DESIGNING THE HOUSE OF THE FUTURE IN THE UAE



INTEGRATING TRADITIONAL EMIRATI RESIDENTIAL ARCHITECTURE INTO A LOW-CARBON DESIGN APPROACH

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Designing the House of the Future in the UAE: Integrating Traditional Emirati Residential Architecture into a Low-Carbon Design Approach

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Abstract

Traditional Emirati architecture, shaped over centuries by the arid climate, limited resources, and social customs of the Gulf, offers passive strategies, courtyards, wind towers, shading, and thermal mass that modern residential design in the UAE has largely abandoned in favor of mechanically conditioned villa typologies built through a repetitive, copy-paste compound logic. This thesis asks whether those vernacular principles can be recovered and reinterpreted, not reproduced, to inform a contemporary low-carbon family residence. Using a qualitative research-by-design methodology, the study analyzes the UAE's climatic conditions and their impact on residential design; traditional Emirati wind tower houses and their courtyards, barjeel, mashrabiya, and thermal mass; contemporary residential compounds and the erosion of passive logic and identity through standardized repetition; and applies these findings within the framework of the Buildner House of the Future competition. The resulting proposal is a two-storey courtyard house for a family of four to six, combining earth-block walls with timber-framed roof and floor assemblies to lower embodied carbon, and a reworked wind tower integrating evaporative cooling, atmospheric water generation, heat pump floor cooling, and rooftop PV/PVT. Courtyard self-shading and other passive strategies reduce cooling demand ahead of mechanical systems, while architectural and urban-scale solutions, including interactive shading and incremental expansion, establish diversity across the residential fabric. Every assembly is verified against Dubai's mandatory Al Sa'fat U-value thresholds, with thermal lag and attenuation providing a fuller measure of performance in a diurnal desert climate, demonstrating that vernacular knowledge, translated rather than copied, can meet present-day environmental and energy demands while restoring diversity and cultural identity to Emirati residential design.

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Designing the House of the Future in the UAE: Integrating Traditional Emirati Residential Architecture into a Low-Carbon Design Approach

Traditional Emirati architecture developed in response to the environmental conditions, available resources, and social practices of the region. Many of its characteristic elements, including courtyards, wind towers, shading systems, and compact spatial arrangements, addressed climatic needs while also supporting privacy and family life. This thesis examines how the principles behind these traditional solutions can inform contemporary low-carbon residential design in the United Arab Emirates without simply reproducing vernacular forms. Developed within the framework of the House of the Future competition, the research combines literature review, architectural analysis, environmental evaluation, and design application to test these principles through a contemporary family residence.

This introductory chapter outlines the context and motivation for the research, defines its aim and objectives, presents the research questions, describes the methodology and scope of the study, and concludes with the overall structure of the thesis.

Background and Motivation

The building sector plays a fundamental role in addressing global environmental challenges, accounting for an important share of worldwide energy consumption, greenhouse gas emissions, and resource use. As climate change, rapid urbanization, and population growth continue to increase the environmental impact of the built environment, the development of low-carbon and climate-responsive buildings has become one of the principal objectives of contemporary architecture. While considerable progress has been made in

improving the operational efficiency of buildings through advanced technologies, achieving meaningful reductions in environmental impacts also requires the integration of passive environmental strategies from the earliest stages of architectural design.

These challenges are especially evident in hot arid regions such as the United Arab Emirates (UAE), where extreme climatic conditions place exceptional demands on residential buildings. The country experiences prolonged periods of intense solar radiation, summer temperatures frequently exceeding 45°C, minimal annual precipitation, and high cooling requirements. As discussed in Chapter 1, residential buildings create approximately three-quarters of the UAE's building stock and account for a substantial proportion of national electricity consumption, primarily due to mechanical cooling systems. Consequently, improving the environmental performance of residential architecture represents one of the greatest opportunities for reducing operational energy demand and carbon emissions within the country's built environment.

Long before the introduction of mechanical air conditioning, vernacular Emirati settlements evolved through centuries of adaptation to these environmental conditions. These settlements achieved high levels of environmental performance while simultaneously reflecting the social, cultural, and religious values of Emirati society. These passive strategies were not isolated architectural features but components of an integrated environmental system that regulated daylight, airflow, privacy, and thermal comfort with minimal energy consumption.

However, the rapid modernization that followed the discovery of oil during the second half of the twentieth century fundamentally transformed residential architecture in the UAE. Traditional settlements were progressively replaced by standardized villas, master-planned

residential compounds, and mechanically conditioned buildings influenced largely by international architectural models. Although these developments improved living standards and accommodated rapid urban growth, they also increased dependence on active cooling systems while reducing the application of climate-responsive passive design principles. As contemporary residential architecture became increasingly standardized, many characteristics that had historically connected buildings to the local climate, culture, and urban context gradually disappeared.

Rather than considering this architectural heritage solely as a form of cultural heritage, this thesis approaches it as a valuable source of environmental knowledge that remains relevant for contemporary sustainable design. The research argues that vernacular architectural principles should not be replicated literally but critically reinterpreted through modern construction methods, current environmental standards, and contemporary lifestyles. By integrating traditional passive strategies with low-carbon design approaches, it is possible to develop residential architecture that simultaneously improves environmental performance, strengthens cultural identity, and responds to present-day functional requirements.

Although traditional Emirati architecture has been extensively documented from historical and architectural perspectives, relatively few studies have translated its passive environmental principles into a comprehensive contemporary residential design proposal. This research aims to address that gap by investigating how vernacular architectural knowledge can be systematically reinterpreted within a low-carbon design framework for present day housing in the UAE.

The research is further motivated by the House of the Future competition in the United Arab Emirates, which challenges designers to develop innovative, sustainable, and energy-

efficient residential architecture. The competition provides an appropriate framework through which traditional passive design principles can be critically evaluated, adapted, and integrated into a contemporary architectural proposal. It also offers an opportunity to demonstrate how vernacular knowledge can contribute to the future of sustainable residential architecture in the UAE.

Research Aims and Objectives

The primary aim of this research is to investigate how the architectural principles and passive environmental strategies of traditional Emirati houses can be reinterpreted and integrated into the design of a contemporary low-carbon family residence in the United Arab Emirates. Rather than replicating vernacular architecture, the study aims to identify the environmental, spatial, and socio-cultural principles contained within traditional Emirati dwellings and evaluate their applicability to contemporary residential design.

The project aims to demonstrate how traditional passive design strategies can be combined with contemporary construction methods, renewable energy technologies, and low-carbon design principles to create a climate-responsive family residence that meets present-day environmental, functional, and cultural requirements. To achieve this aim, the following research objectives have been established:

- To examine the climatic characteristics of the United Arab Emirates and identify the environmental challenges influencing residential architectural design.
- To investigate the spatial organization, architectural elements, and passive environmental strategies of traditional Emirati houses, with particular emphasis on

courtyards, wind towers (barjeel), mashrabiyas, shading devices, natural ventilation, and thermal mass.

- To analyze the transformation of residential architecture in the UAE from traditional settlements to contemporary residential compounds, evaluating the environmental, cultural, and spatial implications of this transition.
- To identify the traditional passive design principles that remain applicable and adaptable to contemporary low-carbon residential architecture.
- To develop a contemporary low-carbon architectural proposal for an Emirati family residence by integrating traditional passive strategies with modern technologies and sustainable design principles.
- To evaluate the proposed design in terms of its environmental performance, cultural responsiveness, and contribution to sustainable residential architecture in the UAE.

Research Questions

This research is guided by the following primary research question: How can the architectural principles and passive environmental strategies of traditional Emirati houses be integrated into the design of a low-carbon, climate-responsive house of the future in the United Arab Emirates? To address this question, the following sub-questions are investigated:

- What climatic characteristics and environmental challenges affect residential architectural design in the United Arab Emirates?
- Which architectural principles and passive environmental strategies define traditional Emirati houses, and how do they contribute to environmental performance and thermal comfort?

- How have contemporary residential compounds and villa typologies in the UAE diverged from traditional Emirati architecture in terms of urban morphology, environmental performance, and cultural identity?
- Which principles of traditional Emirati architecture stay relevant and adaptable to contemporary low-carbon residential design?
- How can these principles be reinterpreted and integrated into the design of a contemporary Emirati family residence that responds to present-day environmental, functional, and socio-cultural requirements?

Scope and Methodology

This research adopts a qualitative research-by-design methodology that combines literature review, architectural analysis, environmental evaluation, and design application. The study focuses on residential architecture in the United Arab Emirates, investigating how the architectural principles and passive environmental strategies of traditional Emirati houses can inform the design of a contemporary low-carbon family residence. The scope of the research is limited to residential architecture and does not examine other building typologies or broader urban planning policies beyond their influence on housing design.

The research begins with an examination of the climatic conditions of the UAE and the environmental challenges affecting residential buildings. Climatic data, environmental literature, and passive design principles are analyzed to establish the environmental context within which residential architecture operates.

The second stage investigates traditional Emirati houses through an analysis of their historical development, urban morphology, spatial organization, architectural elements, and

passive environmental strategies. Particular attention is given to courtyards, wind towers (barjeel), mashrabiyas, shading devices, natural ventilation, thermal mass, and other vernacular design solutions. Historical literature, architectural documentation, and selected case studies are examined to identify the environmental and spatial principles that contributed to the climatic performance of these dwellings.

The third stage focuses on contemporary residential compounds and villa typologies in the UAE. Their urban morphology, architectural characteristics, and environmental performance are analyzed to identify the extent to which traditional passive strategies have been replaced by standardized and mechanically conditioned residential models.

Building upon the findings of the previous chapters, the research synthesizes the identified design principles into a contemporary architectural proposal developed within the framework of the House of the Future competition. The proposal integrates passive environmental strategies derived from traditional Emirati architecture with contemporary construction methods, renewable energy technologies, and low-carbon design principles to create a climate-responsive family residence.

Finally, the proposed design is evaluated against the research objectives to assess how effectively it integrates traditional architectural knowledge with contemporary sustainable design principles. The evaluation considers environmental performance, cultural responsiveness, and the overall applicability of vernacular passive strategies to contemporary residential architecture in the UAE.

Structure of the Thesis

This thesis is organized into five chapters, progressing from the theoretical and environmental context of residential architecture in the United Arab Emirates to the development of a contemporary low-carbon design proposal.

Chapter 1 introduces the research by establishing the environmental context of the study. It examines the climatic characteristics of the UAE, discusses the role of the building sector in addressing climate change, and highlights the environmental challenges affecting residential architecture. The chapter also introduces passive design principles and low-carbon design strategies relevant to hot arid climates.

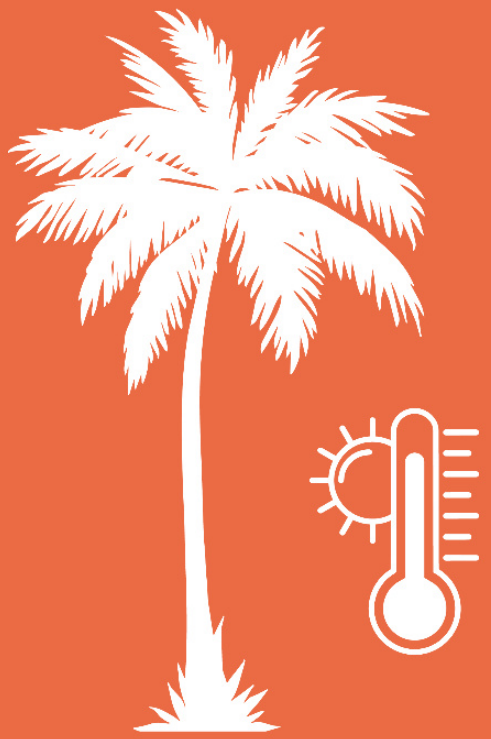
Chapter 2 investigates traditional Emirati residential architecture. It examines the historical evolution of Emirati dwellings, their urban morphology, architectural elements, and passive environmental strategies. Particular emphasis is placed on features such as courtyards, wind towers (barjeel), mashrabiyas, shading systems, and thermal mass, supported by the analysis of traditional settlements and detailed case studies.

Chapter 3 examines contemporary residential architecture in the UAE, focusing on family villas within modern residential compounds. The chapter analyzes their urban morphology, architectural characteristics, and environmental performance, highlighting the differences between contemporary developments and traditional Emirati settlements while identifying opportunities for the reintegration of passive design principles.

Chapter 4 examines the *House of the Future* competition as a contemporary reference for residential design in the UAE. It analyzes winning proposals from 2023/24 and 2024/25, focusing on spatial organization, environmental strategies, adaptability, and the

Chapter 5 presents the design proposal developed through the research. It begins with site selection and analysis in Dubai, followed by the architectural concept, spatial layout, material and building systems, cooling demand, carbon footprint, and urban design strategy, bringing together the contextual research, traditional housing analysis, and competition case studies.

1. Contextual Framework



1. Contextual Framework

This chapter establishes the contextual foundation for the research by examining the environmental, climatic, and architectural conditions that shape residential design in the United Arab Emirates. It begins with a comparison of residential and non-residential buildings, followed by an analysis of the UAE's climatic conditions, environmental challenges, and solar energy potential.

1.1 A Comparative Analysis of Residential and Non-Residential Buildings in the UAE at the Local Scale

The UAE's rapid urban development has resulted in a diverse built environment comprising both residential and non-residential buildings. These two sectors differ considerably in terms of scale, material use, energy consumption, and environmental impact. This section compares their relative prevalence, operational performance, and embodied environmental impacts, with particular attention to their implications for sustainability and carbon emissions at the local scale.

1.1.1 Proportional Distribution of Buildings

According to the Federal Competitiveness and Statistics Centre (FCSC, 2023), residential buildings account for approximately 75% of the UAE's building stock. This category includes a variety of housing types, such as villas, low- and mid-rise apartment buildings, and residential compounds. In contrast, non-residential buildings represent approximately 25% of the building stock and include commercial facilities such as offices, shopping malls, and hotels, as well as public and institutional buildings including schools, hospitals, and industrial facilities. This distribution reflects the UAE's rapid population

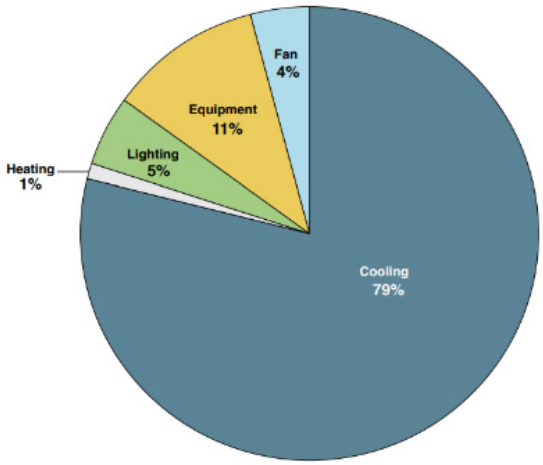
growth and the resulting demand for housing, particularly in major urban centres such as Dubai and Abu Dhabi.

1.1.2 Energy Use and Operational Patterns

Although non-residential buildings constitute a smaller proportion of the total building stock, they consume slightly more electricity annually (approximately 36%) than residential buildings (approximately 32%) (Dubey & Krarti, 2017, p. 4). This higher consumption is primarily attributable to their continuous operational demands, including 24-hour cooling, lighting, and equipment use, particularly within the commercial and hospitality sectors.

Figure 1

Annual Energy End-use Distribution for a typical villa



Note. Reprinted from *Annual energy end-use distribution for a typical villa*, KAPSARC analysis.

Residential buildings generally experience peak electricity demand during the evening and nighttime hours, especially during the summer months, when cooling requirements are highest. Air conditioning accounts for approximately 79% (see Figure 1) of the annual

electricity consumption in villas, which, according to Dubey and Krarti (2017, p. 17), average approximately 99,476 kWh per year, with peak demand reaching 36.9 kW at 5:00 p.m. on 5 August.

By comparison, non-residential buildings—including offices, shopping malls, and hotels—typically reach peak energy demand during daytime working hours, coinciding with the highest levels of solar radiation and ambient temperatures, which frequently exceed 45–50°C. The overlapping demand from both sectors places considerable pressure on the national electricity grid, contributes to the urban heat island effect, and increases cooling requirements, particularly within dense urban areas characterised by high-rise developments.

1.1.3 Embodied Carbon Considerations

Embodied carbon refers to the greenhouse gas emissions generated throughout the life cycle of building materials, including extraction, manufacturing, transportation, installation, maintenance, and end-of-life disposal (Rayner, 2022). In the UAE, non-residential buildings, such as shopping malls and office buildings, generally exhibit higher embodied carbon emissions per square metre because of their extensive use of steel, glass façades, and complex building systems (Rayner, 2022).

Residential buildings, although typically simpler in construction and more standardised in their material use, account for approximately 75% of the country's building stock. Consequently, their cumulative contribution to embodied carbon emissions remains substantial despite their lower carbon intensity per unit area. Furthermore, the widespread use of carbon-intensive materials, particularly reinforced concrete, across both residential and

non-residential construction makes embodied carbon a significant environmental challenge within the UAE's built environment (Ove Arup & Partners Limited, 2023, p. 1).

1.1.4 Summary

Both residential and non-residential buildings play significant roles in shaping the UAE's environmental performance. While non-residential buildings generally exhibit higher operational energy demands, the predominance of residential buildings results in substantial cumulative energy consumption and embodied carbon emissions.

1.2 Climate and Environmental Challenges in the UAE

The United Arab Emirates (UAE) is situated within a hot desert climate zone and is classified as BWh (Arid [B], Desert [W], and Hot [h]) under the Köppen–Geiger climate classification system. This climate is characterized by extremely high temperatures, intense solar radiation, and very low annual precipitation. Such conditions pose significant challenges for architectural design, particularly in the residential sector, where thermal comfort and energy efficiency are critical considerations. Understanding the UAE's environmental context is therefore essential for developing climate-responsive, low-carbon housing solutions that align with both contemporary needs and traditional resilience strategies.According to climate data from January 2017 to June 2022 provided by the Copernicus Climate Change Service (see Figure 2), the UAE experiences two primary seasons—a hot summer and a mild winter—separated by two transitional periods. The annual mean temperature in Dubai is approximately 29°C (84°F), while the city experiences an average of 296 days per year with temperatures above 25°C (77°F) and no days below 0°C (32°F).

