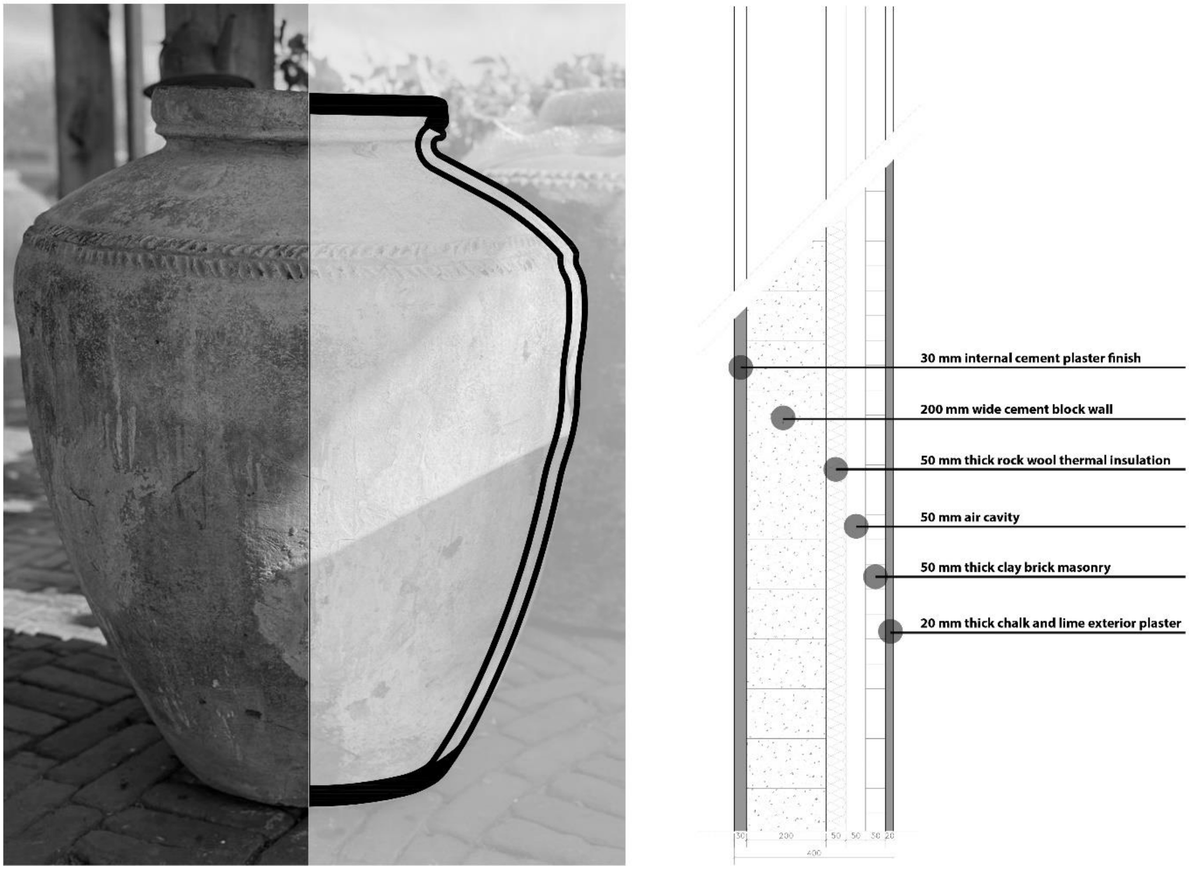
Solar Study



Ground floor under shadow

4.2.6- Double-Skin Wall Inspired by Hobbāneh

In this project, a double-layered wall system inspired by the traditional "Hobbāneh" (porous clay vessels used in southern Iran for cooling and preserving water) has been integrated as a passive cooling strategy. The outer layer, composed of lime and clay, is set apart from the inner wall by an air gap, allowing for natural ventilation and evaporative cooling. This design reduces direct heat transmission to the interior and allows air to circulate between the two layers, lowering surface temperatures. Drawing from vernacular wisdom, the system performs particularly well in hot and humid climates, providing thermal insulation and maintaining indoor comfort without mechanical intervention.