Figure 2

Monthly Average Temperatures in Dubai, United Arab Emirates

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	30°C (86°F)	34°C (94°F)	39°C (102°F)	41°C (106°F)	45°C (114°F)	47°C (117°F)	47°C (117°F)	47°C (116°F)	45°C (114°F)	40°C (105°F)	37°C (99°F)	31°C (88°F)
Mean maximum	29°C (84°F)	32°C (90°F)	37°C (99°F)	41°C (105°F)	43°C (110°F)	44°C (112°F)	46°C (115°F)	46°C (115°F)	44°C (112°F)	40°C (104°F)	35°C (96°F)	30°C (87°F)
Average high	25°C (77°F)	26°C (79°F)	30°C (86°F)	35°C (96°F)	39°C (102°F)	42°C (108°F)	43°C (109°F)	42°C (109°F)	41°C (106°F)	37°C (99°F)	31°C (88°F)	27°C (81°F)
Daily mean	20°C (68°F)	21°C (70°F)	24°C (76°F)	29°C (84°F)	32°C (90°F)	35°C (96°F)	37°C (99°F)	37°C (98°F)	34°C (94°F)	31°C (87°F)	26°C (79°F)	22°C (72°F)
Average low	15°C (60°F)	16°C (61°F)	19°C (66°F)	23°C (74°F)	26°C (80°F)	30°C (86°F)	32°C (90°F)	32°C (89°F)	29°C (84°F)	25°C (77°F)	21°C (69°F)	17°C (63°F)
Mean minimum	11°C (53°F)	11°C (53°F)	14°C (57°F)	18°C (65°F)	23°C (73°F)	26°C (80°F)	29°C (84°F)	29°C (84°F)	26°C (79°F)	21°C (71°F)	16°C (62°F)	13°C (55°F)
Minimum	9°C (49°F)	10°C (50°F)	12°C (54°F)	17°C (63°F)	21°C (70°F)	25°C (77°F)	28°C (82°F)	27°C (81°F)	24°C (76°F)	19°C (67°F)	15°C (60°F)	12°C (54°F)

Note. Reprinted from Copernicus Climate Change Service. Climate data generated from January 2017 to June 2022.

The winter season (December to March) is relatively temperate, with daily mean temperatures ranging from 20°C to 24°C. This period also accounts for most of the country's annual rainfall, with an average monthly precipitation of approximately 11 mm and around one rainy day in each of January, February, and March. Despite this seasonal concentration, annual precipitation remains low at approximately 51 mm, with only five days per year recording more than 1 mm of rainfall. The first transitional period (April to May) is characterized by a rapid increase in temperature, with daily mean temperatures ranging from 29°C to 32°C, marking the onset of the extreme summer season.

The summer season (June to September) is characterized by persistent extreme heat, with maximum daily temperatures reaching up to 47°C and mean temperatures ranging between 34°C and 37°C. The UAE experiences approximately 120–130 days each year with

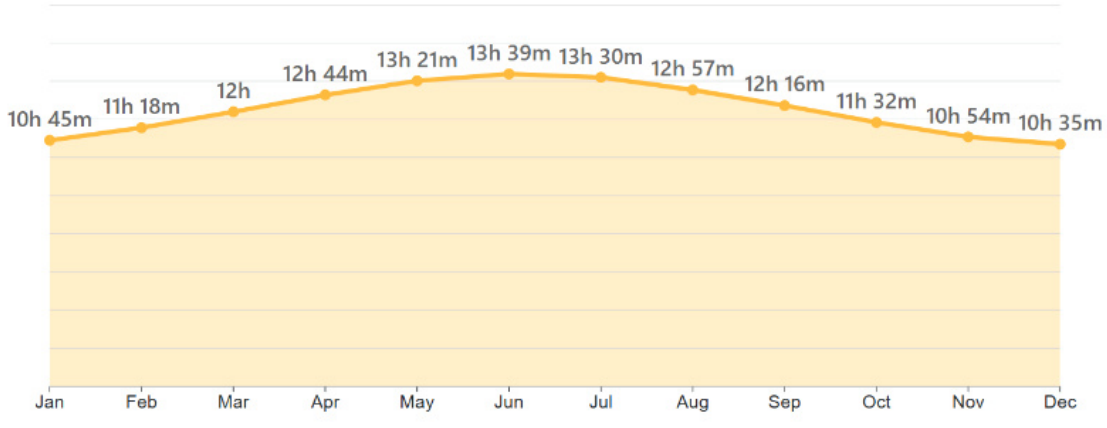
temperatures exceeding 40°C and 20–30 days with temperatures above 45°C, placing considerable thermal stress on buildings, infrastructure, and outdoor environments. In Dubai, one of the country's major urban centres, temperatures exceed 25°C on an average of 296 days per year, while temperatures below 0°C are virtually absent, further illustrating the sustained heat exposure experienced throughout much of the year.

1.2.1 Daylight and UV Radiation

Dubai's daylight and UV patterns follow a clear seasonal cycle, as illustrated in Figures 3 and 4. Figure 3 presents the average monthly daylight duration, showing the total daylight hours between sunrise and sunset throughout the year. Daylight gradually increases from approximately 10 hours 45 minutes in January to a peak of 13 hours 39 minutes in June before decreasing again to around 10 hours 35 minutes in December.

Figure 3

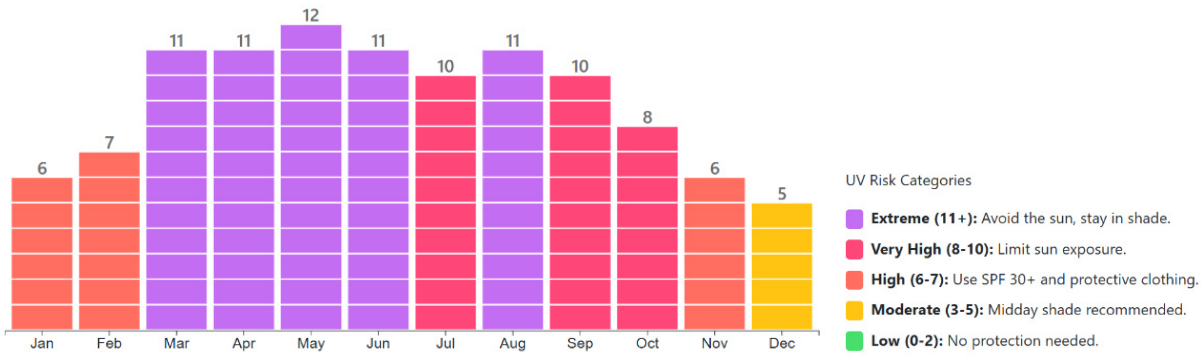
Average Monthly Hours of Sunshine in Dubai, United Arab Emirates



Note. Adapted from *Weather and Climate* (n.d.). United Arab Emirates daylight hours, calculated by summing the hours between sunrise and sunset for each day.

Figure 4

Monthly Maximum UV Index in Dubai, United Arab Emirates



Note. Adapted from *Weather and Climate* (n.d.). United Arab Emirates UV Index data aggregated from multiple regional locations using Copernicus Climate Change Service data.

Figure 4 presents the monthly maximum UV Index, representing the highest UV radiation level recorded each month. The UV Index measures the intensity of ultraviolet radiation from the sun and indicates the potential risk of sunburn and other UV-related health effects. In winter (December to February), daylight lasts around 10–11 hours, and the UV Index is moderate, ranging from 5 to 6, meaning that basic sun protection is advisable during midday. As spring (March to May) arrives, daylight increases to 12 hours in March and April and peaks at 13 hours in May. During this time, the UV Index rises sharply, reaching extreme levels of up to 12, making sun protection, such as sunscreen, shade, and protective clothing, essential. In summer (June to August), both daylight duration and UV levels remain high, with around 13 hours of daylight and a UV Index between 10 and 11, indicating very strong solar exposure that requires strict sun safety precautions. By autumn (September to November), daylight gradually decreases from 12 to 10 hours, and the UV Index declines from 8 in September and October to 6 in November. While the sun is less intense in late

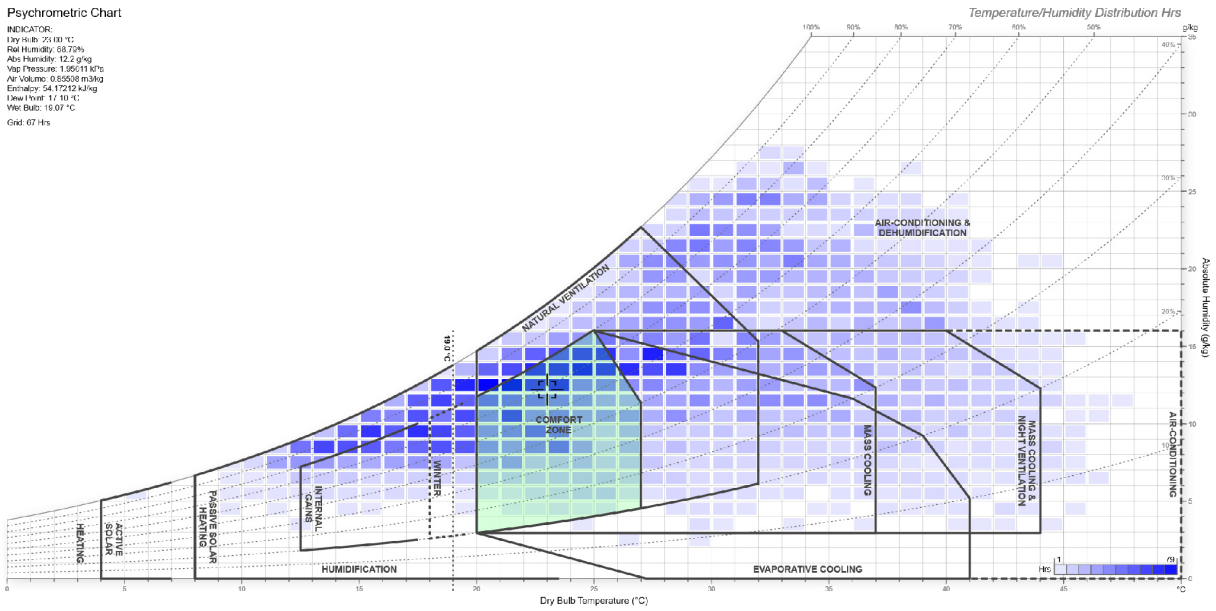
autumn, protective measures remain important during outdoor activities. This seasonal pattern highlights Dubai's sunny desert climate and the need for year-round awareness of sun exposure.

1.2.2 Comfort and Psychrometric Data

The psychrometric chart (Figure 5) illustrates the annual distribution of climatic conditions in Dubai and identifies the passive and active strategies that can be used to achieve thermal comfort. The main observations are summarized below:

Figure 5

Psychrometric Chart for Dubai, United Arab Emirates



Note. Created by the author using the Dubai EPW (EnergyPlus Weather) file in Andrew *Marsh's Psychrometric Chart 2D tool.*

- Comfort zone coverage: The comfort zone is only lightly populated, indicating that the climate is not naturally comfortable for most of the year. As a result, thermal comfort must be achieved through the application of passive and active design strategies.
- Natural ventilation: A significant number of hours fall within the Natural Ventilation zone, indicating strong potential for the use of cross-ventilation or stack ventilation during many periods of the year. Architectural strategies such as appropriately positioned openings, courtyards, wind towers, and ventilation chimneys can be used for this purpose.
- Mass cooling and night ventilation: A large cluster of hours appears within this zone, suggesting that nighttime ventilation combined with thermal mass (e.g., stone, concrete, or adobe) can regulate indoor temperatures efficiently by storing coolness at night and releasing it during the hot daytime.
- Evaporative cooling: Some hours fall within the Evaporative Cooling zone. Since the relative humidity is often low, both direct and indirect evaporative cooling are feasible and energy-efficient solutions. Traditional strategies such as courtyards with water features, fountains, or wind towers incorporating water trays can therefore be effective.
- Air conditioning and dehumidification: A portion of the year (visible in the upper-right area of the chart) falls within this category. During these periods, passive strategies alone may not be sufficient, and mechanical cooling may be required. However, this portion remains relatively small, indicating that considerable energy savings can still be achieved through appropriate passive design.

A significant concentration of climatic conditions also falls within the thermal mass with night ventilation zone. This suggests that buildings with high thermal mass, using materials such as stone or concrete, can absorb heat during the day and release it during cooler nighttime hours when combined with effective night-time ventilation. Such an approach can moderate indoor temperature fluctuations and improve overall thermal performance.

The chart further indicates that evaporative cooling can contribute to thermal comfort during certain periods of the year. Under suitable climatic conditions, direct or indirect evaporative cooling systems may provide an energy-efficient alternative to conventional cooling methods. Traditional passive cooling techniques, including shaded courtyards, water features, and wind towers integrated with evaporative elements, can further support this strategy.

Finally, a proportion of the annual climatic conditions falls within the air-conditioning and dehumidification zone, indicating that passive strategies alone are insufficient during the hottest and most humid periods. Mechanical cooling therefore remains necessary to maintain acceptable indoor comfort under these conditions. Nevertheless, the psychrometric analysis suggests that the effective integration of passive design strategies can substantially reduce cooling demand, improve energy efficiency, and enhance overall building performance.

1.2.3 Climate Change and Future Risks

According to the Köppen–Geiger climate classification system, Dubai is classified as BWh, indicating a hot desert climate. As shown in Figure 6, the Köppen climate classification system uses a three-letter code to describe climate characteristics. The first letter identifies the primary climate group, the second indicates the precipitation pattern, and the third describes

the temperature regime. Accordingly, the BWh classification denotes a dry climate (B), an arid desert precipitation regime (W), and hot temperatures (h).

Current climatic conditions in Dubai are characterized by extremely hot summers, mild winters, limited annual precipitation, high solar radiation, and significant humidity during parts of the year. These environmental conditions have a considerable impact on thermal comfort, energy consumption, and building performance. At present, temperatures in the UAE already reach and often exceed 40°C during spring and autumn (April–May and September–October), with April 2025 recording a peak of 42.6°C, the highest temperature on record.

Figure 6

Köppen Climate Classification Scheme and Symbol Descriptions

1st	2nd	3rd
A (Tropical)	f (Rainforest) m (Monsoon) w (Savanna, dry winter) s (Savanna, dry summer)	
B (Dry)	W (Arid desert) S (Semi-arid steppe)	h (Hot) k (Cold)
C (Temperate)	w (Dry winter) f (No dry season) s (Dry summer)	a (Hot summer) b (Warm summer) c (Cold summer)
D (Continental)	w (Dry winter) f (No dry season) s (Dry summer)	a (Hot summer) b (Warm summer) c (Cold summer) d (Very cold winter)
E (Polar)	T (Tundra) F (Ice cap)	

Note. Reprinted from *Köppen climate classification,* Wikipedia, n.d.

Climate change is expected to worsen these extremes, increasing the frequency and intensity of heatwaves, cooling demand, and pressure on energy systems, especially in residential buildings. Sea level rise threatens coastal areas, while shifting weather patterns may affect biodiversity and water resources. Rainfall could increase by up to 30% by the end of the century, but it is expected to occur in more intense and sudden events, increasing the risk of flooding. These trends highlight the need for climate-resilient residential design that reduces reliance on mechanical systems and adapts to the local environment.

1.3 Sunlight and Solar Potential in the UAE

The United Arab Emirates (UAE) offers excellent conditions for solar energy production due to its geographic location and climate. With consistently high solar exposure, the country is ideally positioned to harness solar power efficiently.

Building skin (average) receives 1,280 kWh/m²/year in Dubai (Gholami & Nils Røstvik, 2021, p. 6). Additionally, the average Global Horizontal Irradiance (GHI) in the UAE ranges from 1,900 to 2,300 kWh/m²/year (Gherboudj & Ghedira, 2016; Mokri et al., 2013). This far exceeds the minimum threshold of 1,600 kWh/m²/year required for efficient photovoltaic (PV) technology, making the UAE highly suitable for solar energy installations (Salameh et al., 2020).

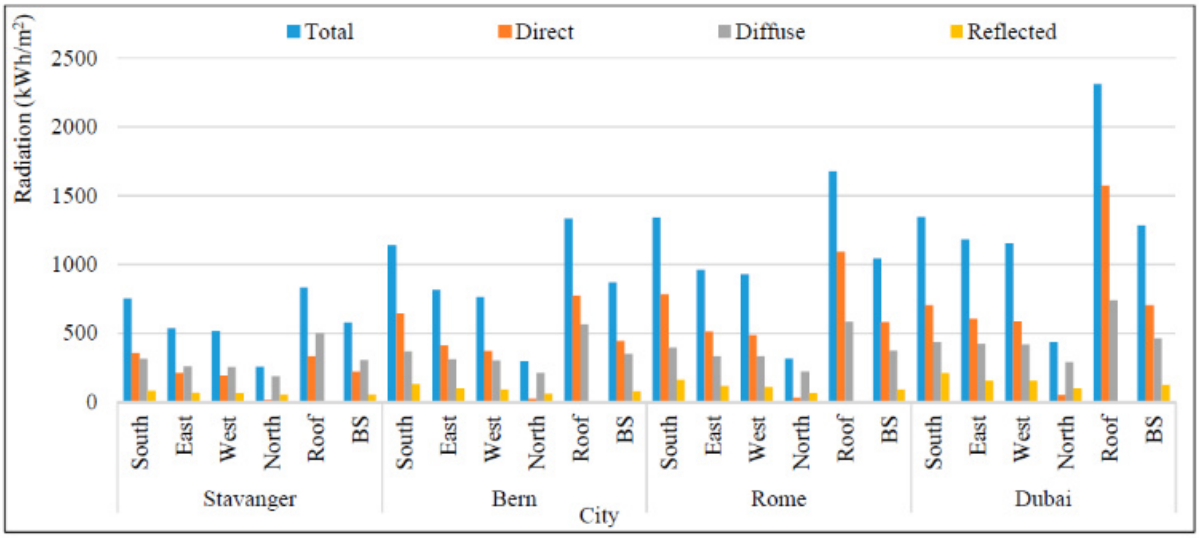
As shown in Figure 7, annual incident solar radiation on building surfaces is substantially higher in Dubai than in the selected European cities across all building orientations. The roof receives the highest annual incident solar radiation, approximately 2,311 kWh/m²/year, due to its continuous horizontal exposure to the sun throughout the day. The south façade receives approximately 1,344 kWh/m²/year, as it is exposed to the sun most

directly around midday. The east and west façades each receive approximately 1,100–1,200 kWh/m²/year, reflecting strong solar exposure during the morning and afternoon, respectively.

Solar radiation on these façades is particularly challenging to control and contributes significantly to indoor thermal discomfort, especially considering that peak electricity demand for cooling occurs at approximately 5:00 p.m. The north façade receives the lowest annual incident solar radiation, approximately 800 kWh/m²/year, owing to its limited direct solar exposure in the Northern Hemisphere. Overall, the average building skin, representing the combined average of the roof and all façades, receives approximately 1,280 kWh/m²/year. For the design proposal, this makes the roof the primary surface considered for PV installation, while the high exposure of the south, east, and west façades reinforces the need for external solar control.

Figure 7

Annual Incident Solar Radiation on Building Surfaces in Selected European Cities and Dubai



Note. Adapted from Gholami and Nils Røstvik (2021, p. 6).

1.3.1 PV Panels and Tilt Angle

The tilt angle is a crucial parameter for the installation of the fixed panels, as the performance of a PV panel is enhanced with increasing exposure to direct irradiation.

Research by Abdallah et al. (2022) indicates that seasonal and semiannual adjustments to the tilt angles could produce approximately 13.5% more energy than a horizontal solar panel. On the other hand, monthly adjustments produce 14.5% more energy than a horizontal panel. It is worth noting that the yearly fixed optimum angle of 23 degrees for the UAE gives about an 8% energy gain higher than a horizontal solar panel (Abdallah et al., 2022, p. 36).

Figure 8 presents the annual, semiannual, seasonal, and monthly optimum tilt angles for solar PV panels in Abu Dhabi, calculated using a mathematical model, PVGIS, and PVWatts. It should be noted that PVWatts and PVGIS restrict the minimum tilt angle to zero, as their frameworks do not allow the use of negative tilt values.

The seasonal variations in optimum tilt angles correspond directly to the changing position of the sun throughout the year: in winter, when the solar altitude is low, higher tilt angles (approximately 50–55°) are required to maximize solar capture, whereas in summer, when the sun is nearly overhead, much smaller tilt angles are optimal, with the mathematical model even indicating negative values (e.g., –7°) to reflect the very high solar altitude. Spring and autumn represent transitional conditions, with moderate tilt angles (10–38°) that align with intermediate solar paths. The data presented in the table are analyzed and taken into consideration for the project.

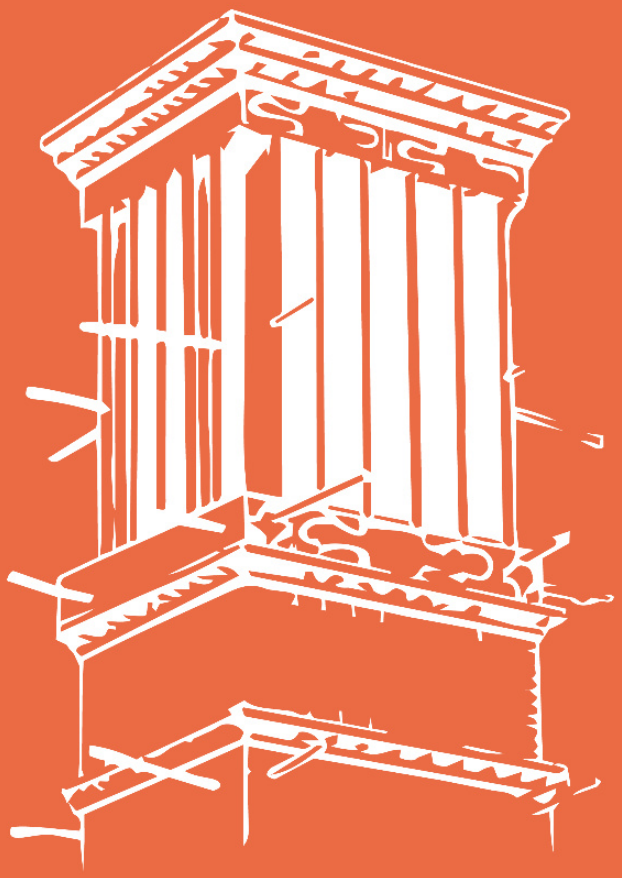
Figure 8

Monthly, Seasonal, Semiannual, and Annual Optimum Tilt Angles for South-Facing Surfaces in Abu Dhabi

Period	Abu Dhabi		
	Annual optimum tilt angle (degrees)		
	Mathematical model	PVGIS	PVWatts
	23	25	25
	Semiannual optimum tilt angle (degrees)		
Warm period	0	3	6
Cold period	45	45	45
	Seasonal optimum tilt angle (degrees)		
Autumn	37	38	37
Winter	51	50	50
Spring	10	12	12
Summer	−7	0	0
	Monthly optimum tilt angle (degrees)		
January	53	52	53
February	43	44	43
March	28	29	28
April	9	11	12
May	−6	0	0
June	−13	0	0
July	−10	0	0
August	3	6	7
September	21	23	21
October	39	39	39
November	51	50	51
December	55	55	55

Note. Adapted from Abdallah et al. (2022).

2. Traditional Emirati Houses



2. Traditional Emirati Houses

This chapter examines the evolution of traditional Emirati houses and the environmental, social, and cultural factors that shaped their development. It explores the urban context, spatial organization, and architectural elements of traditional settlements, with particular emphasis on the wind-tower house and its passive environmental strategies. Finally, a case study is presented to illustrate how these vernacular principles can inform contemporary residential design.

2.1 Emirati Dwellings Throughout History

Traditional architecture in the UAE was both a response and an adaptation to a number of factors that were all connected, including geographical, economic, hierarchical, and tribal factors. Architecture was practical and economical in its use of resources due to the harsh desert environment and the unavailability of resources.

Figure 9

Three Bedouin Sheikhs (c. 1867–1876)



Figure 10

Bedouin encampment near the Dead Sea



Note. Adapted from *Bedouin*. In *Wikipedia*.

These factors influenced the different housing forms that were built, and the most traditional ones were the nomadic Bait Al Sha'r (House of Hair), the Areesh houses, which were made of palm fronds, the more permanent adobe and adobe-stone dwellings, and the wind-tower houses, which will be the focus of the analysis in this paper. Each of those traditional housing types was strictly influenced by the lifestyle and the economic state of the country at different times throughout history.

2.1.1 Nomadic and Semi-Nomadic Lifestyle (Pre-18th to Mid-20th Century)

Documentation about the area where the Emirates are now located is very limited for periods earlier than the eighteenth century ("History of Dubai," 2025). From the pre-eighteenth century until urbanization started with the discovery of oil in the twentieth century, the most common housing types were the Bait Al Sha'r, used by nomadic Bedouins, and the Areesh house, mostly used by coastal fishing communities as permanent housing or erected seasonally by migrating Bedouins (Collins, n.d.).

Figure 11

Bait Al Sha'r (Portable Nomadic Tent)



Figure 12

Areesh House



Note. Adapted from *How Traditional Desert Homes in the UAE Stayed Cool,* MyBayut, 2019.

The *Bait Al Sha'r* tent (Figure 11) was used in different Arab countries, but the basic features remained very similar. It was produced from goat hair, was lightweight, portable, easy to dismantle and erect, and supported by poles, sticks, and ropes (Cruz, 1966, p. 26).

The Areesh house (Figure 12), on the other hand, was made of mangrove poles and palm trunks (or any other wood that was available) for the structure, and palm fronds for the façades and roof surfaces ("Traditional Houses in the UAE," 2012). Both typologies prioritized breathability in the materials, air filtering, sun protection, and privacy. A major shift in building materials occurred after a large fire destroyed much of the Deira settlement along Dubai Creek in the late nineteenth century, prompting the transition from palm-frond (Areesh) structures to more fire-resistant materials ("How Traditional Desert Homes in the UAE Stayed Cool – MyBayut," 2019).

2.1.2 Pearling & Urban Boom (Late 19th–20th Century)

As trade and pearling brought economic prosperity, people began constructing homes from coral stone, gypsum, and mudbrick ("Traditional Houses in the UAE," 2012). This period saw the rise of the traditional (wind-tower) house typology, which included coral stone houses (*Bait Morjan*) and inland houses that were built from stone, gus (a mud mixture made into blocks), or stone ("Traditional Houses in the UAE," 2012). These vernacular typologies introduced courtyards and wind towers to provide natural cooling and ventilation, as well as the incorporation of Islamic architectural elements. The elements of these typologies will be further analyzed and therefore used as a reference for the development of the project in this paper.

2.1.3 Petroleum & Modern (1960s–Present)

After the discovery of oil in the 1960s, the UAE modernized rapidly. The nomadic population was resettled in the so-called Emirati Sha'bī Houses (Elsheshtawy, 2019), developed by Sheikh Zayed's[1] program to establish a modern state, thus putting an end to the nomadic lifestyle. Vernacular houses were replaced by concrete villas and urban buildings, following Western ideas of progress ("Introduction to Architecture in the United Arab Emirates," n.d.). This shift changed both the cityscape and people's way of life. Instead of using passive cooling methods, homes began to rely on fans and air conditioners to stay cool ("How Traditional Desert Homes in the UAE Stayed Cool – MyBayut," 2019).

2.2 Main Urban Elements

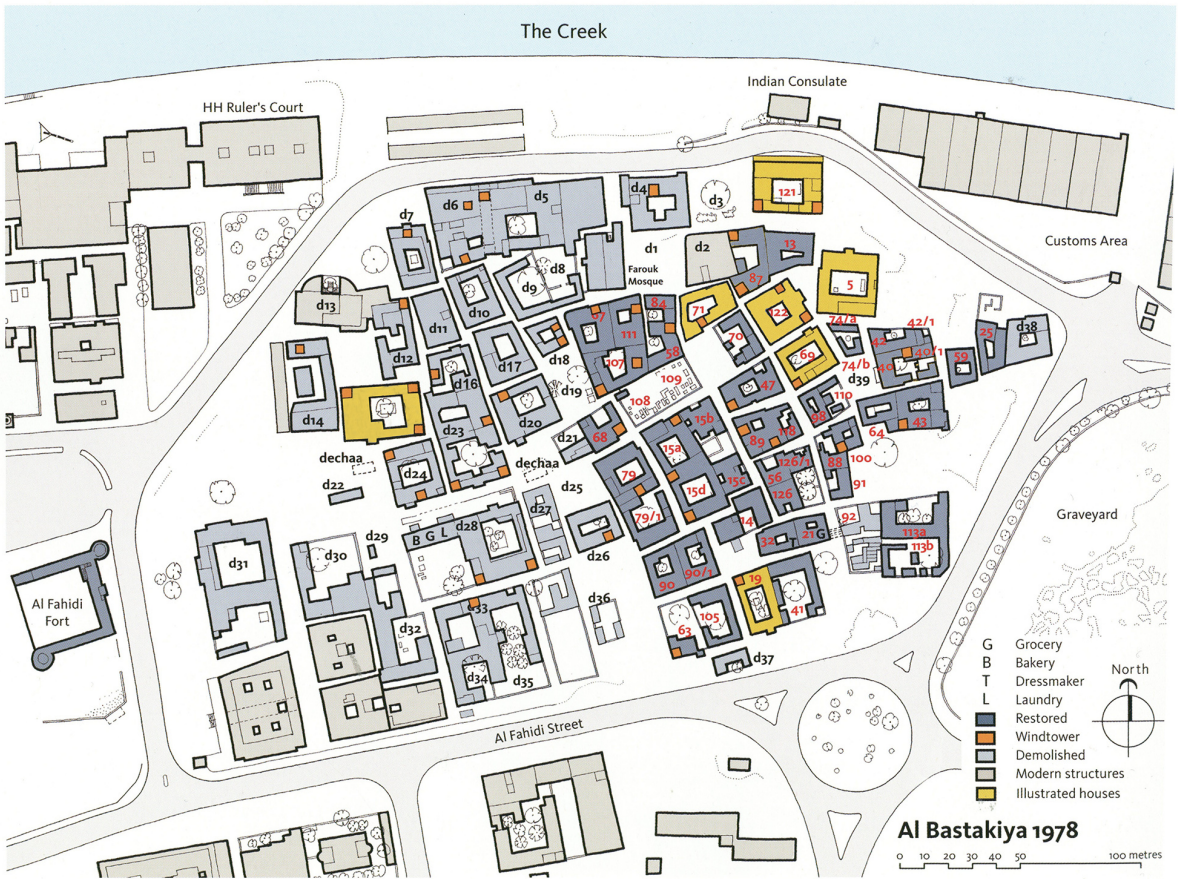
Following the historical overview of Emirati dwellings, this section examines the main urban elements that characterized traditional settlements. Understanding the spatial organization and urban structure of these settlements provides a foundation for analyzing the architectural elements and passive design strategies of traditional Emirati houses in the following sections.

Looking at the masterplan (Figure 13) and the photograph (Figure 14) of Al Bastakiyyah, Dubai (the area that will be used as the main reference throughout the analysis), the main urban elements can be summarized as follows:

- The compactness of the houses in a cellular pattern (Ragette, 2003), shading the buildings and the public spaces around them.
- Organic and narrow streets (*sikka*) that are shaded by the buildings and oriented along the dominant wind direction (northwest).

Figure 13

Site Plan of the Al Bastakiya Historic District, Dubai

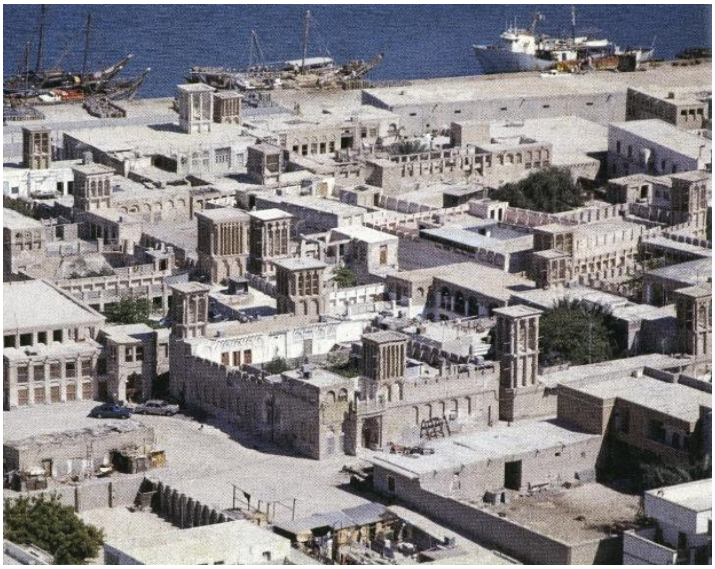


Note. Adapted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing.

- The presence of courtyards in almost every house, creating privacy and comfort for the users.
- Public squares (*saha*) created by each cluster of houses, providing spaces for socializing and commercial activities.

Figure 14

Al Bastakiya Historic District in the 1970s



Note. Adapted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing.

- A relatively low roofline, broken by decorated square wind towers "thrusting upward to catch each breath of air movement," as described by the architect John Harris (Tony & Faculty of Arts, Minia University, 2025).

2.2.1 Social and Religious Influences

Neighbourhoods reflected Islamic values of privacy, mutual responsibility, and community bonds. Tribal clans and relatives clustered together for alliance. To respect privacy, the doors of different houses were usually not facing each other. Shared courtyards, gardens, and mosques encouraged daily interaction and reinforced social cohesion among neighbors (Ragette, 2003).

2.2.2 Types of Public Spaces

Public spaces in traditional Emirati cities, according to their size (in ascending order), include the *Al Hosh*, an inner courtyard within a house or public building; the *Sikka*, a 2–3 m shaded pedestrian walkway between houses; the *Al Baraha*, a neighborhood space for gatherings and children's play; the *Al Musalla*, an open area for prayer in front of the mosque; the *Al Saha*, a larger open space at the district level for markets and social events; and the *Al Maydan*, the largest open public space at the traditional city level, used for major public occasions, local sports activities, and public gatherings (Tony & Faculty of Arts, Minia University, 2025).

2.2.3 Challenges to Urban Identity

After the discovery of oil in the Gulf in the 1960s, traditional cities witnessed dramatic social, cultural, and economic changes that threatened their distinctiveness and uniqueness (Boussaa, 2017). The UAE started embracing globalization trends without giving value to its existing cultural heritage. In fact, historical buildings were demolished to pave the way for new construction, even though there were numerous undeveloped spaces. More than half of Al Bastakiya, the district shown in Figure 13, was demolished to be replaced by modern office buildings.

In 1989, the Municipality of Dubai proposed demolishing the remainder of Al Bastakiya, but fortunately, a preservation campaign led by the British architect Rayner Otter succeeded in removing Al Bastakiya from the demolition list (Ibrahim et al., 2025). Due to this campaign, we are able to study and admire traditional Emirati cultural heritage.

During the construction boom in the UAE, architects and real estate developers mainly built towers and residential districts consisting of housing modules repeated across a plot of land, disregarding climatic and social factors in both approaches. Modern urban development and changes in urban form have resulted in public spaces becoming scarce, streets becoming car-centered, the harsh climate and sunlight not being adequately considered, and the built environment growing vertically.