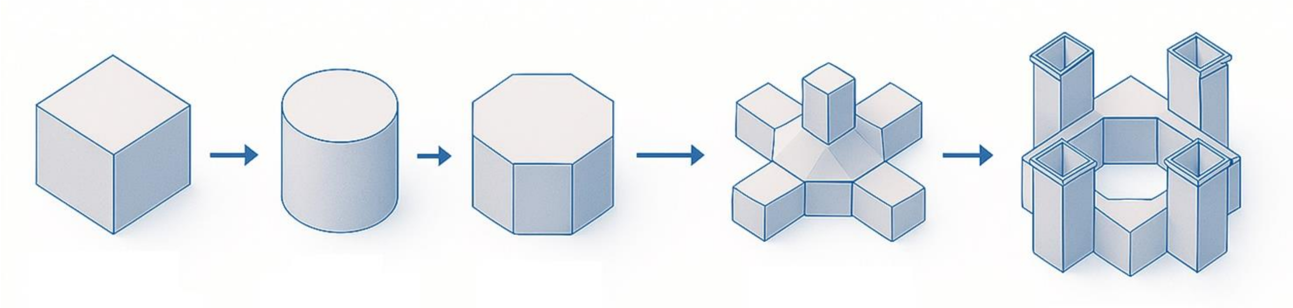


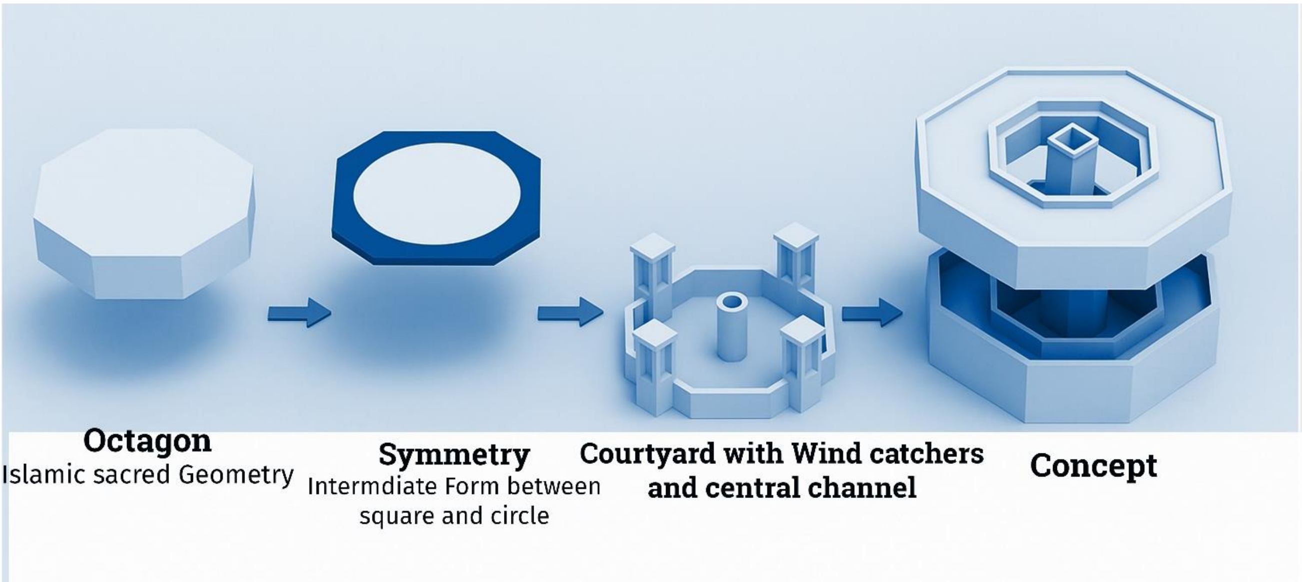
Double skin wall inspired from Hobbane

4.3. Design Concept Rooted in Islamic and Emirati Traditions

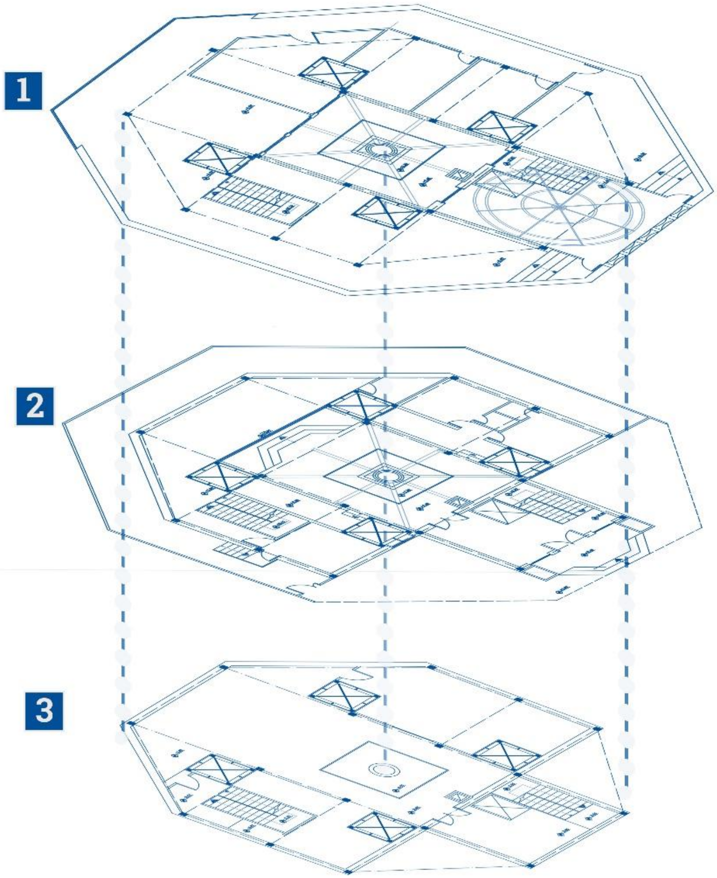
The design concept of this project is deeply rooted in the cultural values and architectural traditions of the Emirates, particularly emphasizing the importance of privacy, hierarchical spatial organization, and Islamic spatial principles. Inspired by traditional Emirati homes, the layout carefully separates public and private zones, providing distinct access paths for residents, guests, and household staff—a common feature in local residential architecture. The inclusion of a Majlisiyyah space for male gatherings respects social customs, while service-related rooms such as those for drivers and staff are positioned with discreet yet functional accessibility. The geometric logic of the floor plan draws from Islamic architecture, utilizing elements such as symmetry, octagonal forms, and sacred geometry, not only for visual harmony but also to reflect cultural identity in the built environment.

4.3.1. Concept prosses





4.3.2. Cultural Spatial Logic and Privacy in Design

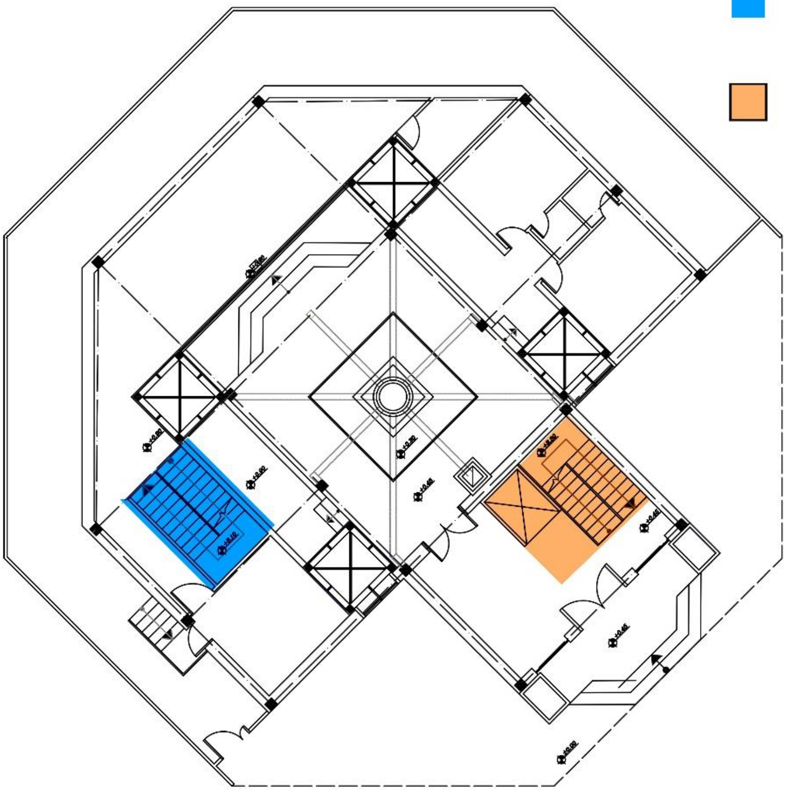


1 First Floor- private zone

2 Ground Floor Floor-Semi-private zone

3 Basement Floor- Public zone

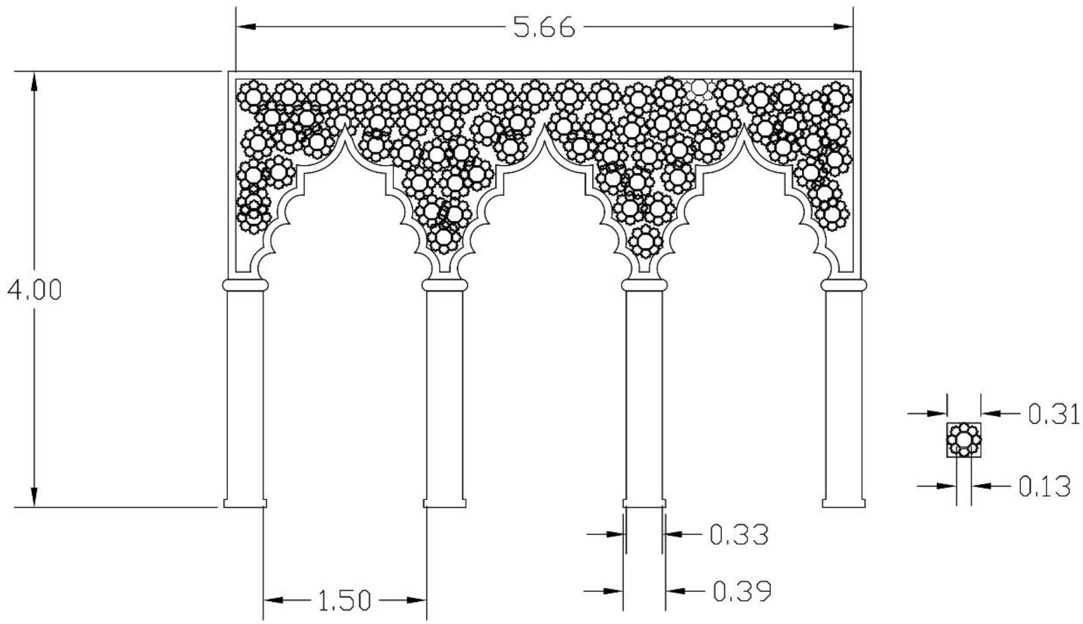
4.3.3. MAJIAZ (indirect Accessibility)



Way of access to floors for members of the house

Way of access to floors for members of the guests

4.3.3. Geometric Aesthetics in Islamic-Inspired Design



Detail of the Arch design in this project

4.4. Material Strategy and Vegetation for Hot-Humid Climate

4.4.1. Natural Hydraulic Lime Plaster (NHL) with Clay and Natural Fibers: An Ideal Solution for Humid Climates

For the external envelope of the building, a composite plaster made of Natural Hydraulic Lime (NHL), clay, and natural fibers such as straw or hemp is employed, offering an effective and sustainable solution for hot-humid regions like Persian Gulf region.

- NHL (Natural Hydraulic Lime) provides excellent resistance to moisture, salt efflorescence, and biological growth such as mold and mildew.
- Clay enhances breathability, preventing the entrapment of water vapor within the wall structure.
- Natural fibers like straw or hemp not only lighten the material but also help in controlling shrinkage and cracking during drying.

4.4.1.1. Key Advantages:

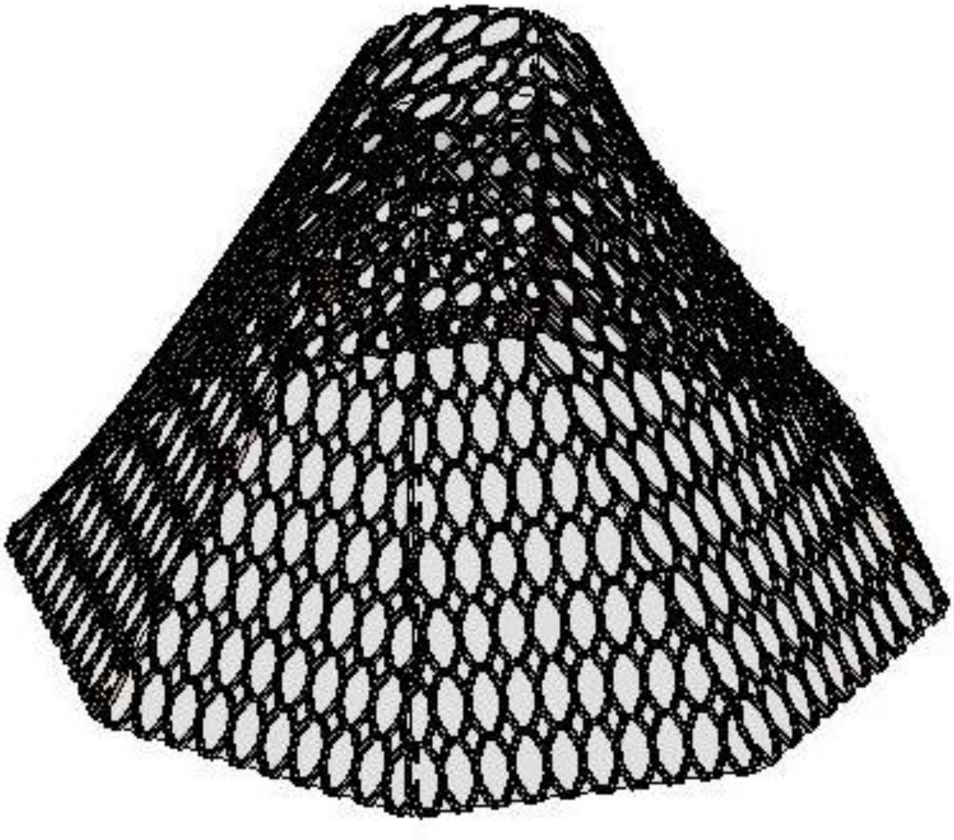
- Naturally moisture-resistant
- Durable and resistant to weathering
- Highly breathable, reducing the risk of condensation and dampness
- Fully compatible with the climatic and environmental conditions of southern coastal Iran

This material strategy aligns with both ecological principles and local construction traditions, ensuring thermal comfort, structural longevity, and sustainability.