2.3 Wind-Tower House

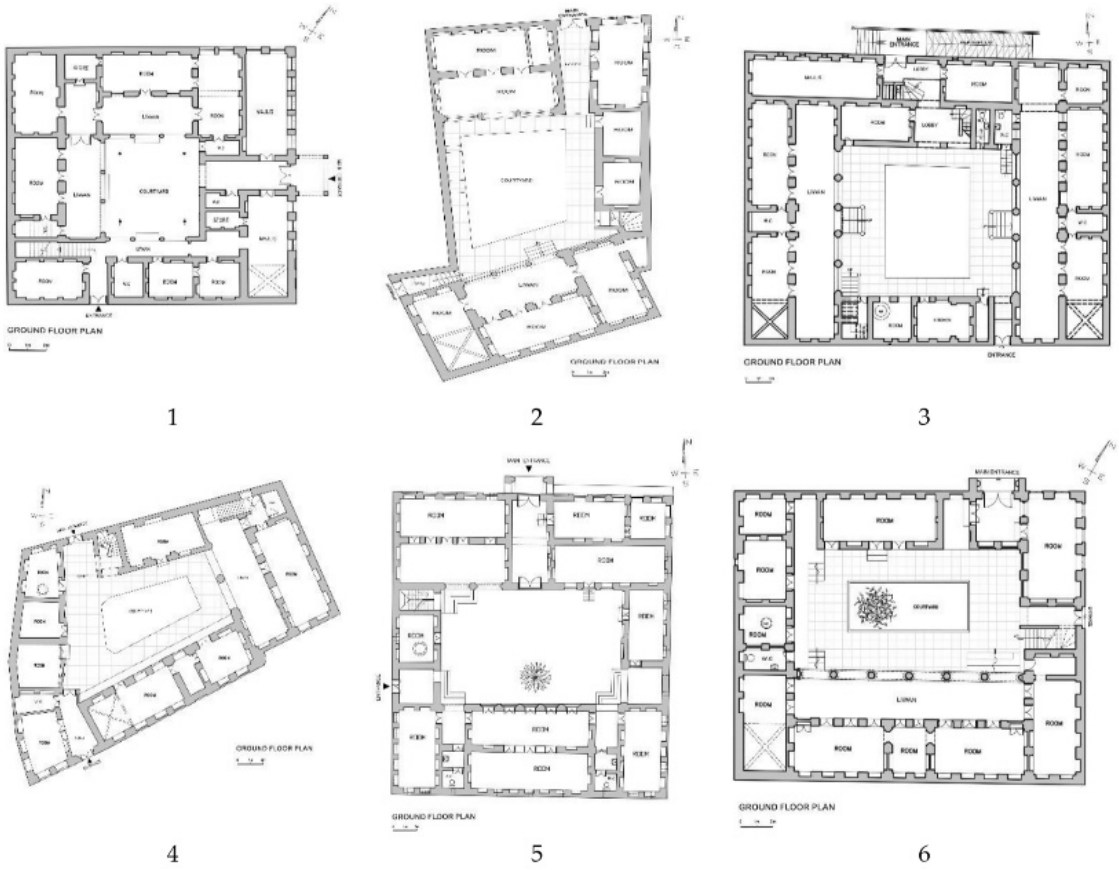
Traditional Emirati *Barjeel* (wind-tower) houses are the perfect example of how the climate and Islamic principles shaped residential architecture in the UAE. Islamic principles, derived from the Qur'an, Hadith, and centuries of cultural traditions, emphasize privacy, family unity, and respect for social interactions. These three concepts strongly influenced the layout, design, and functionality of homes. The concept of privacy, or *satr*, for example, is achieved through architectural elements such as courtyards, screens, and the separation between semi-public and private spaces. Semi-public spaces are created to host guests and people outside the family, while private spaces provide designated areas for family members (Danish & Roni, 2021).

2.3.1 Layout

The houses were mostly two-storey and were built around a large courtyard (Ibrahim, 2018). They were constructed using local materials such as coral, shell, wooden joists, palm trunks, and woven mats (Dubai Municipality, 2006; Ragette, 2003; Rashdan & Mhatre, 2019).

Figure 15

Plans of wind tower houses in Al Bastakiya Historic area in Dubai



Note. Reprinted from *Layers of Meaning and Evolution of Cultural Identity: The Case of Wind Towers in Dubai, by E. Assi, 2022, Conservation*, 2(1), pp. 38–50. (1)-House of Abdul-Rahman Farouq. (2)-House of Mir Abdel Wahid MIRI. (3)-House of Mohammed Sherif Al-Olama. (4)-House of Mohammed Saleh Fikree. (5)-House of Abdul-Razzaq Al-Bastaki. (6)-House of Abdulla Mohammed Al-Bastaki.

In some cases, such as Plans 3, 5, and 6 in Figure 16, a wall in front of the main entrance creates a visual barrier, preventing anyone outside from looking directly into the house and ensuring the privacy of the residents. As shown in Figure 15, in all plans the courtyard acts as the core of the house, distributing the house into semi-public and private

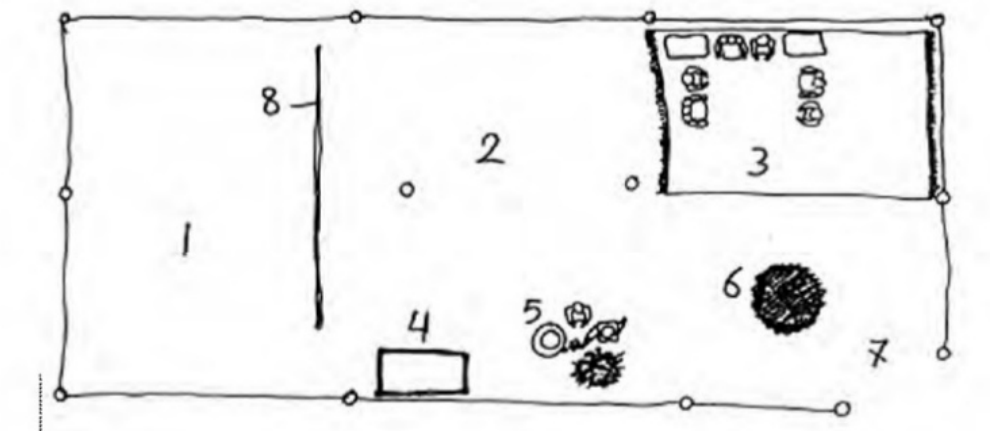
areas, linking different rooms together, ventilating the whole house, as well as allowing people to connect with nature by providing the opportunity to integrate greenery within it.

The courtyard was also used to allow light to enter without compromising the privacy of the residents by orienting the spaces towards it instead of outside. In addition to all the previously mentioned benefits, the courtyard provided an opportunity for future expansion (Tony & Faculty of Arts, Minia University, 2025). Even within the UAE, house designs varied from one emirate to another, but the courtyard remained the main design element in all house types across the different emirates (Ibrahim, 2018). The layout of the traditional wind-tower house was further characterized by the following features:

- The male *majlis* and guest room were placed beside the entrance on the ground floor (Ibrahim, 2018) to prevent guests from accessing more private family spaces.
- The *liwan* separated the public domain from the open courtyard, where the private domain began (Ibrahim, 2018).
- The main rooms were placed facing the courtyard and were wider along the courtyard than in depth to ensure that daylight entering from the courtyard was distributed evenly. On the opposite side, facing the street, the room walls usually did not have openings, except for some ventilation holes at the top of the walls (Tony & Faculty of Arts, Minia University, 2025).
- Since rain is rare in the region, roofs were flat in all cases, and residents sometimes slept on them during summer nights to escape the heat. They were usually surrounded by a fence to protect against falling and to prevent visibility from the outside (Tony & Faculty of Arts, Minia University, 2025).

Figure 16

Plan of interior division of bait al sha'r (Nomadic Tent) and Activities at day time



Note. Adapted from Amaireh, 2011. 1- Khidan (parents sleeping area) 2 - Al - Nous (family section) 3- Majles (reception) 4 -Mendaban (store) 5- Hearth 6 - Braided Round mat (sarrouge,dining mat) 7 - closed door 8 - wood partition

- Comparing Figures 15 and 16, many similarities can be observed, reflecting how Islamic architecture has been the foundation of the layout distribution since the Bait Al Sha'r was used. These similarities include the location of the male majlis near the entrance, the separation between male and female areas, and the emphasis on privacy from the outside.

2.3.2 Architectural Elements

Traditional Emirati houses incorporated a variety of architectural elements that contributed to both environmental performance and the everyday functioning of the house. The following sections examine the principal elements of this architectural language.

2.3.3 Architectural Screens (Mashrabiya) and Fences

The term *mashrabiya* is an Arabic word meaning "drinking spot." It originally referred to a cantilevered space with a lattice opening where water jars were placed to cool by the air passing through from outside. *Mashrabiyas* are used as architectural screens for windows and balconies, providing occupants with the ability to look outside while maintaining privacy. *Mashrabiya* patterns are used for more than just aesthetics; they are precisely designed to provide occupants with indoor comfort and functionality (Fathy, 1986).

In simple terms, the *mashrabiya* has five functions: it regulates the amount of light entering the space, directs the airflow, reduces the temperature of the air entering the space, increases the humidity of the air entering the space, and provides privacy for the occupants. Each *mashrabiya* is designed to address several, or sometimes all, of these functions (Fathy, 1986).

The amount of diffuse daylight entering a room depends largely on the size and porosity of the *mashrabiya*, as well as the material and reflectivity of its balusters (Samuels, 2011). The use of rounded balusters, unlike angular or square balusters, helps soften light by gradually distributing it across their surfaces, thus reducing the sharp contrast between solid elements and bright openings. At eye level, the spacing between balusters was made tight to ensure that direct sunlight was prevented from passing through, thus reducing glare. To compensate for the reduced light, the upper parts of the *mashrabiya* usually had wider openings, allowing more light to filter through from above (Fathy, 1986).

2.3.4 Arches and Liwan

Al Liwan, also known as Al Iwan, is a semi-open, roofed space that was placed in front of the rooms facing the courtyard. Its roof was typically constructed from wood and gypsum, while the courtyard-facing façade was composed of columns decorated with floral and natural patterns, as well as a variety of geometric patterns.

Figure 17

Liwan inside of the House of Sheikh Saeed Al Maktoum



Note. Adapted from *Step Inside Dubai's Oldest Royal Home: House of Sheikh Saeed*, by P. Sahu, April 7, 2025, *UAE Stories*

Functionally, Al Iwan served as a shaded transitional zone that shielded interior rooms from direct sunlight while providing visual and physical links to the courtyard. It was usually used as an external family living space, especially during the spring and winter seasons, when the weather was more comfortable. The seating areas in Al Iwan were equipped with furniture

and carpets, making it a comfortable space for daily activities and social interaction (Al Salem, 2020).

2.3.5 Courtyard

Courtyards are a key element of traditional Islamic residential architecture, functioning as the heart of the home. They form private, inward-facing open spaces that support family life while remaining visually and socially protected from the outside by high surrounding walls. This enclosed configuration of the courtyard promotes daily living and social interaction in a peaceful environment. Courtyards often include elements that enhance both comfort and aesthetic quality, such as gardens, fountains, and liwans, which provide shaded seating. The rooms surrounding the courtyard are wider on the courtyard side, allowing better illumination by natural light [1]. Apart from providing social support, the courtyard plays an important role in providing comfort in hot arid climates, where the air temperature inside the courtyard can drop by as much as 10–20°C (18–36°F) at night, cooling the adjacent indoor spaces (Fathy, 1986).

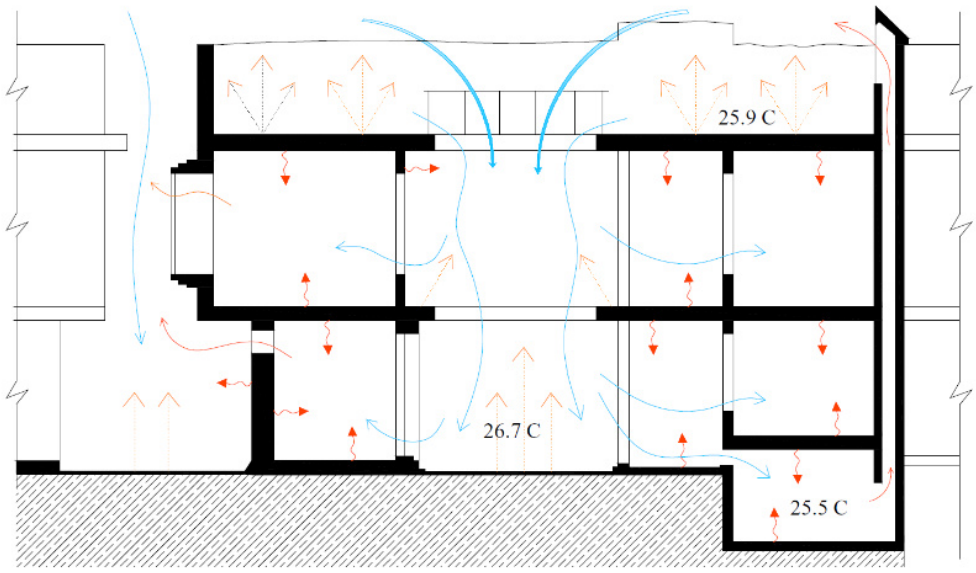
To understand the performance of the courtyard in a hot arid climate, the studies conducted by Abdulkareem (2016) and Al-Azzawi (1984) were used due to the similarity between the traditional climatic solutions of the UAE and Iraq, both of which have hot arid climates. Abdulkareem (2016) adopted as a case study a traditional courtyard house in Baghdad, Iraq, building upon the study originally conducted by Al-Azzawi (1984). According to Abdulkareem (2016), the courtyard experiences four different scenarios over a 24-hour period: night, morning, noon, and afternoon.

Night

By nightfall (Figure 18), the surfaces of the courtyard, such as the floor, surrounding walls, and the ground beneath, which were heated directly by the sun and indirectly by the surrounding buildings, are much warmer than the sky. This is because these elements are made of materials with high thermal mass that absorb and store large amounts of heat during the day, turning them into major heat sources within the courtyard. As a result, heat exchange between the courtyard house and its surroundings mainly occurs through two mechanisms: convective heat transfer and radiative heat exchange (Abdulkareem, 2016).

Figure 18

Thermal performance of a traditional courtyard house during the night in Baghdad



Note. Reprinted from *Thermal Comfort through the Microclimates of the Courtyard: A Critical Review of the Middle-Eastern Courtyard House as a Climatic Response*, by H. A. Abdulkareem, 2016, *Procedia – Social and Behavioral Sciences, 216*, pp. 662–674.

In terms of convection, air that has cooled through exposure to the night sky becomes denser and descends into the courtyard, gathering at floor level (Dunham, 1960). Since the courtyard surfaces are warmer than this incoming air, contact between them initiates convective heat transfer, allowing the stored heat to be released into the air. This process lowers the surface temperatures and contributes to a cooler courtyard environment. Known as thermosyphonic convection, this mechanism depends largely on the temperature difference between the cooled night air and the warmer courtyard surfaces (Givoni, 1998).

At the same time, indoor air temperatures in the rooms surrounding the courtyard are close to their daily maximum, while the courtyard itself continues to cool. This temperature difference between the indoor and outdoor spaces drives further convective air movement: cooler air is drawn into the adjacent rooms through the lower portions of the openings facing the courtyard, while warmer indoor air rises and exits through higher outlets (Heidari, 2000).

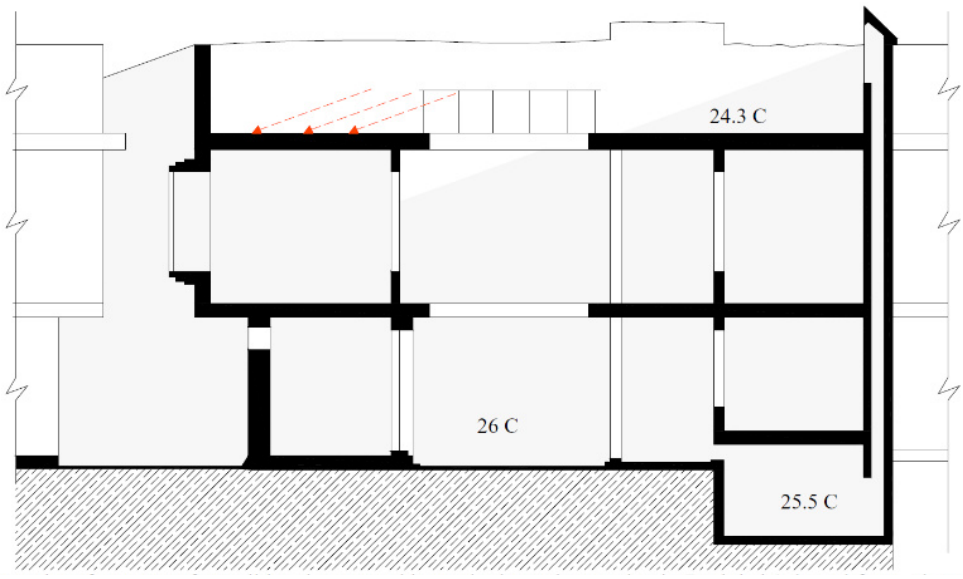
In addition to convection, heat stored in the courtyard floor is released at night through long-wave radiative emission to the clear sky, which further reduces temperatures in the central space (Batty et al., 1991). However, this cooling process is influenced by cloud cover and by the courtyard's proportions, particularly its width and height. Narrow and deep courtyards have a limited view of the sky, reducing their ability to release long-wave radiation, whereas wider courtyards are more exposed and can dissipate heat more effectively (Meir et al., 1995). Similarly, horizontal surfaces with greater sky exposure, such as roofs, cool more efficiently due to the absence of surrounding walls that would otherwise absorb a significant portion of the radiation (Givoni, 1998).

Morning

In the early morning, when the second cycle starts (Figure 19), the microclimate is stable since the impact of solar radiation is insignificant, and the building mass has cooled down during the night. During this time of day, the temperature of the building envelope is at its lowest, and the temperature inside and outside the courtyard house is either equal or the courtyard temperature is slightly higher than the indoor temperature. Due to this negligible temperature difference, the variation in air pressure between the indoor and outdoor environments is also minimal; therefore, convective air currents can hardly be considered a significant factor in heat exchange.

Figure 19

Thermal performance of a traditional courtyard house in the early morning in Baghdad



Note. Reprinted from *Thermal Comfort through the Microclimates of the Courtyard: A Critical Review of the Middle-Eastern Courtyard House as a Climatic Response*, by H. A. Abdulkareem, 2016, *Procedia – Social and Behavioral Sciences, 216*, pp. 662–674.

Noon

By midday, the courtyard enters its third thermal phase (Figure 20). The floor is completely exposed to direct sunlight, causing the air temperature to increase significantly. The thermal mass of the floor and walls assists in absorbing the heat, which is transferred to the surrounding walls. This minimizes the increase in temperature.

Figure 20

Thermal performance of a traditional courtyard house at midday in Baghdad



Note. Reprinted from *Thermal Comfort through the Microclimates of the Courtyard: A Critical Review of the Middle-Eastern Courtyard House as a Climatic Response*, by H. A. Abdulkareem, 2016, *Procedia – Social and Behavioral Sciences, 216*, pp. 662–674.

This effect is, however, reduced as the materials that absorbed the heat during the morning begin to release it in the afternoon. At the same time, the thick adobe walls reduce the rate at which outdoor heat enters the rooms. This creates a temperature and pressure

difference between the courtyard and the rooms. As a result, the courtyard functions as a chimney, where hot air rises to the top while cooler air is drawn from the rooms through the openings .

Afternoon

In the late afternoon, the fourth thermal cycle is experienced. By this time, the rooms surrounding the courtyard have already lost most of their coolness, and both the courtyard and the rooms are no longer comfortable. At this stage, occupants typically rely on other strategies to cope with the heat. These strategies include evaporative cooling or moving to an underground room, which is better protected from the heat, is partially covered by the earth that emits coolness, and is, in some cases, connected to the windcatcher.

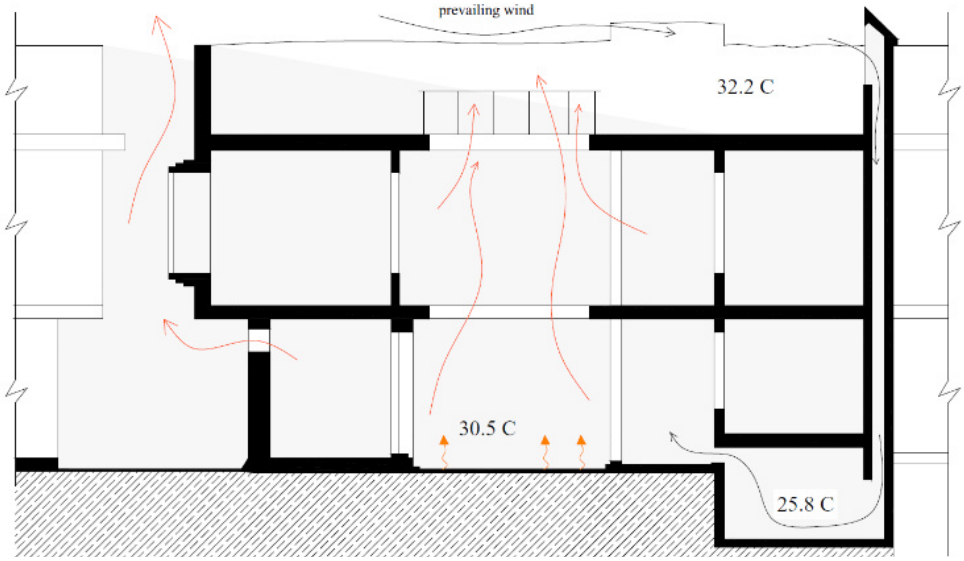
In summary, after sunset, temperatures within courtyard houses decrease as stored heat is dissipated to both the surrounding air and the night sky through combined convective and radiative processes. By morning, the building has cooled down, and the temperature is almost equal between the courtyard and the interior of the building. At noon, the walls, floors, and roofs begin absorbing the sun's heat, while the stored coolness gradually leaves the house. Finally, by the end of the afternoon, both the interior of the house and the courtyard become uncomfortable, as the stored coolness has already escaped completely, and some surfaces begin releasing the heat they absorbed during the day.

Research on family living patterns indicates that shading the courtyard is more important than exposing it to the sky, particularly since there is already an alternative outdoor space on the rooftop (Abdulkareem, 2016). For this reason, Dunham (1960) argues that, from an environmental viewpoint, if a large space is needed, it is better to divide it into two or more

smaller courtyards rather than one large courtyard. Smaller courtyards provide a greater percentage of shaded floor space, reducing the area exposed to direct sunlight compared with a single large courtyard.

Figure 21

Thermal performance of a traditional courtyard house in the late afternoon in Baghdad



Note. Reprinted from *Thermal Comfort through the Microclimates of the Courtyard: A Critical Review of the Middle-Eastern Courtyard House as a Climatic Response*, by H. A. Abdulkareem, 2016, *Procedia – Social and Behavioral Sciences, 216*, pp. 662–674.

2.3.6 Water Features

In the Arab house, the fountain fulfills a role comparable to that of the fireplace in temperate climates: while the fireplace provides warmth, the fountain contributes to cooling. Due to its importance and to ensure that it functioned efficiently, it was usually placed at the center of the courtyard, with the iwanat and the main living spaces opening onto it. Beyond its environmental function, it also carried strong symbolic value. The fountain was typically

square in overall form, enclosing an inner basin shaped as an octagon or, in some cases, a hexadecagon (Fathy, 1986).

Fountains have numerous benefits, extending well beyond their aesthetic value, especially in hot and dry climates such as the UAE:

- Relaxation and stress reduction: The sound of moving water naturally helps calm people, creating a sense of tranquillity.
- Improved aesthetics: Fountains add elegance and beauty to their surrounding environment and often give it more character.
- Attracting wildlife: Fountains attract birds, contributing to the local ecosystem while adding movement and life to the space.
- Noise reduction: The soothing sound of the fountain helps mask background noise, creating privacy and enhancing comfort.
- Improved air quality: They increase the humidity of the air, creating a more comfortable atmosphere, especially in hot and dry climates such as Dubai.
- Natural cooling: Fountains help reduce the air temperature through evaporative cooling. Based on the studies by Fernandes and Correia-da-Silva (2007), the natural cooling process of fountains can be summarized as follows: as warm air passes over the water surface and droplets, its sensible heat provides the energy needed for evaporation. During this process, heat is absorbed from the air, leading to a temperature reduction (usually between 1 and 4.7°C; Reducing Heat with Water, 2026) while simultaneously increasing air humidity.

Additionally, when water in the fountain splashes and breakes into small droplets, it comes into contact with more air, thus increasing the rate of evaporation. This means that the

more the droplets are broken down, the higher the efficiency of the cooling system, as more heat will be drawn from the air (Reducing heat with water, 2026).

2.3.7 Wind Towers

Throughout history, wind towers have been used in hot and arid regions as architectural devices to improve indoor thermal comfort, and today they strongly reflect the cultural identity of the UAE. A wind tower is a vertical shaft with an opening at the top, oriented toward the prevailing wind direction. These openings may be unidirectional, bidirectional, or multidirectional. By capturing cooler outdoor air and directing it into the interior while facilitating the extraction of warmer air through the same shaft by the chimney effect, the wind tower promotes effective air circulation in the rooms below it.

Wind towers are particularly important as bioclimatic elements in hot and arid climates, where air circulation is essential for comfort. To simplify, wind towers are used mainly for the following purposes:

- Enable air circulation and air renewal through natural ventilation.
- Enhance human comfort by functioning similarly to a fan.
- Provide passive, natural cooling.

In traditional Emirati houses, wind towers, also referred to as the barjeel, were not only functional elements for cooling the house but also had social significance. Their number often reflected the social and economic status of the household, as not everyone could afford more than one or two wind towers in their house. Moreover, the position of the wind towers within the house indicated the importance of the rooms beneath them. These rooms were generally reserved for the head of the family or elderly family members. Otherwise, the rooms

beneath the wind towers served as social spaces where family members gathered, slept during the night, or performed their daily prayers (Assi, 2022).

The wind tower is one of the main elements to be included in the practical part (project) of this thesis. There are many types of wind towers that will be explored in this chapter; however, the most common type in Dubai is the multidirectional wind tower with a square cross-section and an internal X-blade (Figure 23). Therefore, this type will be the focus of this chapter.

Functionality

Wind towers operate by using differences in air pressure to create natural ventilation in the spaces below. They enhance air circulation without allowing direct solar heat to enter the building. Additionally, as air moves downward through the tower, its speed increases, and it cools in the process. This increase in airflow promotes convective heat loss from the surface of the human body by accelerating the evaporation of sweat (Figure 22).

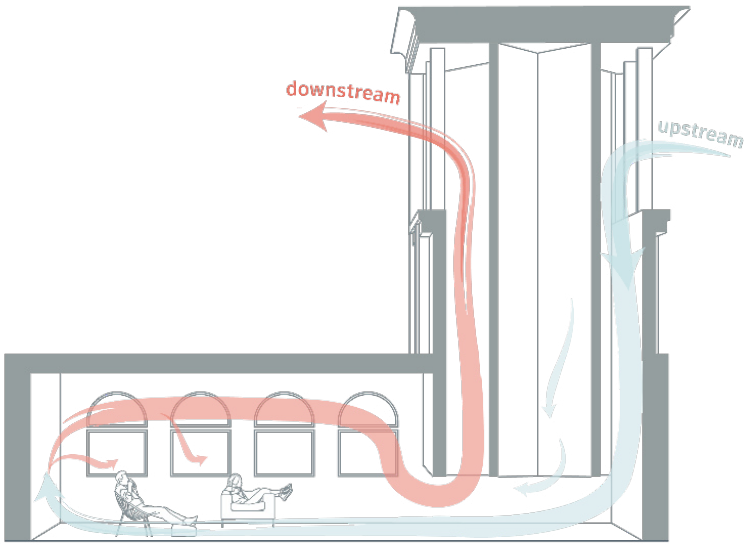
In climates such as Dubai's, where summer temperatures and humidity levels are high, evaporation occurs at a slow rate when the air is still. For this reason, air movement becomes essential for thermal comfort. Without wind, sweat does not evaporate efficiently, making people feel uncomfortable due to the high temperature and humidity. On the other hand, when there is sufficient airflow, sweat evaporates more effectively, helping to cool the body and improve comfort levels (Jackson & Coles, 2022).

The comfort provided by the wind tower is quite different from that provided by an air conditioning unit. While air conditioning relies on mechanically cooled and dehumidified air, wind towers improve comfort primarily by increasing air movement and supporting the

body's natural evaporative cooling process. The traditional wind tower has always been considered an element of great value with significant benefits, but its main drawbacks were that it could not prevent dust and insects from entering the room.

Figure 22

Visualisation of the air movement from the outside to the inside of the room through the wind tower



Note. Created by the author

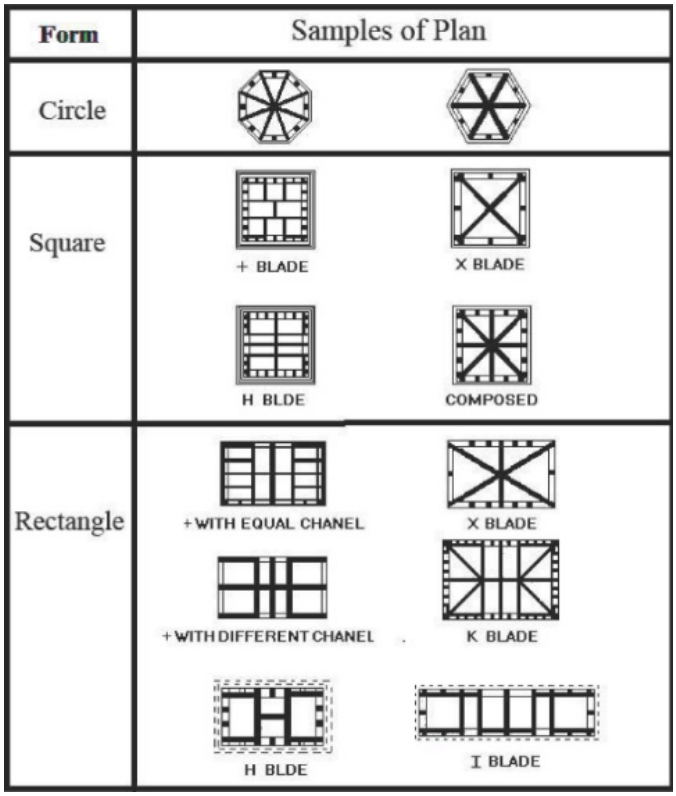
Fortunately, with today's technology and innovation, several elements have been added to the wind tower to address these two issues. Some of these solutions were incorporated into the project of the first-place winner of the House of the Future 2023/24 competition, where curtains were installed over the wind tower openings (inlets). These curtains move with the wind, allowing air to enter while preventing insects from entering when the wind is negligible. In addition, a filter was incorporated into the shaft.

Form and Types

Wind towers in traditional Emirati architecture typically have a square cross-section, with the interior divided by diagonal partitions into four vertical shafts (X-blade in Figure 23). This configuration allows the tower to capture wind from all directions. Rare examples of circular wind towers also exist, such as one found in Sharjah, which is believed to reflect Indian architectural influence (Assi, 2022).

Figure 23

Various cross-sections and internal blades (partitions) in traditional windcatchers



Note. Reprinted from Ghadiri et al., 2014; Mahmoudi and Mofidi Shemirani, 2009

To capture ambient winds efficiently, the height of a wind tower in residential buildings is usually 2–6 m above the roofline. However, in some historical buildings, such as

the wind tower in Dawlat Abad Garden, Iran, it reaches approximately 33 m (Grosso & Ahmadi, 2016). In Dubai, the total height of wind towers generally does not exceed 15 m and rises at least 2 m above the roof level to access higher and cooler air currents. In the historic district of Al Bastakiya, Dubai, most wind towers reach approximately 12 m above ground, with a cross-section of 3.5 × 3.5 m (Assi, 2022).

Wind towers were constructed using locally available materials, primarily coral stone and seashells. The porous nature of coral provided natural thermal insulation, helping the internal surfaces remain cool, while the exterior was finished with a smooth plaster made from chalk and water. Decorative elements were often added around the tower openings, appearing as simple plant-inspired motifs on the crown, along the edges of the openings, or within recessed areas. Additionally, the projecting ends of wooden poles were intentionally left exposed after construction, allowing them to be used as scaffolding for maintenance and re-rendering (Assi, 2022).

Performance

The effectiveness of windcatchers (barjeel) as passive cooling elements depends on how well they respond to the climate, building form, and spatial layout. Research shows that several factors influence the performance of windcatchers:

- Wind speed and wind direction strongly influence the performance of wind towers, which operate more efficiently under higher wind speeds (Assi, 2022).
- Courtyards play an important supporting role by helping create pressure differences that encourage airflow (McCabe & Roaf, 2013; Karakatsanis et al., 1986).

- Taller wind towers generally perform better because they can capture cooler and stronger winds; however, beyond a certain height, additional gains become minimal.
- Adding evaporative cooling elements can significantly improve cooling performance and enhance indoor air quality (Khan & Janajreh, 2017; Sangdeh & Nasrollahi, 2022; Bahadori, 1994; McCabe & Roaf, 2013).
- Wind towers are mainly used during the summer months. In winter, the openings were traditionally covered to keep out cold air and dust (McCabe & Roaf, 2013; Karakatsanis et al., 1986).
- The orientation of the room with respect to the windcatcher affects its performance. Spaces aligned with the prevailing winds benefit from better ventilation, whereas poorly aligned rooms can disrupt airflow (Assi, 2022).
- Wind towers are most efficient when the opening area (inlet) at the top is approximately twice the area of the triangular chimney cross-section below (Jackson & Coles, 2022).
- The size and placement of openings throughout the building also influence how well the system performs (Montazeri & Montazeri, 2018).

Studies comparing different internal blade configurations (Figure 23 shows these blade configurations) indicate that windcatchers with +-shaped blades perform less effectively, whereas K-, H-, and X-shaped blades provide progressively better cooling performance, respectively (Sangdeh & Nasrollahi, 2022).

Number of Openings

The variation in the number of openings in a windcatcher affects how it performs (Cuce et al., 2016), giving rise to different characteristics:

- One-sided windcatchers are most suitable for regions with stable and predictable wind directions, as the full cross-section of the tower is used as an inlet for airflow (Mayhoub et al., 2025; Sangdeh & Nasrollahi, 2022).
- In two- or multi-sided windcatchers, only half or less of the cross-section is responsible for delivering air indoors. In two-sided configurations, one side supplies fresh, cooled air to the interior, while the opposite side simultaneously acts as a chimney, drawing indoor air upward and out of the building (Sangdeh & Nasrollahi, 2022).
- Four-sided windcatchers provide the highest level of flexibility and maintain more consistent performance under varying wind conditions. However, they are more complex and costly to construct (Mayhoub et al., 2025).

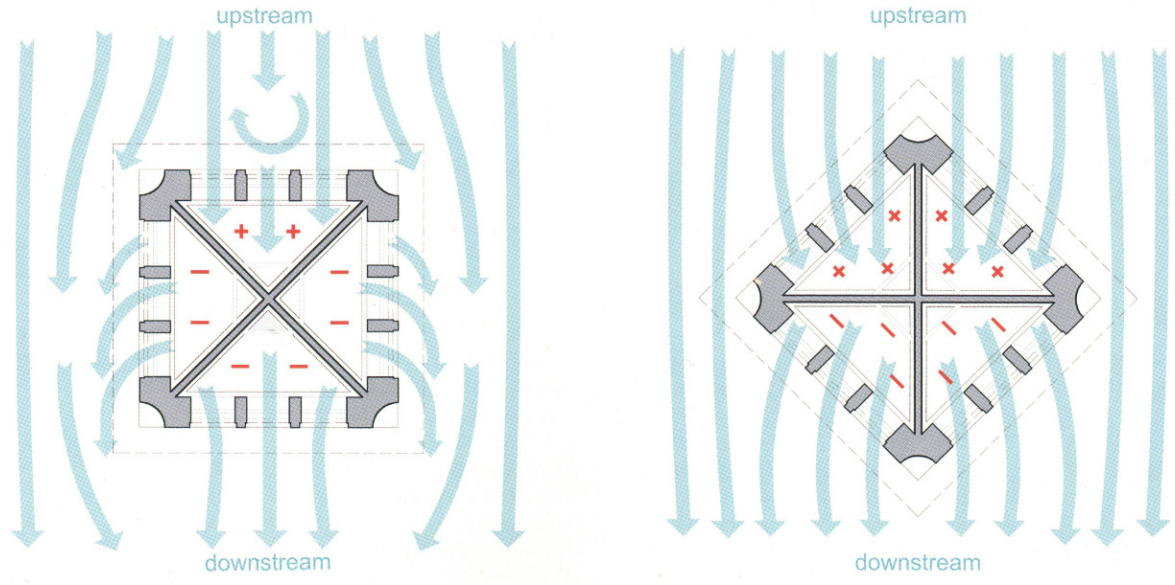
To summarize, windcatchers with fewer openings deliver air to interior spaces faster and more efficiently. Meanwhile, windcatchers with more openings are less affected by changes in wind direction, as the additional sides act as chimneys that help exhaust warm air.

Orientation

The incident wind angle has a significant influence on the performance of the wind tower. In multidirectional wind towers, which are the most common type in the UAE, two main situations can be observed.

Figure 24 **Figure 25**

The incident angle of the wind with respect to the different orientations of the wind tower



Note. Adapted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing.