4.4.2. Climate-Responsive Vegetation Strategy

In hot-humid climates, the selection of vegetation plays a vital role in regulating microclimate and mitigating humidity. Plants with high transpiration rates and dense foliage help absorb moisture and provide natural shading. In this project, species such as bamboo, palm, and plumeria (frangipani) are considered for their resilience, aesthetic value, and climate adaptability. Processed bamboo is also used as a sustainable material for the canopy structure, creating harmony between landscape and built elements.

The canopy structure is made of engineered bamboo, a sustainable and durable material that is lightweight, moisture-resistant, and suitable for hot-humid climates



4.5. Thermal Reduction through the Integration of Vernacular Architecture and Natural Systems

This chapter has explored the integration of passive design strategies inspired by both vernacular architecture and natural systems, tailored specifically for the hot-humid climate of the Gulf region. Through spatial planning, material selection, airflow engineering, and cultural sensitivity, the architectural interventions aim not only to respond environmentally but also to reflect regional identity.

Recent studies on passive cooling systems in hot-humid climates—particularly those examining the integration of windcatchers, double-skin walls made from lime and clay (inspired by Habbaneh jars), solar chimneys, and central vertical shafts—have demonstrated an indoor temperature reduction of up to 22–25°C during peak summer conditions.

These findings are supported by simulation-based analyses using tools such as EnergyPlus, DesignBuilder, and Ladybug for Grasshopper, which model the thermal behavior and airflow performance of passive systems in Gulf-region housing (Bahadori, 1978; Fathy, 1986).

In this project, by applying a similar passive strategy framework to the hot-humid climate of Abu Dhabi, a theoretically-supported temperature drop of approximately 24°C is estimated—particularly when combined with additional canopy shading and strategic spatial orientation.

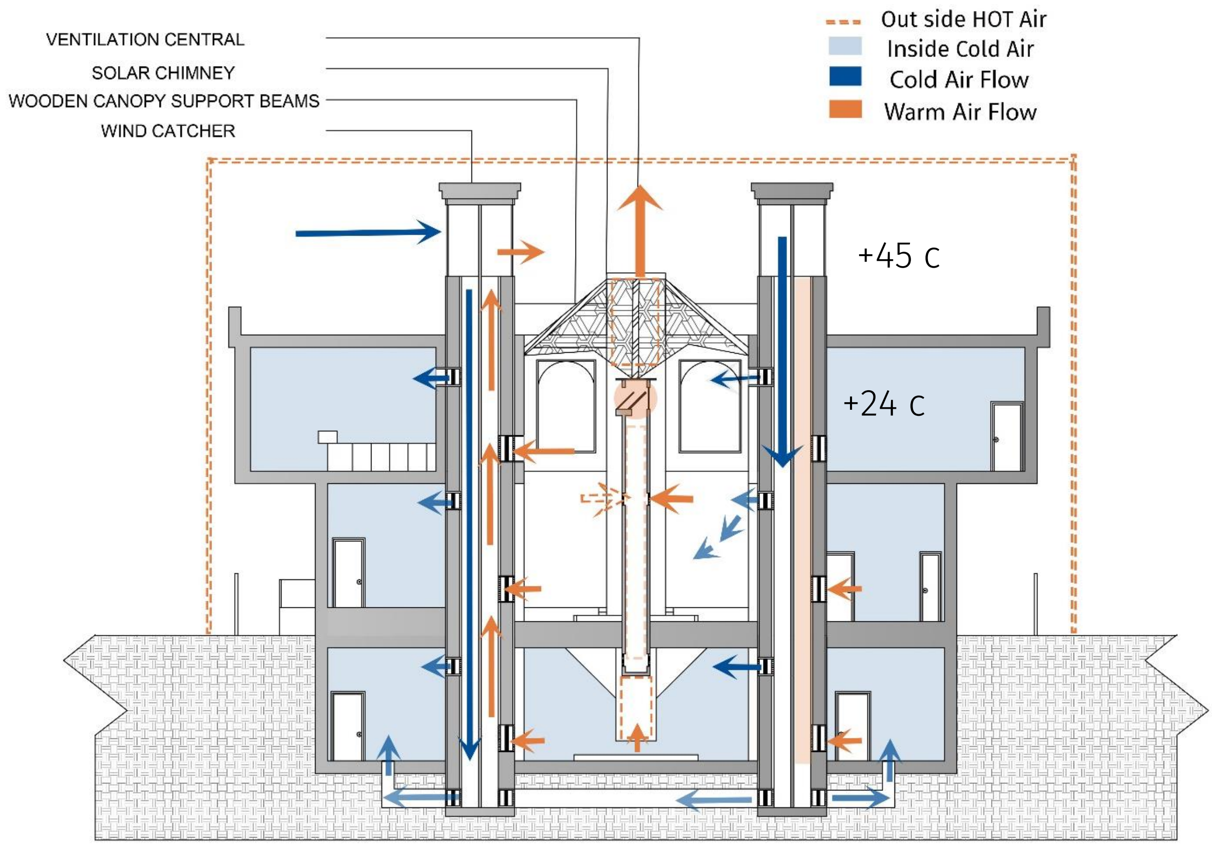
Component	**Indoor Temperature Reduction (°C)**	**Relative Humidity Reduction (%)**
Combined Windcatcher	15–18°C	10–15%
Natural Convection (Termite-inspired)	3–5°C	5–8%
Double-layer Brick/Clay Wall	3–5°C	5–10%
Total Combined Effect	**21–26°C** reduction	**15–25%** reduction

4.5.Recommended Number and Placement of Openings and Channels

Element	Recommended Quantity	Location
Wind Towers	2 to 4	North or northwest side, connected to stairwell or open zones
Vertical Ventilation Shafts	6 to 8	On ceilings of major rooms, above stairs, near courtyard
Low Inlet Openings	10+	Near wind towers, on lower floor, in rooms facing the courtyard
Roof Vents	6+	On top floors or above domed ceilings

4.5.1.Daily Performance Overview

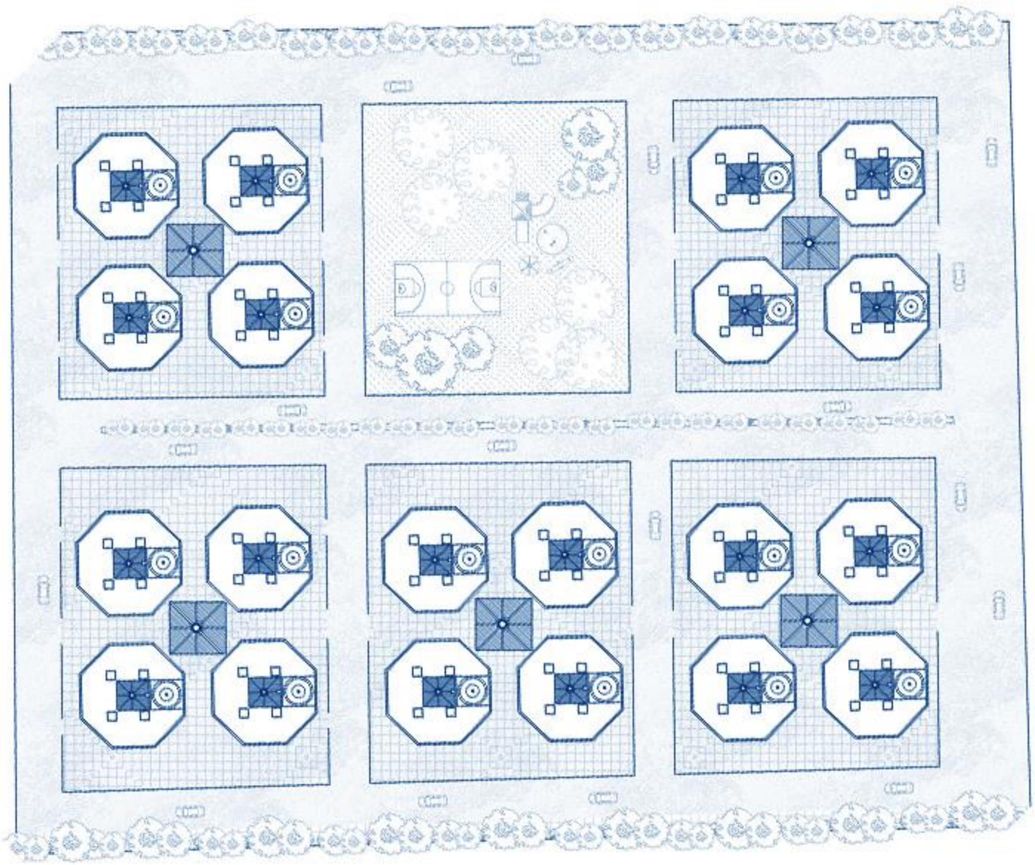
Time	Wind Tower Function	Termite-Inspired Shaft Function
Night	Intake of cool air	Expulsion of remaining heat
Morning	Brings fresh air	Starts vertical circulation
Midday	Reduced cooling	Strong stack effect to expel heat
Evening	Cross ventilation	Re-cooling of interior


VENTILATION CENTRAL
SOLAR CHIMNEY
WOODEN CANOPY SUPPORT BEAMS
WIND CATCHER
Out side HOT Air
Inside Cold Air
Cold Air Flow
Warm Air Flow
+45 C
+24 C

CHAPTER 5

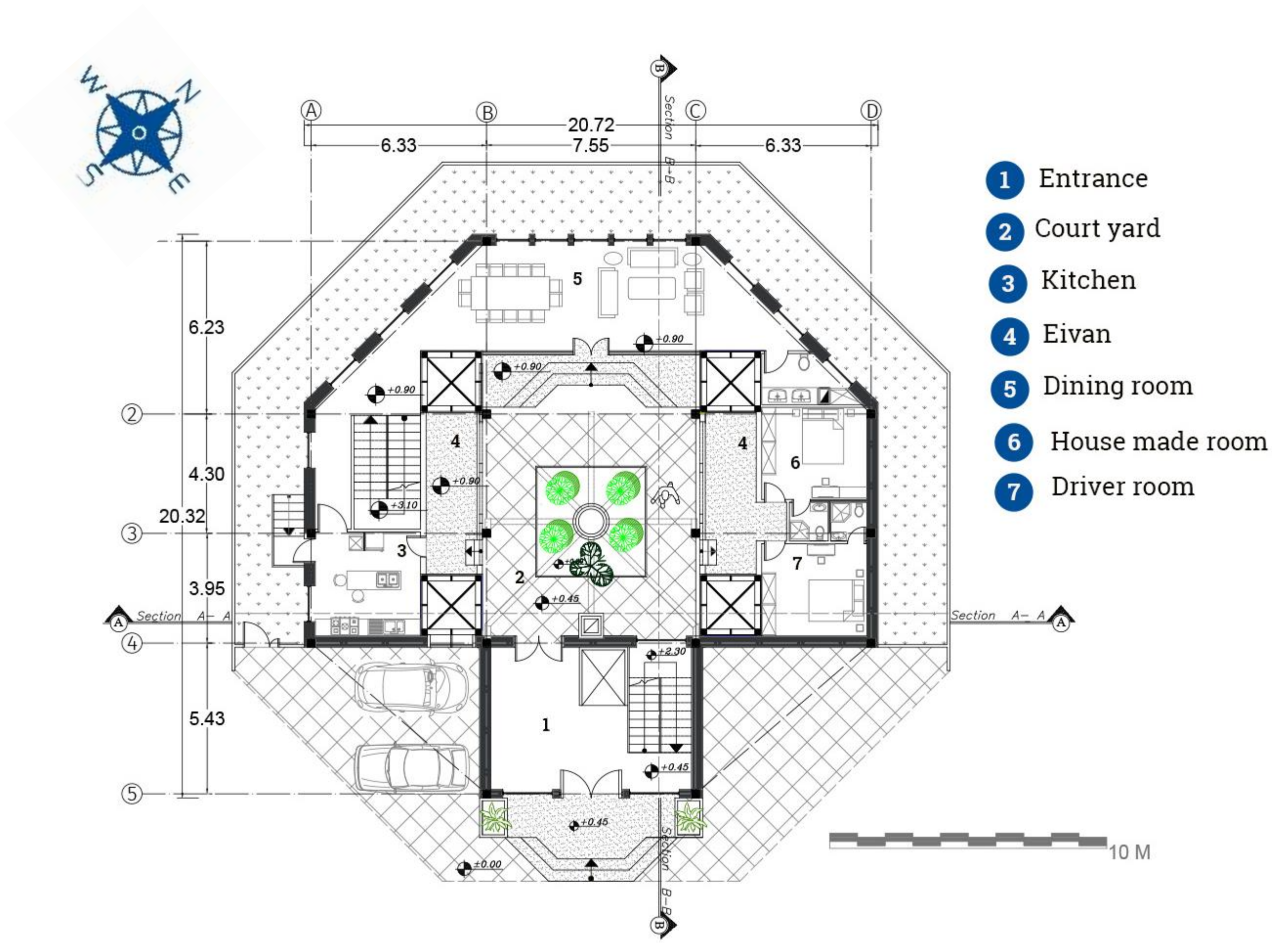
Architectural Drawings & Visual Representations