When the opening is oriented toward the wind direction (Figure 24), and the internal triangular partition walls are positioned at a 45° angle, the wind enters through the windward opening and is directed into the room below, while the other three shafts act as outlets for the return airflow. In this configuration, a small turbulent recirculation zone (bubble effect) forms at the inlet facing the wind direction.

On the other hand, when the wind tower is positioned diagonally to the wind direction (Figure 15), with two openings facing the wind and their internal walls forming a 90° angle with the airflow, the wind enters through these two openings and exits through the other two. In this case, a larger volume of air enters the space, and the airflow moves faster than in the previous case (Figure 14). This occurs because the airflow can turn more smoothly along the

internal dividing walls and change direction with less resistance due to the geometry of the partitions.

Case Study

This house, which has since been demolished (Figure 26), was originally studied and surveyed by the authors in the 1970s. Its decorative features were documented through extensive photographs and architectural drawings, which were subsequently redrawn and are presented in the following pages. These records provide rare documentation of a way of life that no longer exists.

The house was considered one of the finest examples in Al Bastakiya. It was constructed over two floors around a central courtyard and contained three wind towers serving the first-floor rooms. In two-storey houses, many ground-floor rooms were replicated on the upper floor, with the ground floor typically occupied during winter and the first floor during summer. This arrangement was a distinctive characteristic of the Bukhash House. The original plot measured approximately 22.5 × 33.5 m, excluding a strip measuring 18 × 2.7 m along the western boundary.

The house was built in two phases. Construction began in 1924 with the east wing, which contained the living rooms and a steep, curved staircase leading up from the central lobby. The south wing was completed soon afterwards, containing the kitchen, bathroom, main entrance, and majlis on both the ground floor and the upper floor, where an additional family room was built above the majlis. Later, a simpler L-shaped wing was added along the original western and northern boundaries. Although built to a lower standard than the rest of the house, it included two living rooms on the western side, a storeroom along the north, and a

separate women's entrance at the northeast corner of the courtyard. Masonry columns along the roof once supported areesh screens in this section, but these were destroyed in the fire of 1940, which did not reach the main house.In 1945, after Mohammed Sharif acquired the western strip of land, the western and northern wings were rebuilt and expanded. Two long, narrow storerooms with external access were added along the western edge, and the western rooms were rebuilt into five stores opening onto a new verandah. The northern room was shortened, and its walls were decorated, while a ladder was installed in the northeast corner leading up to a shaded rooftop area. The upper floor of the western wing was never completed, and the wind tower above the northwest bedroom remained unrendered.

Figure 26

House of Mohammed Sharif Bukhash



Note. Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing

That bedroom had been intended for Mohammed's elderly parents. He died in 1947 before it could be completed. Even so, the room remained cool and pleasant, fully open to the summer afternoon breeze. This was made possible because Mohammed had also purchased the adjoining plot to the north from Sheikh Saeed, keeping it undeveloped. He later enclosed that land to keep the family's goats and chickens.The most striking part of the house was its façade: a steady rhythm of tall, shuttered majlis windows running across both floors, clearly expressing the building's structure. This rhythm led to a graceful entrance porch, topped by the windows of a small summer room.

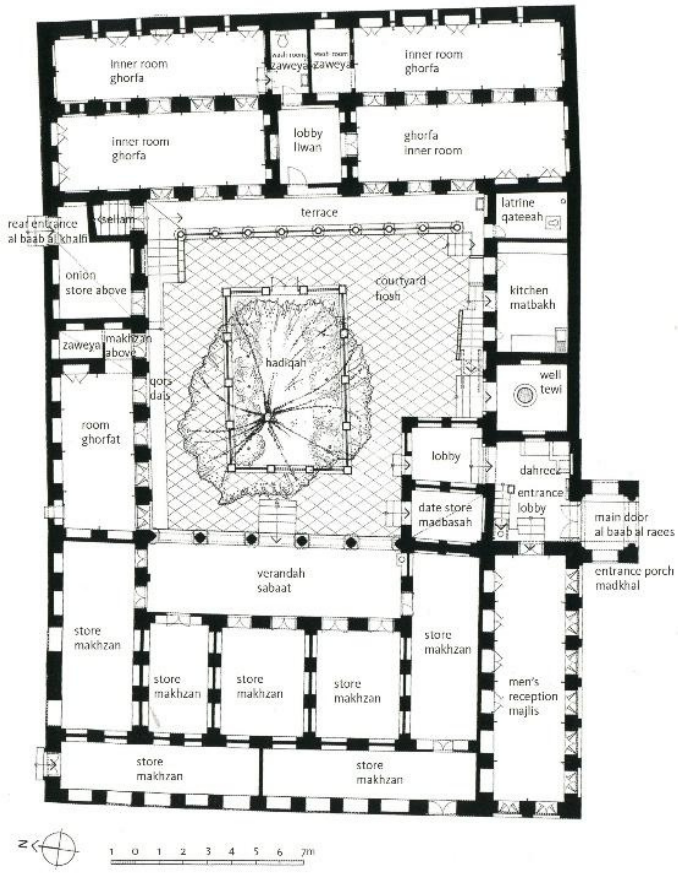
The three wind towers each had their own character. The one at the southeast corner was a fairly standard example for the area, rising 6.3 m above the roof. Its vent was divided into three bays and topped with a floral crown of overlapping circles. The northeast tower, above Mohammed's summer room, was larger, rising 7.5 m, with six narrow openings per vent and a finer, more delicate version of the same floral crown. Both towers had curved, chamfered corners where the base met the vents and again at the cornice, tying their different designs together and breaking the symmetry of the courtyard elevation below. The third tower, at the northwest corner, appeared taller than the others only because it stood on a higher part of the roof. It was actually the same height as the southeast tower, although about 1 m narrower, with its width likely determined by the size of the additional land acquired for the western wing.

Distribution

The analysis of the Bukhash House reveals several spatial and functional design principles that characterize the organization and distribution of traditional Emirati houses. The main observations are summarized below.

Figure 27.

Ground Floor Plan

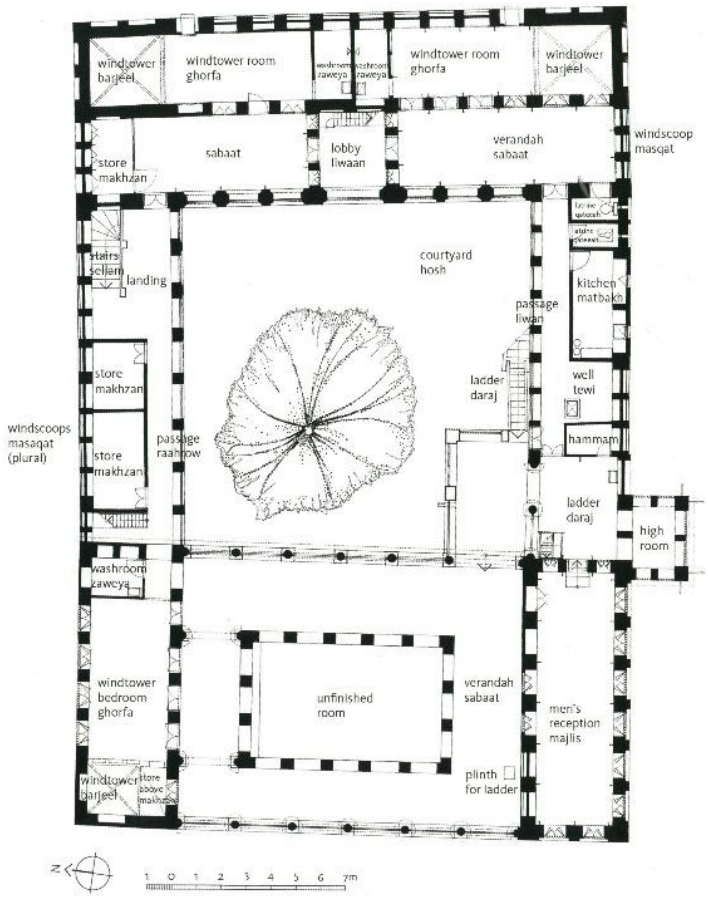


Note. Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing

- The sequence of the entrance and lobby establishes a privacy buffer by obstructing direct views into the courtyard while facilitating efficient distribution between the public social zones (*majlis*) and the private residential areas.

Figure 28.

First Floor Plan

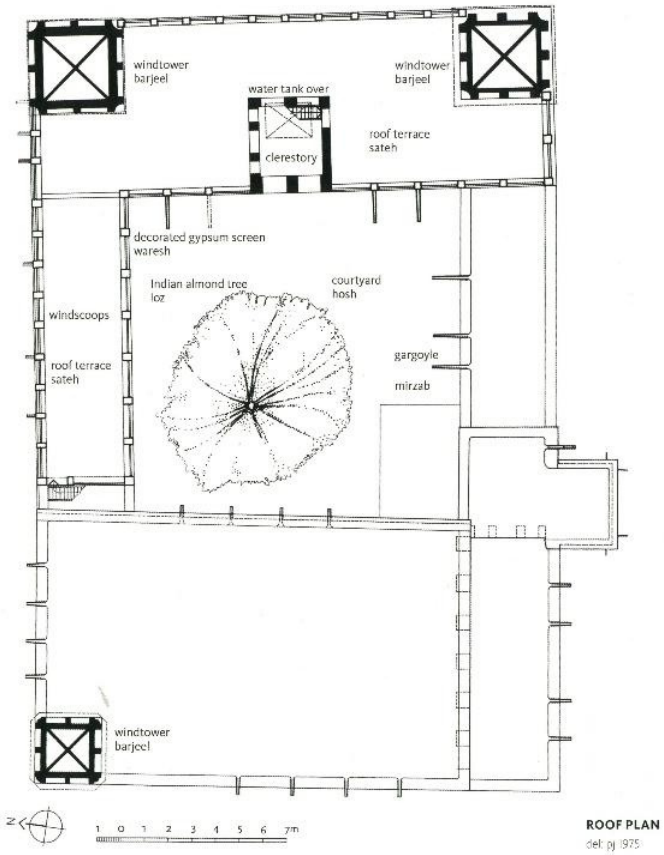


Note. Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing

- Vertical connectivity via a ladder from the courtyard enhances accessibility and spatial flexibility, particularly for reaching the shaded terraces and rooftop areas. A large number of storage units (*makhzan*) are located along the perimeter. Storage units with external entrances support residents economically through commercial use, while others are used for domestic food preservation

Figure 29

Roof Plan



Note. Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing

- Some ground-floor rooms (winter rooms) do not have direct openings to the outside; instead, they open into another room, providing greater privacy.The height difference between the courtyard and the surrounding rooms establishes a spatial hierarchy, reinforcing the courtyard's role as the secluded central core of the house.The first-floor verandahs provide shaded spaces for residents and children during their seasonal move to the upper level, offering both shade and natural ventilation.

- The kitchen is centrally positioned, serving as a connection between the primary living area and the *majlis*.
- Lowering the washroom ceiling created additional space for a small mezzanine storage area, a maintenance zone for the water systems, and structural support.

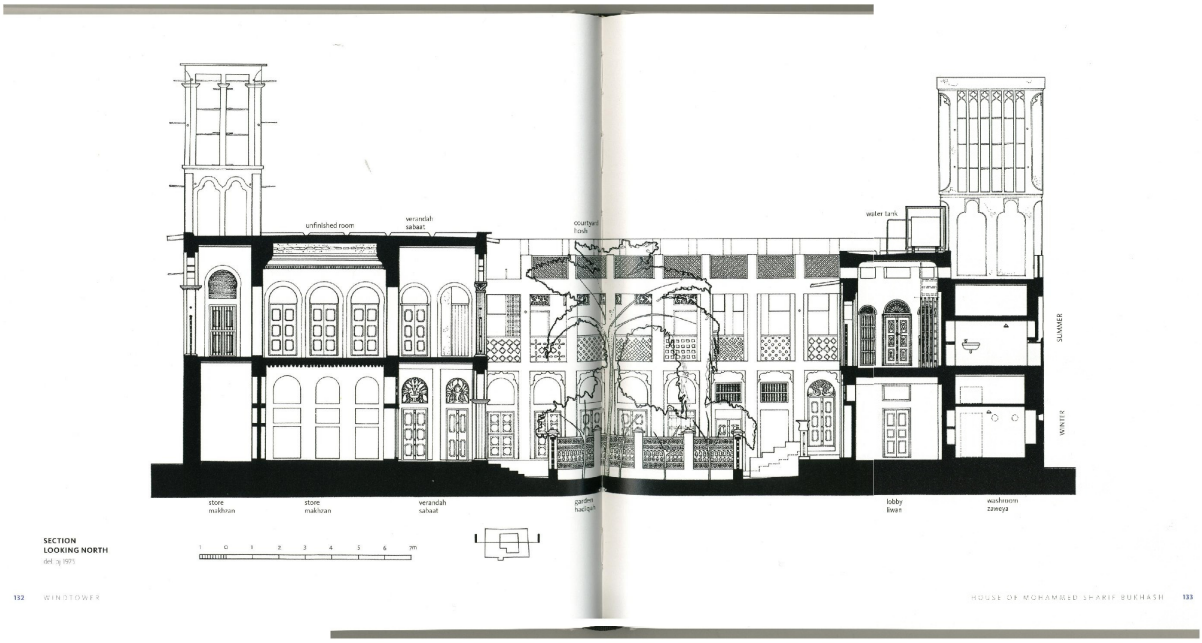
Energy Strategies

The Bukhash House incorporates a range of passive energy strategies that respond to the hot arid climate while improving thermal comfort and reducing the need for mechanical cooling. The main observations are summarized below.

- The ground- and first-floor verandahs provide shaded, ventilated semi-outdoor living areas that significantly improve thermal comfort during the hot season.
- A large number of storage units (makhzan) along the perimeter serve as thermal buffers, insulating the interior living spaces from external heat. This configuration is particularly important for controlling the impact of direct sunlight on the western façade.
- Small, high-level openings on the western façade are designed to minimize solar heat gain while still providing essential ventilation and natural light for the storage rooms.
- By situating the courtyard slightly below ground level, the design encourages the accumulation of cooler air, thereby enhancing the efficiency of passive cooling.
- The ground-floor layout prioritizes thermal mass and enclosure, creating a stable environment suitable for occupation during the cooler months.
- While mirroring the ground-floor plan, the first floor is climatically optimized for summer use through increased openness and enhanced airflow.

Figure 30.

Section Looking North



*Note.*Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing

- The central garden within the courtyard facilitates shading and microclimatic cooling through evapotranspiration. While a traditional water basin would provide more intensive evaporative cooling, it involves higher resource and maintenance demands.
- Ground-floor winter rooms are intentionally inward-facing with limited openings to reduce heat loss. This prioritizes thermal stability, although it results in lower levels of daylight and ventilation.
- Small wall openings on the eastern and western façades of the winter rooms allow gentle, controlled airflow without causing significant drafts or heat loss.

- The reduced ceiling height and internal voids in the washrooms optimize ventilation to extract moisture. This prevents potential rot in the wooden beams and protects the porous coral stone walls from dampness and seepage.
- To remain cool during the day and retain warmth during winter nights, the ground-floor winter rooms have high thermal mass and lowered ceilings.
- Summer rooms are designed with increased porosity, featuring higher ceilings and more frequent openings to facilitate maximum airflow and leverage the cooler air at the lower levels of the space.

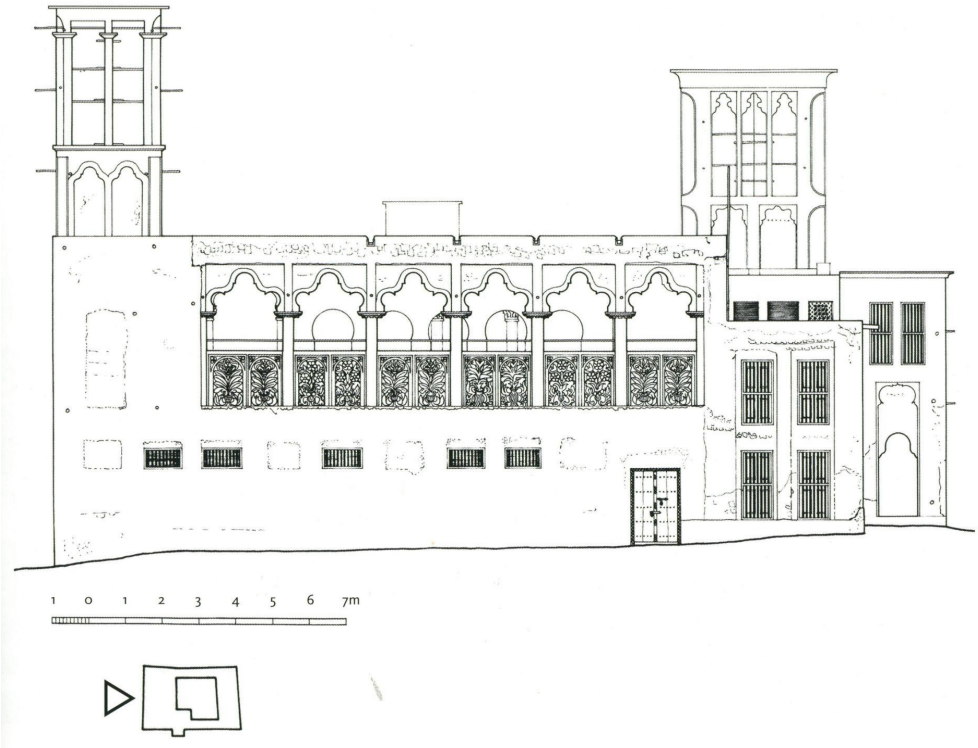
Architectural Form

The architectural form of the Bukhash House reflects both functional and aesthetic considerations, combining climatic adaptation with traditional Emirati architectural expression. The main observations are summarized below:

- The external façades maintain a sense of solid enclosure, with openings restricted to the majlis windows and the functional integration of wind scoops and parapet vents (Figure 31).
- Upper-level verandahs and roof perimeters feature balustrades composed of gypsum or timber lattice screens. These elements utilize repetitive geometric motifs, including square or triangular cut-outs and simplified vertical bars.The verandahs are defined by repetitive columns connected by ornamental, non-structural Islamic arches. These gypsum elements function as a delicate decorative frame for the outdoor living spaces.
- Openings overlooking the central courtyard are predominantly rectangular and are frequently surmounted by semicircular decorative panels. These configurations incorporate lattice screens or secondary rectangular apertures dedicated to ventilation.

Figure 31.

West Elevation



*Note.*Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing

- In accordance with the formal nature of the space, the majlis windows maintain a consistent rectangular geometry.
- Internal wall surfaces are articulated with a series of rectangular and semicircular niches (Figure 33). These features often incorporate decorative artwork, rectangular doors, and, in certain cases, semicircular polychromatic glass panels with decorative patterns positioned above them (Figure 32).
- Some rooms incorporate small, square lattice screens positioned in the upper portions of the walls (Figure 33).

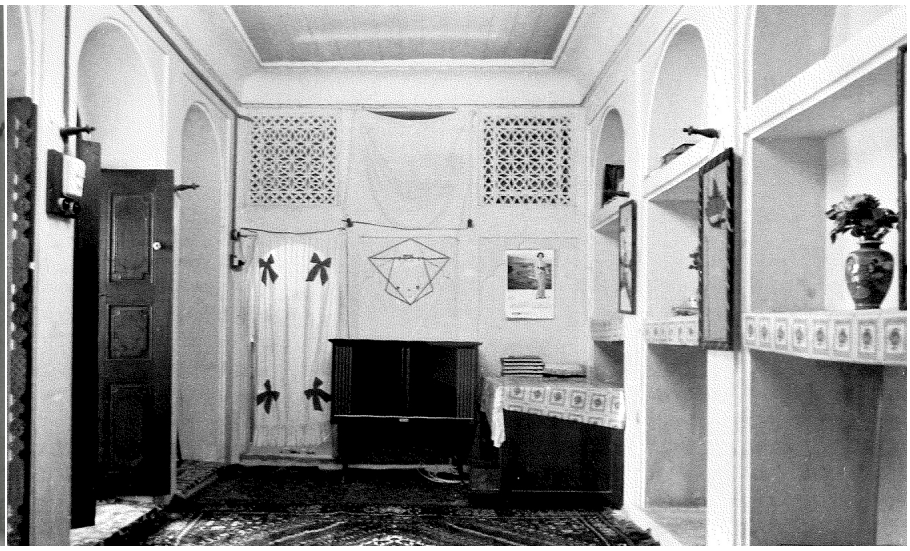
Figure 32

Finely carved hardwood panelled doors with arched fanlights of stained glass



Figure 33

Bedroom with niches and storage area behind the screened mezzanine



*Note.*Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing

- Consistent with traditional wind-tower houses, the structures feature flat roofs.
- The ceilings are constructed of timber beams.
- The large-scale main entrance door, typically reserved for formal events and festivals, incorporates a smaller pedestrian door embedded within its framework to accommodate daily use.
- The entrance porch (madkhal) is recessed from the street alignment, establishing a cooler transition zone between the public and private residential areas.
- Simple gargoyles project from the roof toward the courtyard and the external façade to direct rainwater away from the structure.

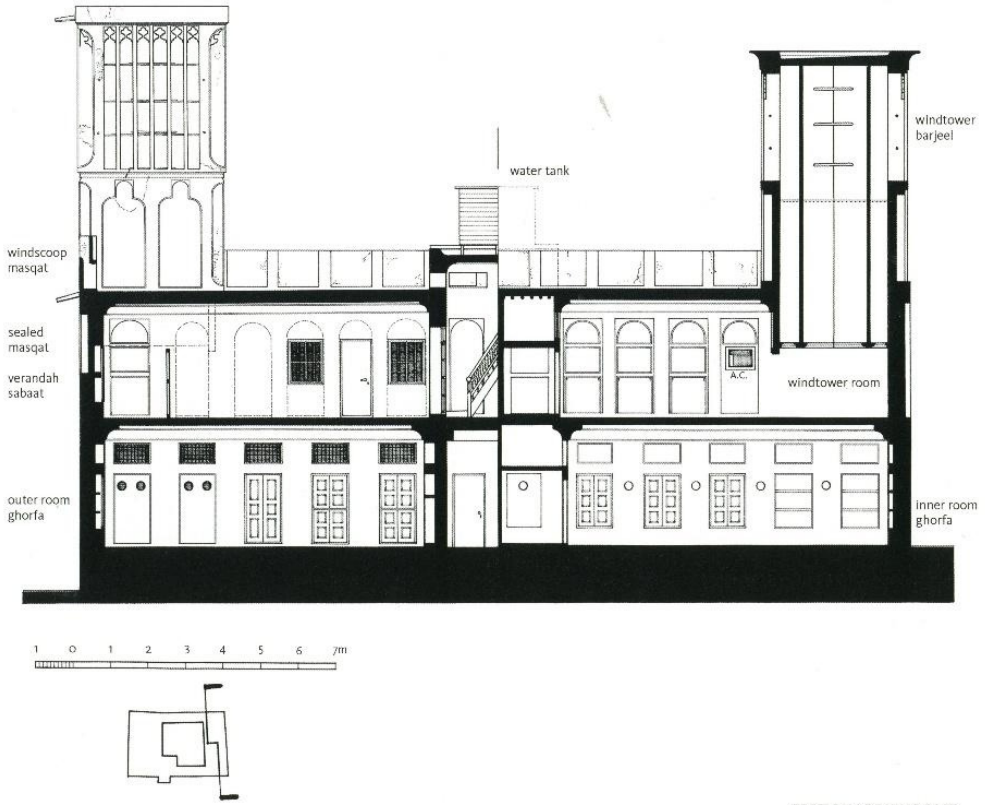
Wind Towers' Form

The wind towers of the Bukhash House combine functional and decorative features, serving both environmental and architectural purposes. The main observations are summarized below:

- Wind towers function as the dominant vertical elements, contrasting with the horizontal expanse of the main building.
- The upper sections of the wind towers feature more detailed openings and structural divisions, creating a decorative crown for the building.
- Below the main air shafts, a series of rectangular or arched niches adds decorative texture to the roof level, continuing the façade patterns. These arches often feature pointed or ogee forms common in Islamic architecture.
- The three wind towers exhibit distinct variations in scale and ornamentation. The southeastern tower represents a standard Bastakiya design, measuring 6.3 m above the roof level. Its vent is divided into three bays, each surmounted by a floral crown of intersecting circles.
- The northeastern wind tower, positioned above the summer room, rises 7.5 m above the roof level. This larger structure features six narrow openings per vent, capped with a smaller and more delicate version of the same floral motif.
- On both towers, pronounced corner chamfers curve outward to meet the horizontal bands at the base, the vent junctions, and the cornices, visually unifying the different designs.
- Within the overall architectural composition, the wind towers interrupt the otherwise symmetrical balance of the classically proportioned courtyard elevations below.

Figure 34

Section Looking East



Note. Reprinted from *Windtower: The Merchant Houses of Dubai,* by P. Jackson & A. Coles, 2022, Medina Publishing.

- The northwestern tower appears to be the tallest element; however, this is an optical illusion. It is the same height (6.3 m) as the southeastern tower but rises from a higher roof level. Additionally, it is 1.0 m narrower.

Wind Tower Orientation in Al Bastakiya

The orientation of most wind towers in Al Bastakiya coincides with the prevailing northwestern afternoon sea breeze. The towers have openings facing approximately north,

south, east, and west, optimally exposing their diagonal orientation to this breeze. However, this orientation may also have resulted from the fact that the houses were generally aligned with Dubai Creek. While wind towers in the Dubai and Deira souks are similarly oriented, this pattern does not apply in Al Shindagha.

With different wind directions, it was observed that whenever nearby wind towers on adjacent houses were located upstream of one of the towers under study, the neighbouring tower disrupted the airflow to the downstream tower in its lee, effectively "stealing" its wind and reducing its performance.

When the wind came from the northwest, two openings of the wind tower acted as air inlets, while the other two served as exhausts. This increased the volume of air entering the room and, consequently, improved thermal comfort. With all the windows closed, the increased airflow, together with the balance between the positive pressure in the inlet openings and the negative pressure in the outlet openings, ensured very good air movement immediately beneath the wind tower. Indoor air velocity directly below the tower was measured to be 1.7 times greater than the outdoor air velocity at roof level.

The orientation of the room in relation to the position of the wind tower and the direction of the prevailing wind was also shown to be important. For example, when the wind came from the north and the long axis of the room was oriented north–south, good ventilation was achieved. However, if the room was oriented east–west under the same wind conditions, ventilation became less effective. This occurred because the descending air struck the interior wall before spreading into the room, thereby reducing its momentum.

Generally, air circulation immediately beneath the wind tower was greatest when all external openings remained closed. However, when the external openings and courtyard-facing doors were opened, the airflow was distributed more evenly throughout the room. Approximately half of the incoming air circulated around the room, while some escaped into the courtyard and the remainder was drawn back up through the wind tower.

The calculations showed that good thermal comfort could be maintained beneath a wind tower for occupants who were seated rather than physically active. Conditions further into the rooms were more variable, less comfortable, and at times moderately stressful. Nevertheless, there was no doubt that the wind towers were effective in reducing the impact of the summer climate. Based on the authors' study, thermal comfort depended more on wind speed than on air temperature. Similarly, increasing air movement by opening external windows or wind scoops significantly reduced the discomfort otherwise experienced in a wind-tower room after midday.

Wind towers can make an important contribution to improving thermal comfort in both humid and dry hot climates and continue to do so today. In a world where energy conservation is becoming increasingly important, passive systems based on natural ventilation offer a valuable and sustainable alternative to mechanical cooling.

3. Contemporary Residential Architecture in the UAE



3. Contemporary Residential Architecture in the UAE

As discussed in the previous chapter, the discovery of petroleum and the subsequent construction boom significantly transformed the urban development patterns of the UAE.

Following the discovery of petroleum in the 1960s, the UAE underwent rapid modernization that significantly transformed its urban fabric. Influenced by Western planning ideals and accelerated by the construction boom, traditional settlements were progressively replaced by concrete villas, high-rise towers, and master-planned residential districts, reshaping both urban morphology and socio-cultural practices. This chapter specifically focuses on villas located within contemporary residential compounds.

3.1 Urban Morphology of Contemporary Residential Compounds

Contemporary urban expansion in the UAE often follows linear planning strategies characterized by wide road networks, repetitive plot divisions, and segregated zoning systems. Residential compounds are typically organized along major vehicular corridors, where rows of detached villas are distributed in a highly ordered and repetitive pattern.

Figure 38

Linear distribution of the repetitive villa plots in Jumeirah Park



Note. Adapted from Nad Al Sheba 1 – Community & Area Guide by Driven Properties, n.d.

The city's infrastructure is further fragmented by extensive highways that act as physical barriers between compounds, rendering each enclave spatially and socially isolated rather than economically and socially interconnected. Unlike the compact and organically clustered structure of traditional Emirati settlements, which responded closely to climate, pedestrian movement, and social interaction, these modern layouts prioritize vehicular accessibility and infrastructural efficiency over community cohesion (Elsheshtawy, 2010).

3.2 Villas in Contemporary Residential Compounds

A clear example of this planning approach can be observed in developments such as Jumeirah Park (Figure 38), which follows a master-planned structure based on hierarchical road systems and repetitive villa plots.

Figure 39

Repetitive villas in Jumeirah Park



Note. "Areas to Buy Villas in Jumeirah Park," n.d.

Such developments demonstrate a broader tendency toward architectural homogenization and the erosion of local identity through the widespread adoption of international and suburban design languages. Consequently, the spontaneous social and economic interactions that once characterized traditional Emirati neighborhoods are largely absent from these contemporary residential developments.

Architectural elements such as inclined roofs and decorative façades (Figure 39) are frequently implemented despite being climatically unnecessary in a hot arid environment and incompatible with the socio-cultural context. Standardized residential villa typologies are replicated across large areas with limited adaptation to the cultural context, environmental performance, or the evolving needs of residents (Figure 38).

While these developments provide privacy and controlled residential environments, they also reduce architectural diversity and limit opportunities for incremental growth, customization, and long-term spatial evolution. Unlike traditional settlements, where housing evolved incrementally in response to family structure and environmental conditions, contemporary compounds offer limited capacity for customization or long-term spatial evolution (Alawadi, 2017; Bianca, 2000). Furthermore, these residential models rely predominantly on active cooling and ventilation systems, while passive environmental strategies remain insufficiently integrated. The materials used in construction also contribute to significant environmental impacts and high carbon footprints.

3.2 Summary

Overall, contemporary residential development in the UAE represents a significant departure from the principles that once defined traditional Emirati architecture and urbanism. Driven by rapid modernization, Western planning ideals, and globalized design practices, the built environment has shifted toward standardized, vehicle-oriented compounds that prioritize efficiency and privacy over social connectivity, cultural continuity, and environmental responsiveness. The erosion of traditional architectural identity, evident in the uncritical adoption of climatically inappropriate elements, repetitive villa typologies (Figure 39), and the physical fragmentation of urban space, reflects a broader disconnect between contemporary buildings and the local cultural, climatic, and social context.

As a result, residential compounds in the UAE increasingly lack the adaptive capacity, user identity, spatial flexibility for expansion, and communal vitality that characterized the organic settlements of the past. These observations provide the foundation for a deeper

investigation into how architectural design at the villa scale can begin to reintegrate traditional principles within a contemporary framework.

4. House of the Future Competition

4. House of the Future Competition

The House of the Future competition provides the practical framework within which the architectural proposal developed in this thesis is situated. Organised in the United Arab Emirates, the competition encourages innovative residential designs that respond to contemporary environmental challenges while promoting energy efficiency, low-carbon construction, and high standards of living. By establishing clear sustainability objectives and performance requirements, it offers an appropriate context for exploring how traditional Emirati architectural principles can be reinterpreted within a contemporary residential design. This chapter introduces the competition, reviews the winning proposals, and analyses the design approaches that informed the development of the project presented in this thesis.

4.1 Competition Winners (2023/24 and 2024/25)

The competition has attracted proposals from multidisciplinary teams worldwide, resulting in a diverse range of architectural responses to the challenges of sustainable housing in the UAE. Examining the winning projects provides insight into current design trends, recurring strategies, and innovative approaches to climate-responsive residential architecture. These projects serve as valuable precedents for understanding how the competition objectives have been translated into built design proposals.

4.2 Evaluation Criteria

To better understand the architectural responses encouraged by the competition, the winning proposals are analysed according to their spatial organisation, environmental strategies, material choices, and passive design solutions. The analysis identifies recurring

design principles and evaluates how each project addresses the competition's sustainability objectives.

Highly Applicable

→ The strategy is coherent with my thesis objectives (passive systems, climate responsiveness, cultural integration) and can be directly adapted or reinterpreted in your project.

Conditionally Applicable

→ The idea has value, but depends on specific factors (climate, scale, technology, socio-cultural context). It may require modification before integration.

Not Applicable

→ The solution conflicts with my design goals, climate logic, or construction constraints, or relies on assumptions irrelevant to your project context.

4.3 Analysis of the Winning Projects

4.3.1 Winning Projects 2023/24

The following section examines the winning proposals from the 2023/24 edition of the competition. Each project is briefly analysed with particular attention to its architectural concept, passive environmental strategies, and integration of low-carbon design principles.

AL DARA - 1st place winner

Al Dara: Harnessing Heritage for a Sustainable Future, designed by Mohamed Al Mufti, Souaid Georges, and Natalie Elmir (Lebanon), was selected as one of the winning

proposals in the 2023/24 House of the Future Competition.The proposal draws inspiration from traditional Emirati architecture by integrating courtyards, wind towers, water elements, and compact building volumes into a contemporary residential design. Rather than replicating vernacular forms, it adapts their environmental and spatial principles to create a low-carbon, climate-responsive dwelling that responds to the climatic and cultural conditions of the UAE.

Figure 40

Front view of Al Dara project: Harnessing Heritage for a Sustainable Future proposal.



Note. Reprinted from *Al Dara: Harnessing Heritage for a Sustainable Future*, by M. Al Mufti, S. Georges, & N. Elmir, House of the Future Competition 2023/24.

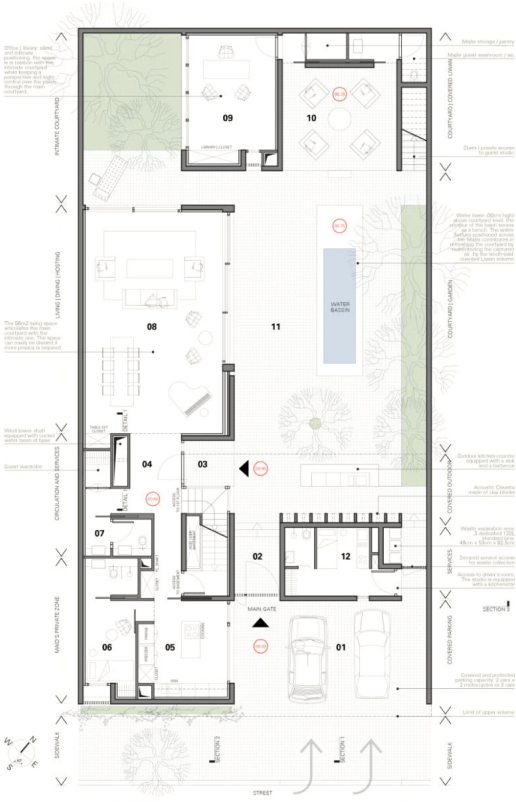
Distribution

- The living area is designed to extend and integrate with the courtyard.
- The courtyard offers a versatile, open space designed for both recreational activities and children's leisure.
- The external kitchen is highly functional, positioned separately from the main kitchen and incorporating dedicated storage and shading.

- The architectural layout ensures that all spaces are highly accessible.
- A supplemental kitchenette is integrated into the first floor to enhance the convenience and daily autonomy of the residents.

Figure 41

Ground floor plan showing the spatial organization of the proposal.