5.1. Master plan

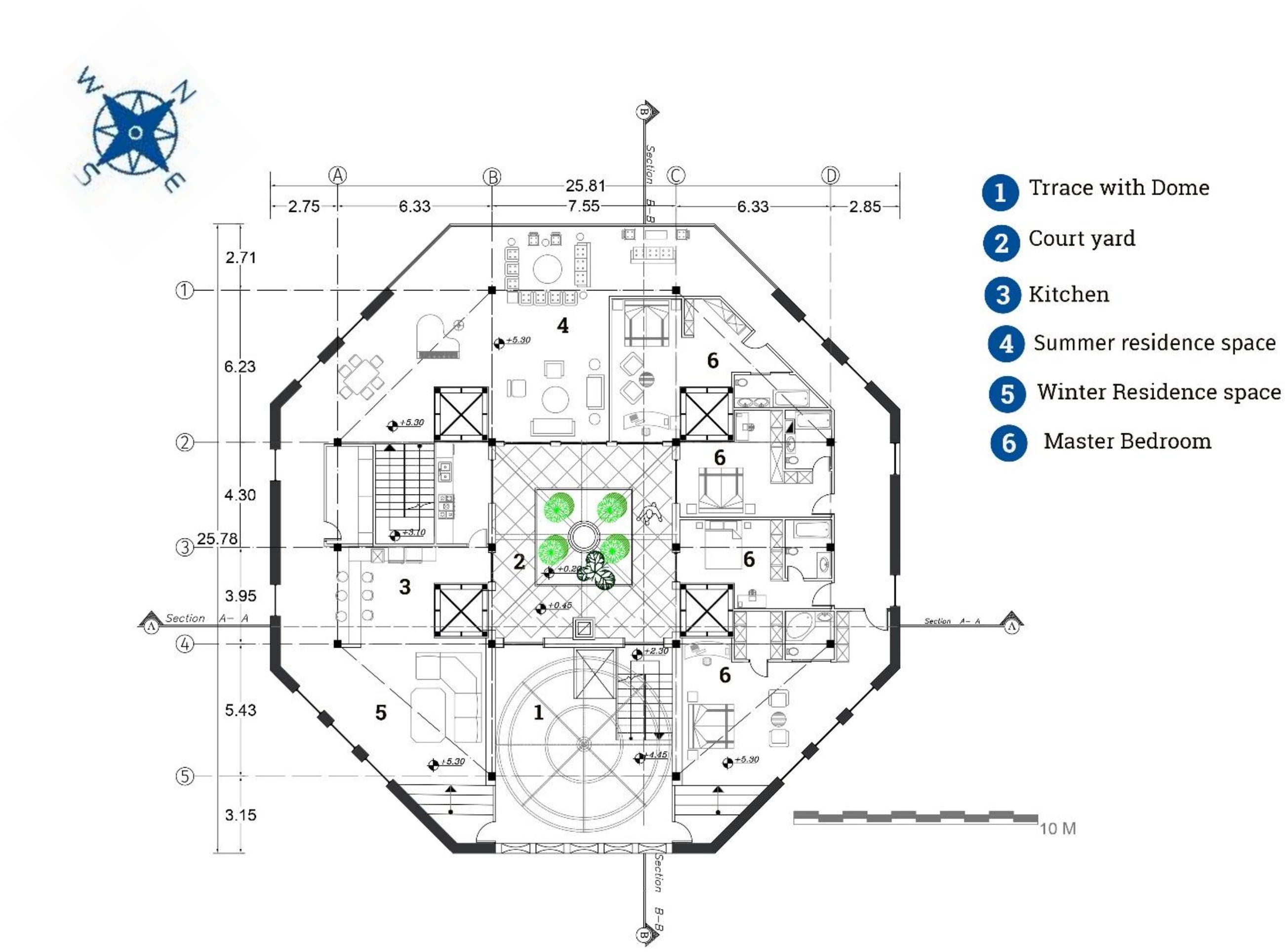


5.2. Plans

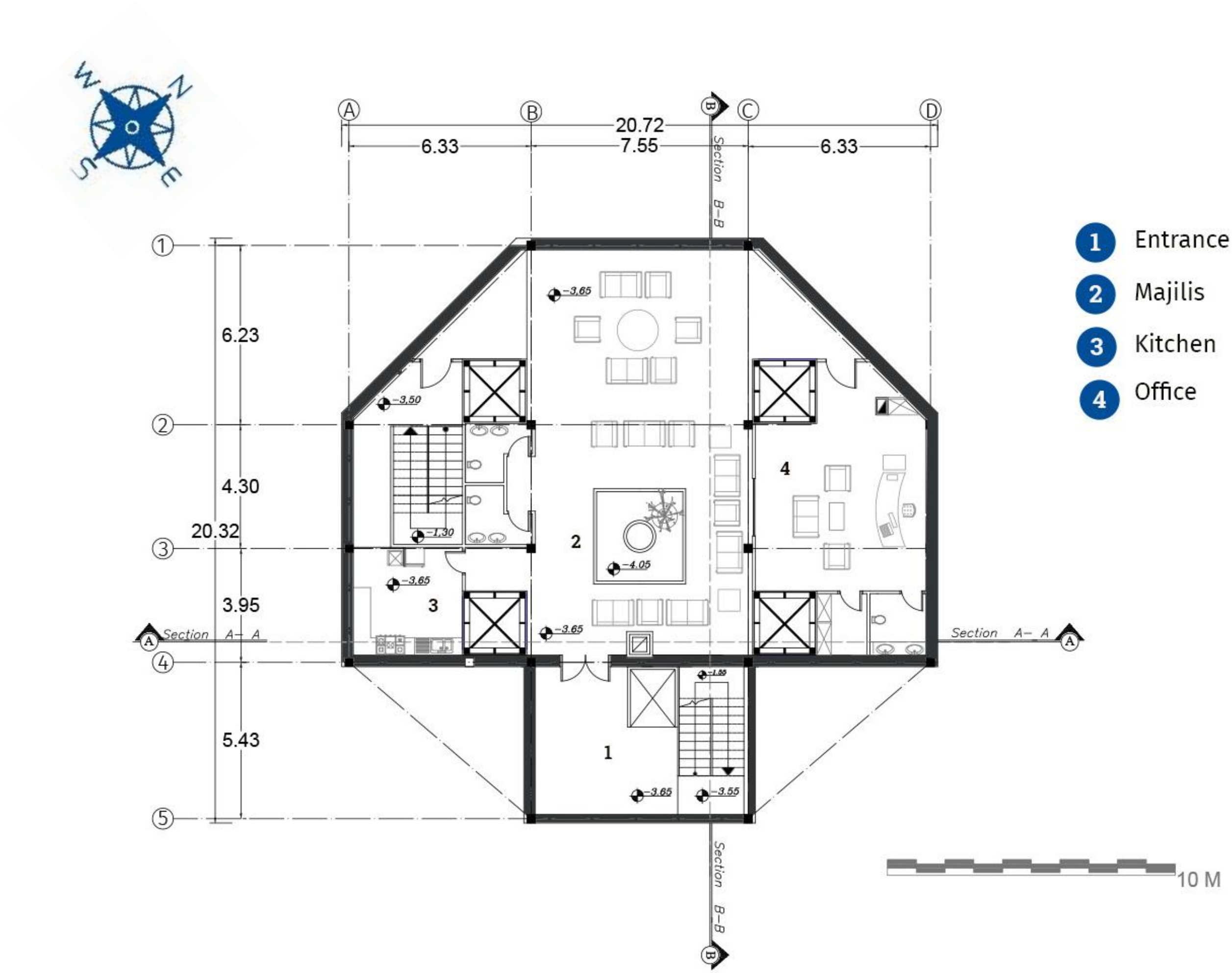
5.2.1. Ground Floor plan



5.2.2. First Floor Plan



5.2.3. Basement Floor Plan

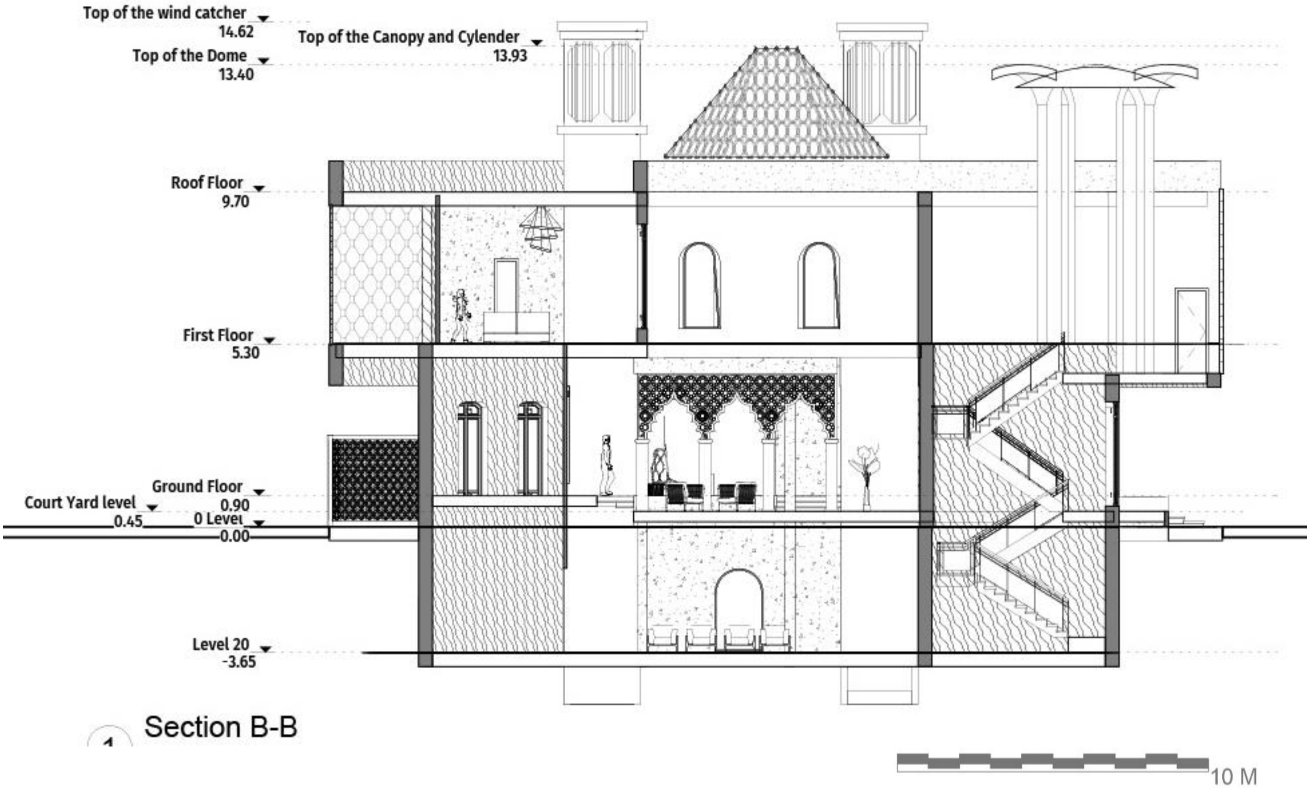


5.3. sections

5.3.1. section A-A

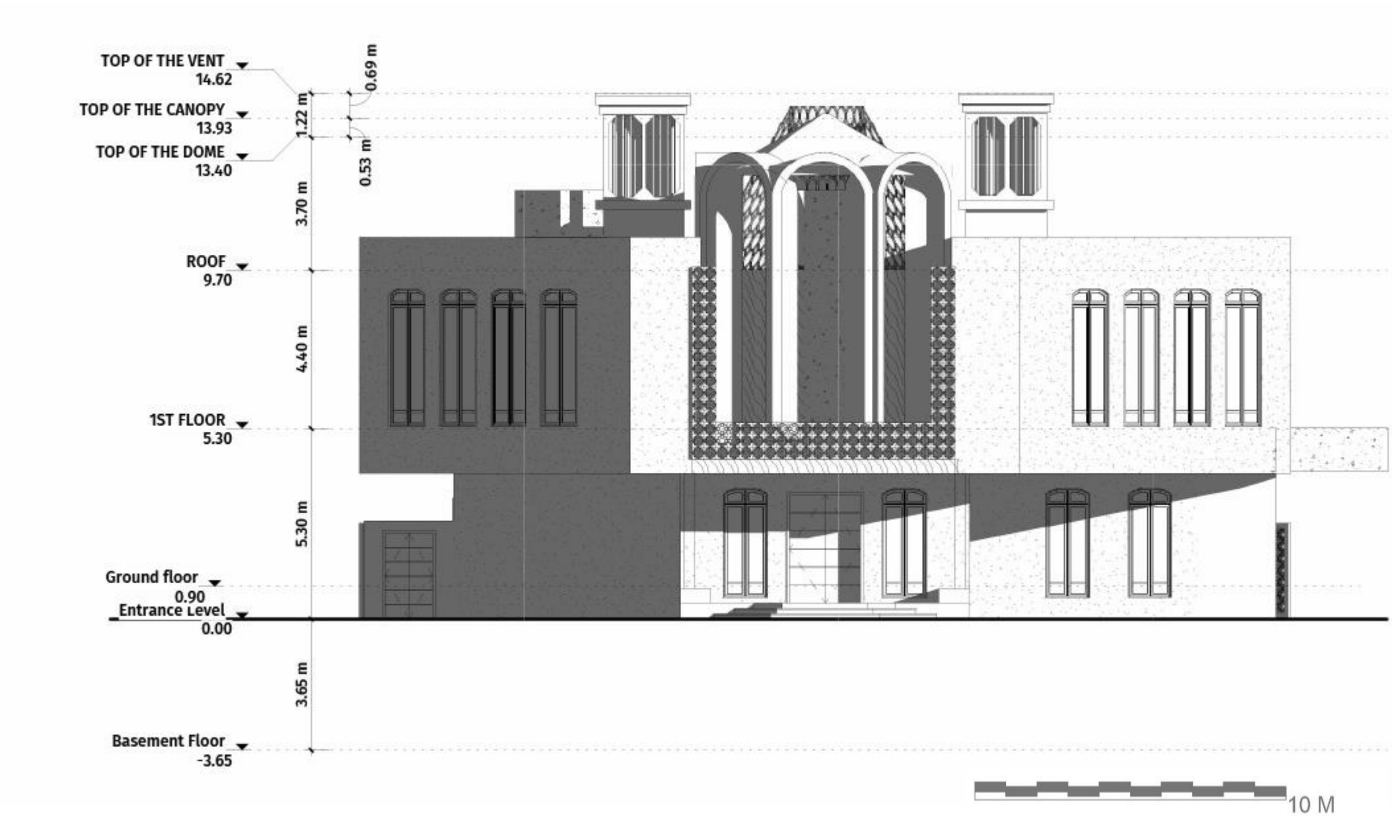
1 section A-A

5.3.2. section B-B

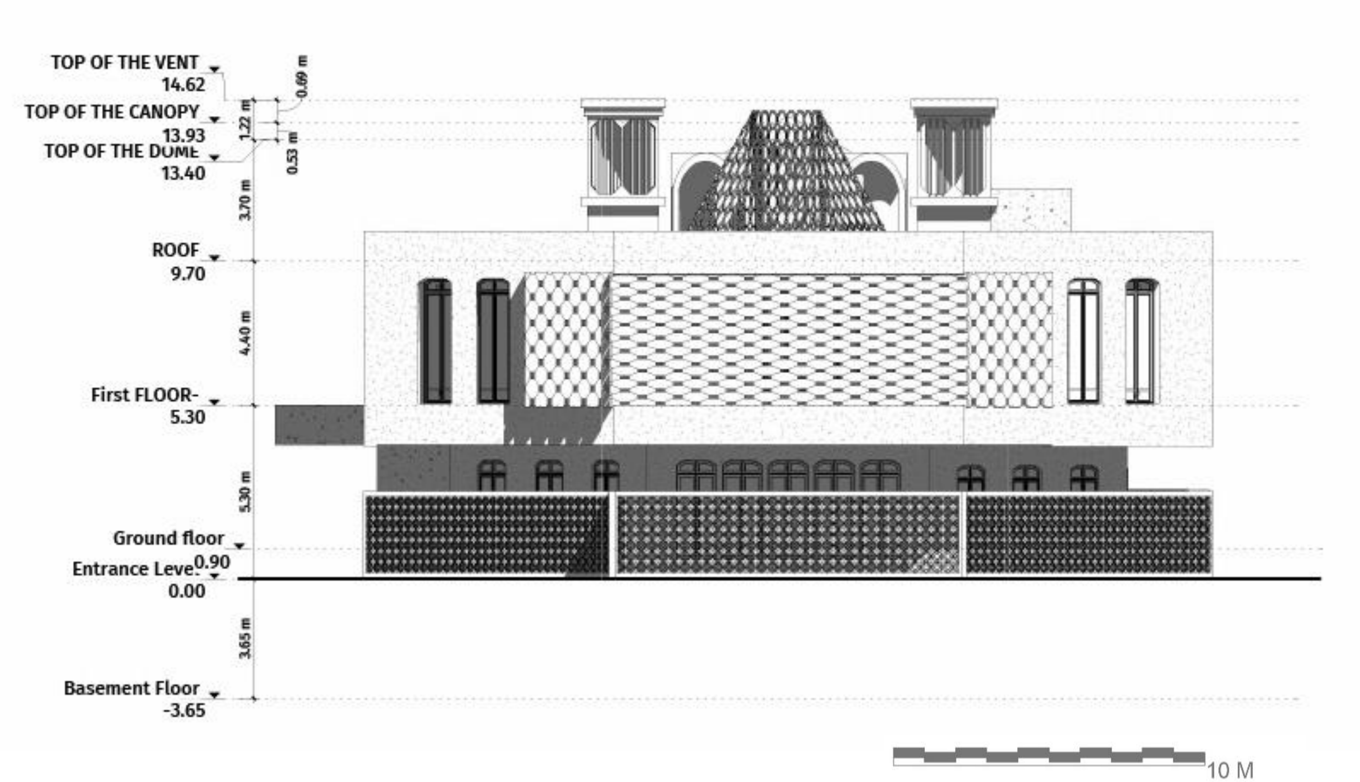


5.4. Elevation

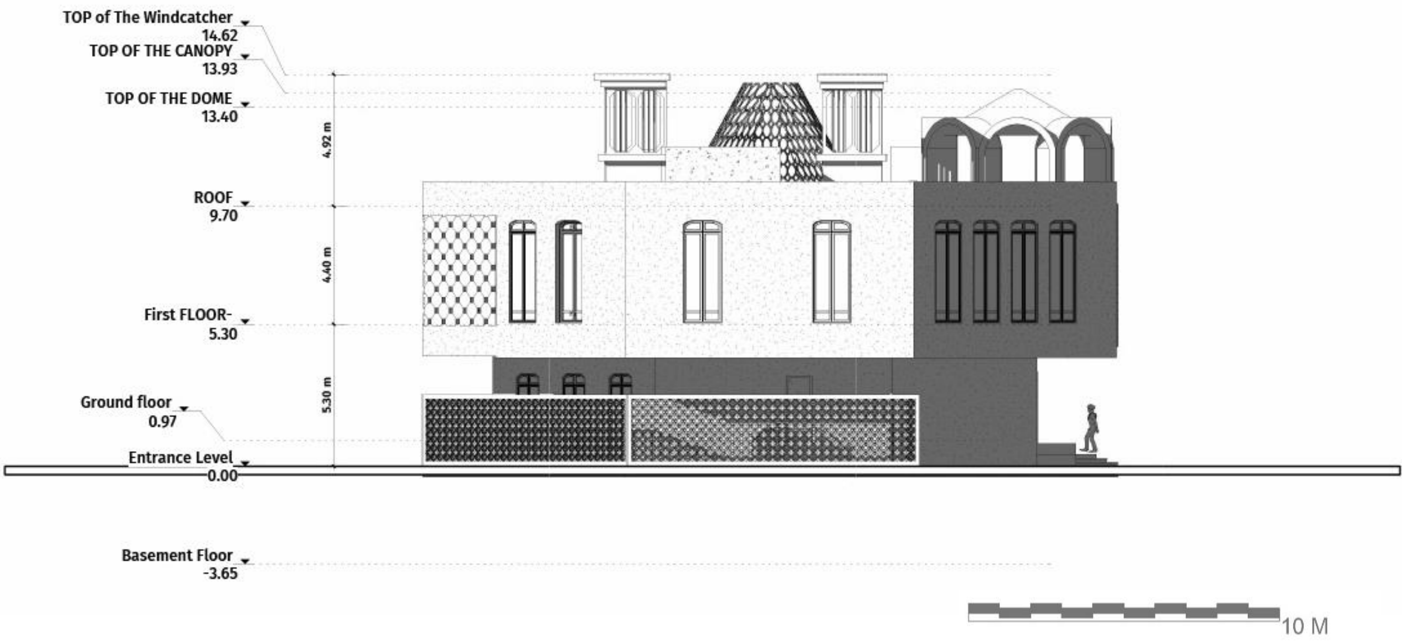
5.4.1. South Elevation-Front side



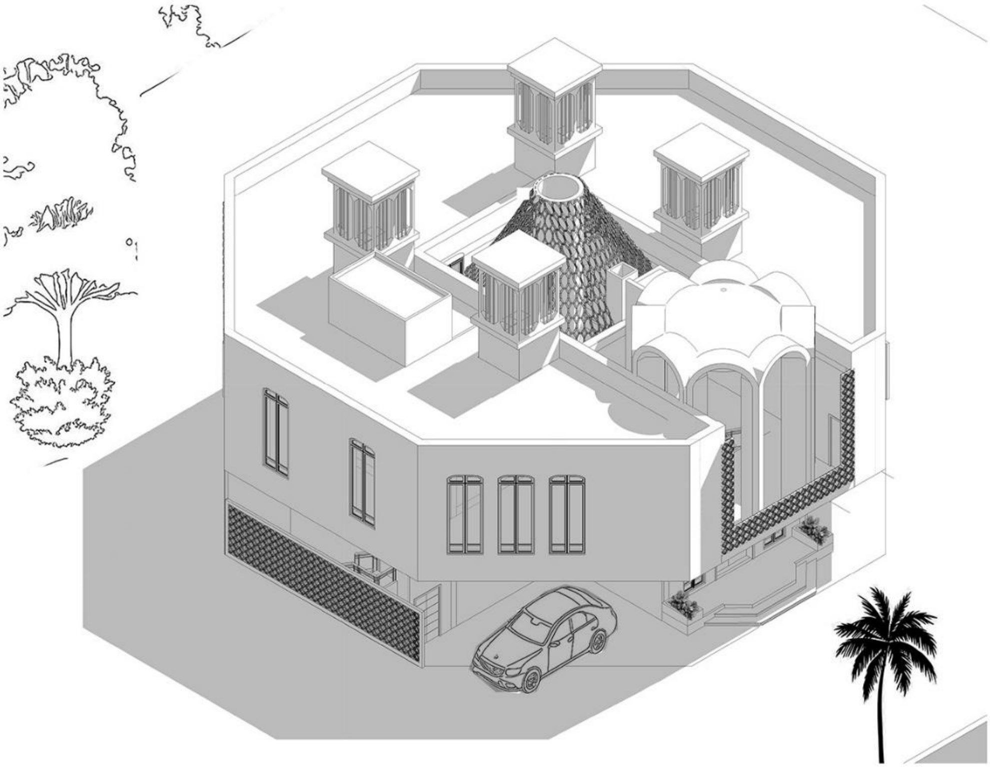
5.4.2. North Elevation -Back side



5.4.3. East Elevation-Left side

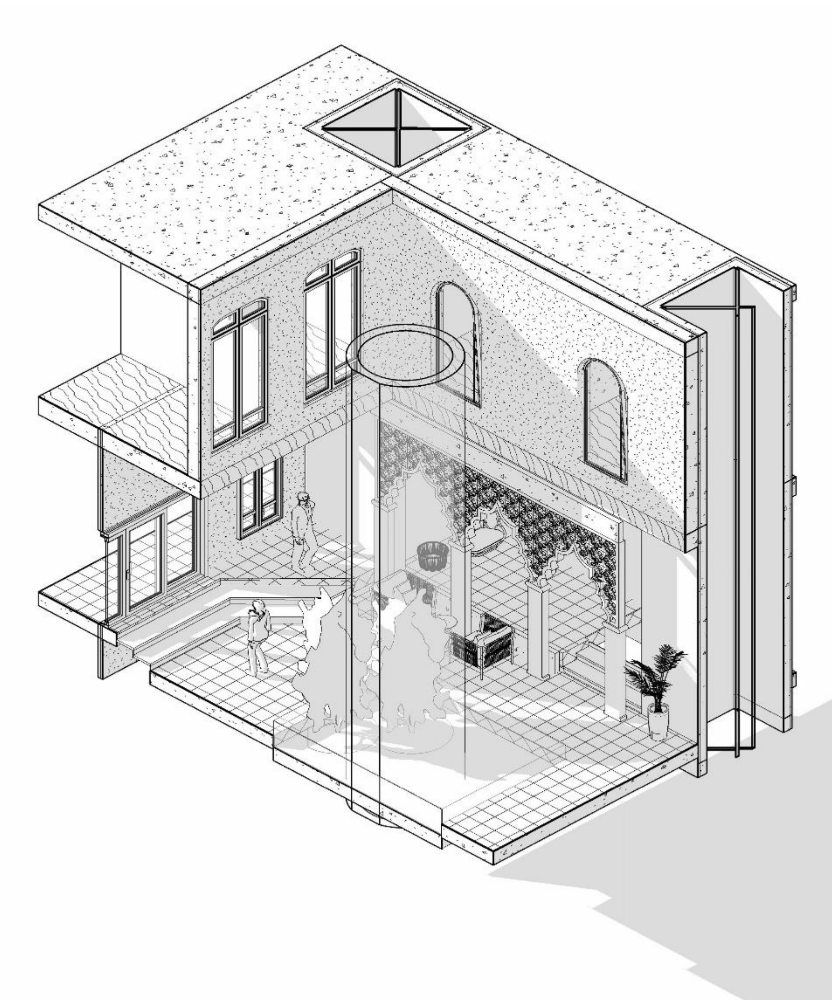


5.5. perspective 3D view

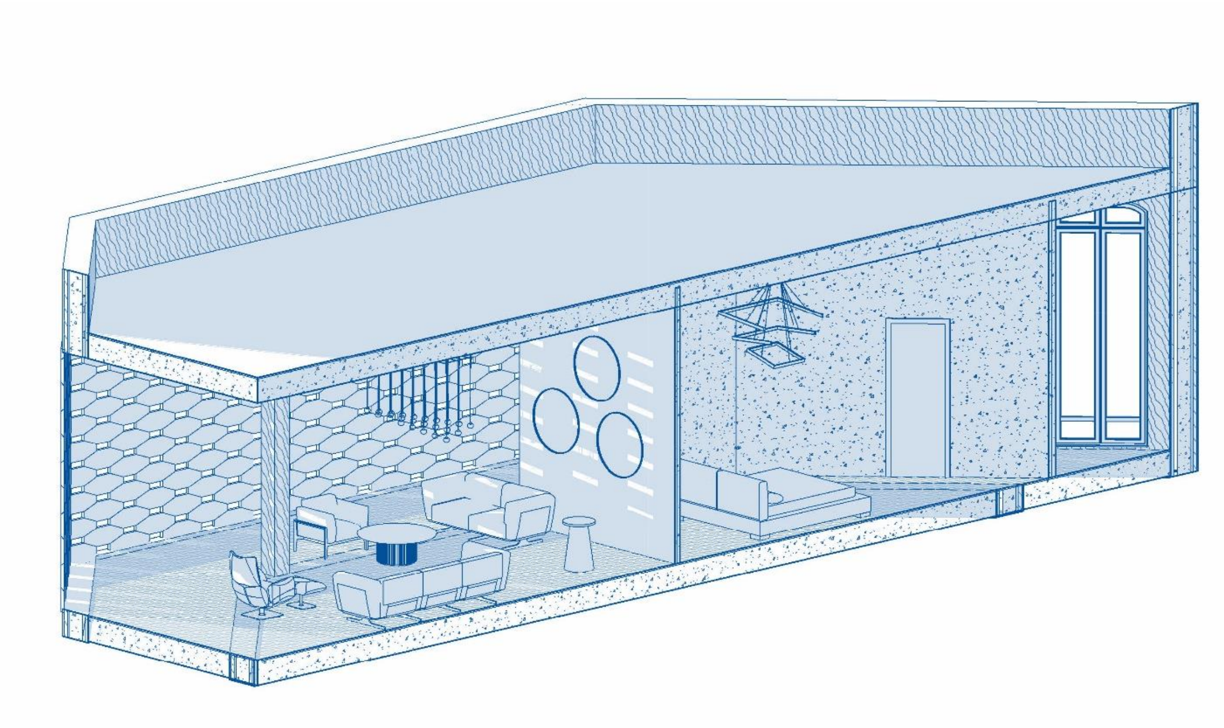


5.6. Interior views

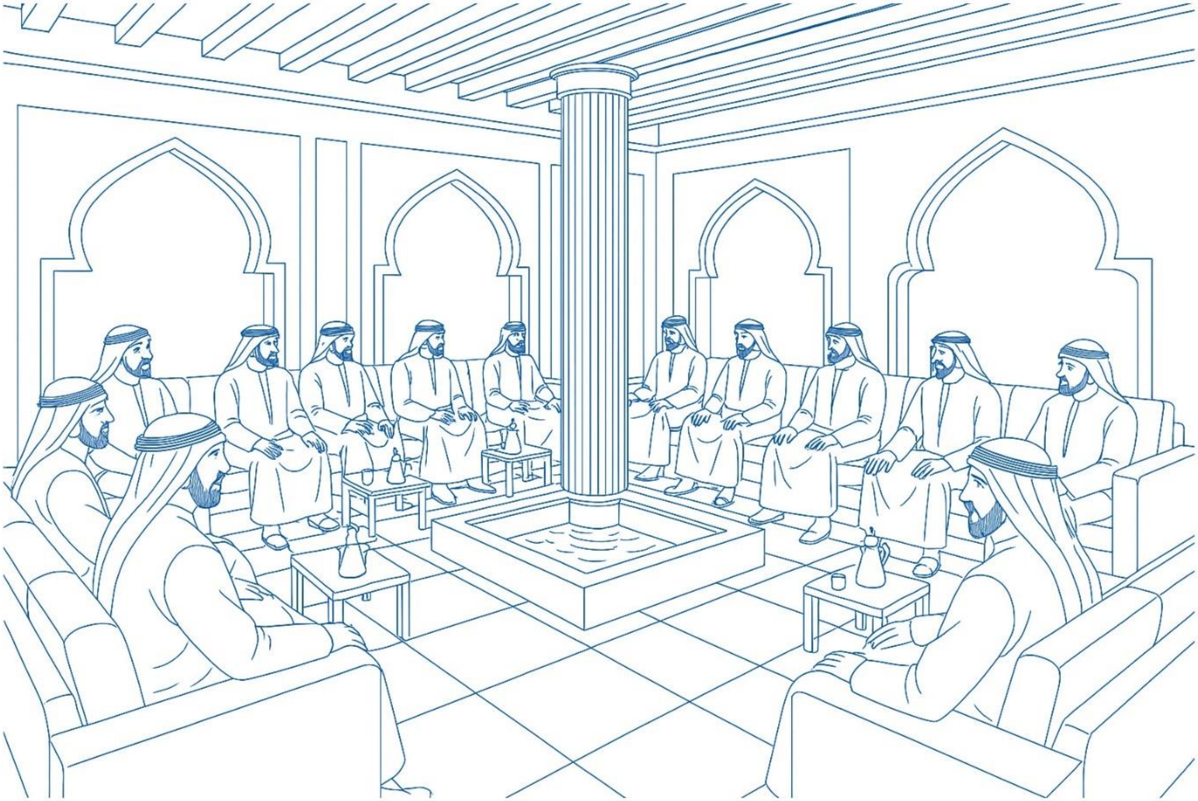
5.6.1. 3D section of Court yard



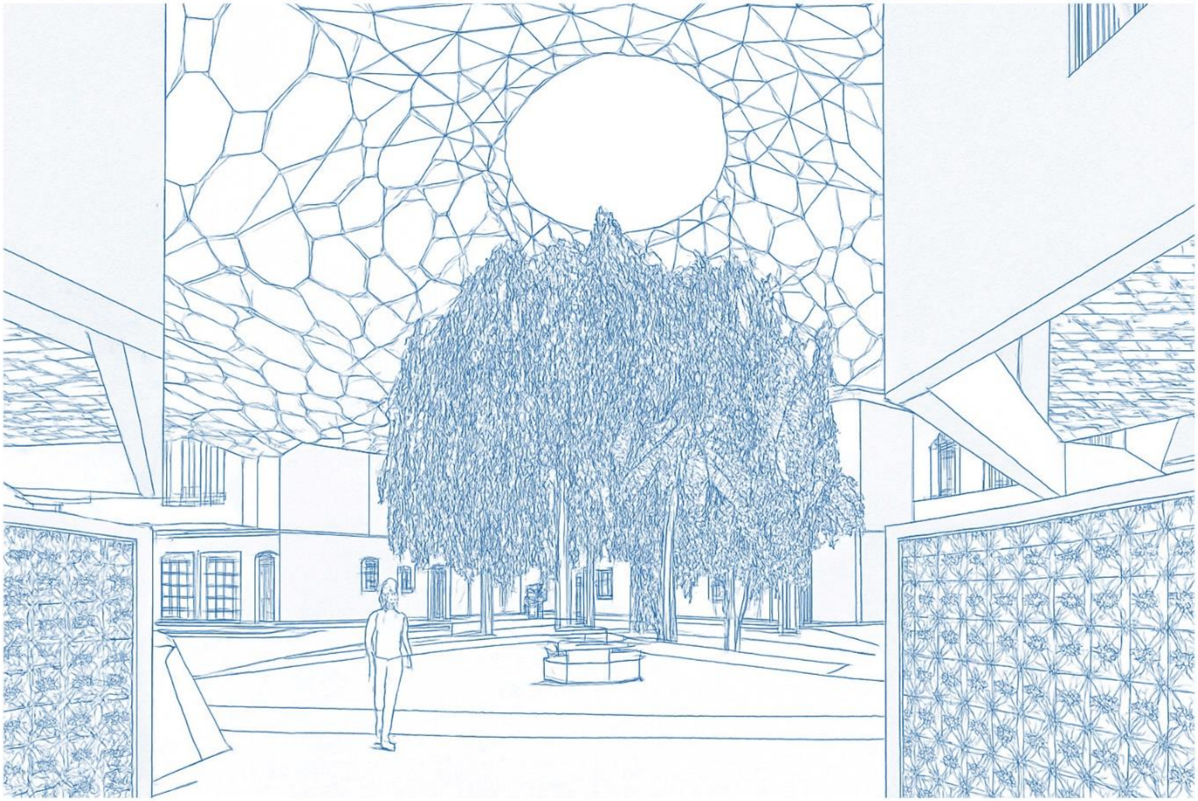
5.6.2. 3D section of interior Shanshil Space

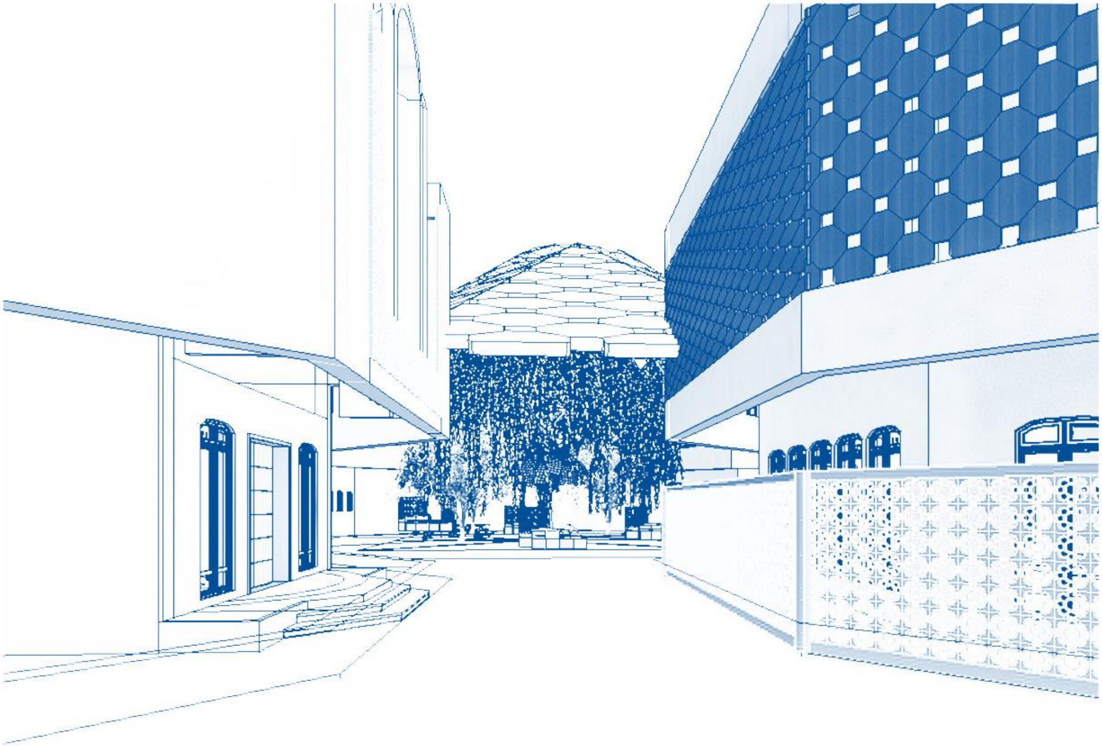


5.6.3. Majlis interior view



5.6.4. In the settlement view





CHAPTER 6

Conclusion and Reflection

The “House of the Future” competition, held in the UAE, invites a rethinking of what the future of housing truly means. Contrary to the common perception that futuristic homes must rely solely on high-tech solutions and sleek digital interfaces, this project proposes a future rooted in cultural identity, environmental harmony, and passive design principles. By revisiting vernacular architectural wisdom—such as wind catchers, solar chimneys, central ventilation shafts, and double-skin facades made of breathable materials—this design demonstrates that the future can emerge from the intelligent revival of the past.

The octagonal form, inspired by sacred Islamic geometry, and the spatial hierarchy based on privacy and function, reflect local traditions while addressing contemporary environmental challenges. In a hot and humid climate, the strategic integration of passive cooling systems significantly reduces indoor temperature—by up to 24°C—without the use of active energy-consuming methods. This house is not a nostalgic return to the past, but a forward-looking, resilient model that proves tradition and innovation are not mutually exclusive, but rather mutually empowering.

This design ultimately offers a holistic vision: a home that breathes with the climate, respects cultural values, and presents a grounded, sustainable narrative for the homes of tomorrow.

Appendix

Passive Cooling Energy Impact Assessment

In the context of high-energy demand for cooling in hot and humid climates like the UAE, the integration of passive cooling strategies into residential architecture offers substantial environmental and financial benefits. Based on regional studies, an average household consumes approximately **59,000 kWh** of electricity annually, of which **about 60% (~35,400 kWh)** is attributed to cooling demands.

By implementing passive cooling systems—such as windcatchers, solar chimneys, central ventilation shafts, and double-skin lime-clay walls—the energy required for cooling can be significantly reduced.

◆ **If passive cooling achieves a 50% reduction in cooling load**, the system could save approximately:

- **17,700 kWh** of electricity per year
- **1,416 USD** or **~5,200 AED** annually

◆ **With a 60% reduction**, the savings would increase to:

- 21,240 kWh per year
- 1,699 USD or ~6,200 AED

This demonstrates the economic viability and sustainability of passive cooling in future-oriented housing. The result not only reduces dependence on mechanical HVAC systems but also aligns with the objectives of low-carbon architecture and energy efficiency in residential design.

Passive Cooling Energy Savings Table

Cooling Load Reduction	Energy Used (kWh/year)	Energy Saved (kWh/year)	Cost Saved (USD/year)
No Reduction	35400	0	0
50% Reduction	17700	17700	1416
60% Reduction	14160	21240	1699

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