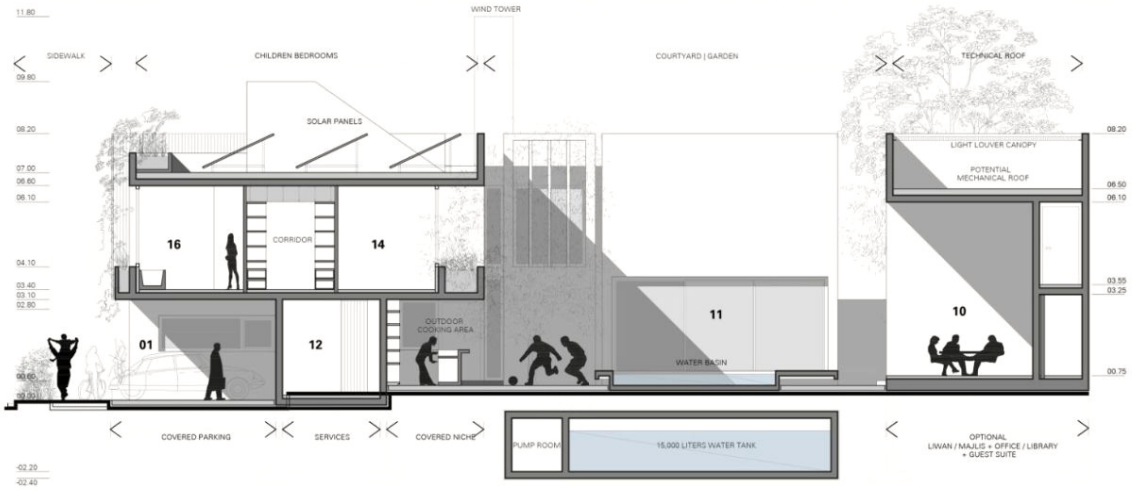


Note. Adapted from *Al Dara: Harnessing Heritage for a Sustainable Future*, by M. Al Mufti, S. Georges, and N. Elmir, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

- The orientation of the *majlis* toward the internal courtyard may potentially compromise the privacy of the residents.

Figure 42

Longitudinal section illustrating the relationship between interior spaces, the courtyard, and passive environmental systems.



Note. Adapted from *Al Dara: Harnessing Heritage for a Sustainable Future*, by M. Al Mufti, S. Georges, and N. Elmir, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

- The exclusive exterior placement of the *majlis* renders the space underutilized during adverse weather conditions.

Link with Tradition

- The design incorporates water features and a windtower, representing the fundamental elements of traditional housing.
- Openable shutters function as modern *mashrabiya* screens to ensure privacy while providing functional flexibility.

- The inclusion of a large-scale courtyard aligns with the most common organizational strategies found in traditional housing.

Figure 43

Central courtyard as the primary climatic and social space of the proposal.



Note. Adapted from *Al Dara: Harnessing Heritage for a Sustainable Future*, by M. Al Mufti, S. Georges, and N. Elmir, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

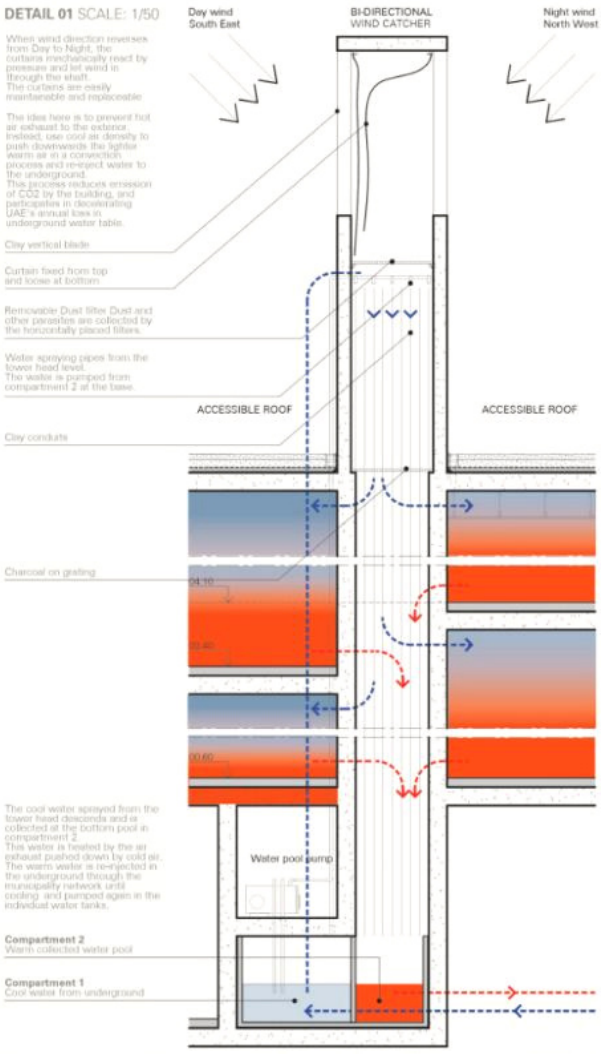
Energy Strategies

- A water basin is placed in the courtyard to naturally cool the air and make the immediate surroundings feel more refreshed.

- The windtower utilizes cooling mechanisms to enhance natural ventilation and cooling.

Figure 44

Passive ventilation strategy based on the wind catcher and water-cooling system.



Note. Adapted from *Al Dara: Harnessing Heritage for a Sustainable Future*, by M. Al Mufti, S. Georges, and N. Elmir, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

- Photovoltaic panels are implemented to mitigate operational CO2 emissions and overall energy demand.

- Vessels filled with sand and vegetation are positioned against sun-exposed surfaces to increase thermal mass and provide shading, serving as a high-efficiency passive cooling strategy.
- An underground water tank is included for the efficient storage and management of water resources.
- Openings ensure that all habitable rooms are well-lit and ventilated via large, shaded openings.
- The inclusion of roof gardens enhances the building's thermal regulation while simultaneously reducing its ecological footprint.

Technology and Materials

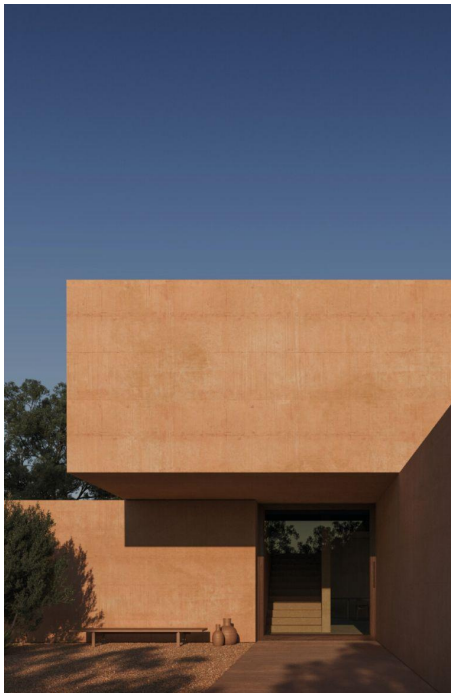
- Most of the construction depends on concrete and other materials with high embodied carbon.

Block Yard - 2nd place winner

Block Yard, designed by Andrea Baldo, Angelo Emilio Brollo, and Gino Leonardo Brollo (Spain), received the Second Prize in the 2023/24 House of the Future Competition. The proposal reinterprets traditional Emirati architecture through a monolithic rammed-earth form organized around courtyards and natural light. Its design emphasizes flexibility, passive environmental performance, and the use of low-impact materials to create a contemporary climate-responsive dwelling.

Figure 45

Exterior perspective of the Block Yard proposal.



Note. Adapted from *Block Yard*, by A. Baldo, A. E. Brollo, and G. L. Brollo, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

Distribution:

- The bedrooms are designed as modular components, allowing for straightforward building expansion if required.
- Placing the structures centrally allows the side pathways to function as effective buffer zones.
- The layout includes several shaded outdoor areas, which are the most practical solution for this specific climate.

Figure 46

Ground and first floor plans illustrating the spatial organization of the proposal.

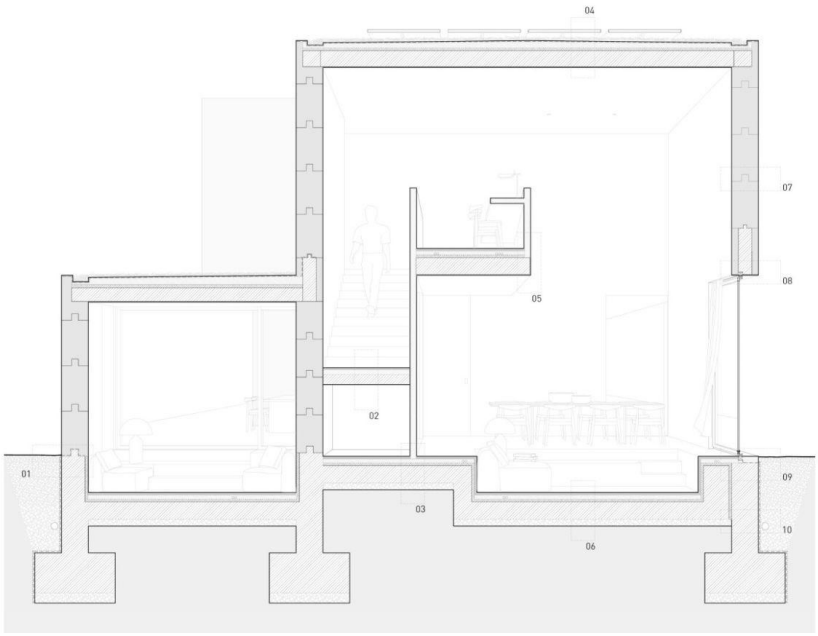


Note. Adapted from *Block Yard*, by A. Baldo, A. E. Brollo, and G. L. Brollo, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

- A study area overlooks the living room, allowing for a connection between workspace and social areas.
- The water basin is located in a courtyard that is used less frequently than the one situated near the kitchen.

Figure 47

Perspective section showing the relationship between interior spaces, and the building envelope.



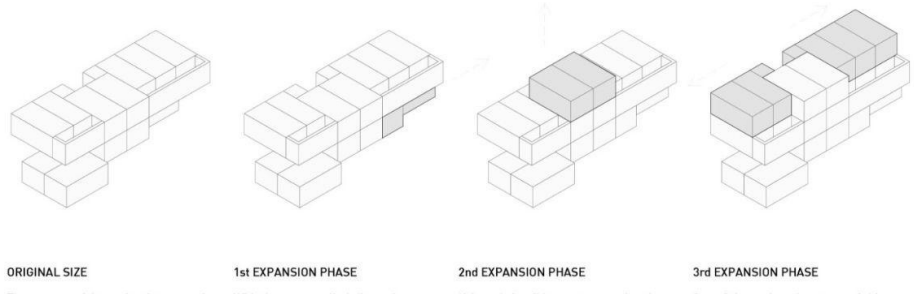
Note. Adapted from *Block Yard*, by A. Baldo, A. E. Brollo, and G. L. Brollo, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

Link with Tradition

- The inclusion of a conversation pit in the *majlis* references traditional floor-level seating arrangements.
- The modules are customizable based on the family size, creating diversity and individual identities on a neighbourhood scale.
- Utilizing rammed earth directly connects the project to the material choice of traditional regional architecture.

Figure 48

Modular expansion strategy illustrating the adaptability of the proposal over time.



Note. Adapted from *Block Yard*, by A. Baldo, A. E. Brollo, and G. L. Brollo, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the authors.

- The inclusion of water features follows the established functional and aesthetic patterns of traditional houses.

Energy Strategies

- A water basin is placed in the courtyard to naturally cool the air and make the immediate surroundings feel more refreshed.
- The conversation pit increases thermal comfort because cooler air naturally settles at the floor level.
- Photovoltaic panels are implemented to mitigate operational CO2 emissions and energy demand.
- Thick earth walls provide high thermal mass to store coolness within the structure.

- Double-height spaces are used across different levels to create a chimney effect, which drives natural ventilation and cooling.
- First-floor bedrooms are designed without shading, not obstructed to direct sunlight.
- The solid walls of the first-floor balconies lack openings, which intentionally limits the natural light entering the bedrooms.

Technology and Materials:

- The primary construction material is locally produced, natural rammed earth blocks, which lowers the total embodied carbon of the building.

Dune house - 3rd place winner

Dune House, designed by Thomas William Ewing (United Kingdom), received Third Prize in the 2023/24 House of the Future Competition. The proposal combines traditional Emirati architectural principles with contemporary low-carbon construction methods, emphasizing passive environmental design, locally sourced materials, and self-sufficient building systems. Drawing inspiration from the desert landscape and vernacular architecture, the project seeks to create a climate-responsive family home adapted to the environmental conditions of the UAE.

Distribution:

- While the inclusion of walk-in closets in the bedrooms provides utility, replacing the solid partitions with transparent dividers would improve spatial flow.

- The external kitchen is designed as a highly enclosed space, which mimics the interior kitchen and limits its practical utility as an outdoor facility.
- There is a lack of direct connectivity between the parking area and the primary residence or central courtyard.
- The space program does not include a dedicated driver's room.

Figure 49

Exterior perspective of the Dune House proposal.



Note. Adapted from *Dune House*, by T. W. Ewing, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the author.

Figure 50

Ground and first floor plans illustrating the spatial organization of the proposal.



Note. Adapted from *Dune House*, by T. W. Ewing, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the author.

- Accessing the bathroom through the walk-in closet in specific rooms creates a typological continuity, though it presents certain practical challenges for the user.

Link with Tradition:

- The *nakhle* pattern is applied throughout the facades and interior spaces, serving as both a decorative element and a functional tool for privacy and light filtration.
- The design omits the use of traditional water features.
- Unlike in traditional vernacular architecture, the windtower or "windcatcher" is not treated as a primary or essential component of the building’s identity.

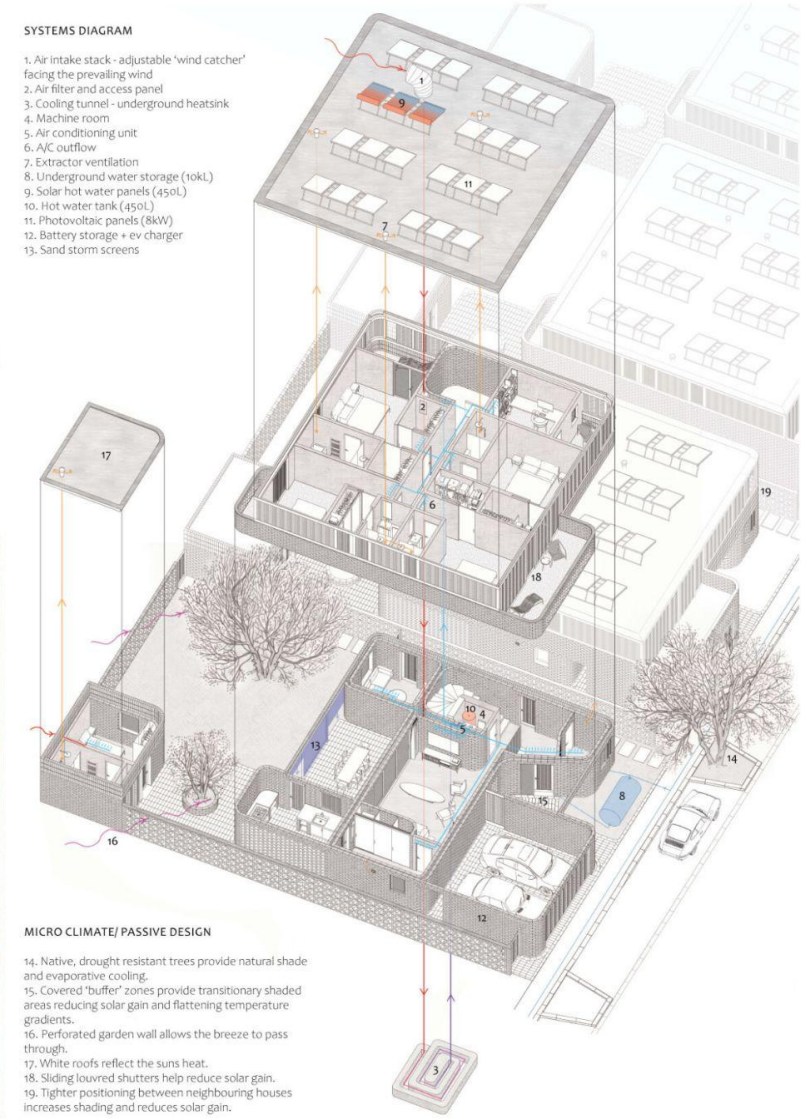
- While the material selection is notable, the use of bricks lends the project a European aesthetic rather than reflecting a traditional Arabic residential character.

Energy Strategies:

- An underground water storage is included for the efficient storage and management of water resources.
- The project utilizes both thermal and photovoltaic solar panels for energy generation.
- Electric vehicle (EV) charging stations are incorporated into the infrastructure.
- The garden utilizes a combination of aggregates and greenery to mitigate solar radiation and reduce heat absorption.
- Thermal mass is utilized as a core strategy for natural cooling.
- The perforated garden wall facilitates airflow through the site, though it slightly reduces the visual privacy of the courtyard.
- The windtower provides minimal performance due to its low height, limited opening area, and unidirectional orientation.
- The restricted size and quantity of openings, combined with low-transparency shading, result in inadequate natural lighting and ventilation, thereby increasing reliance on mechanical systems. Small amount and restricted size of openings combined with low transparency shading causing poor lighting and ventilation, increasing the need to compensate using energy.

Figure 51

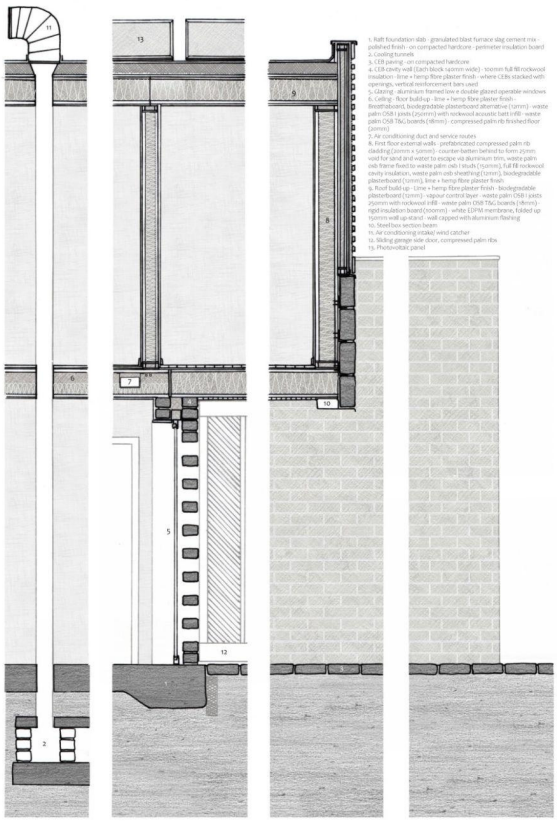
Building systems diagram illustrating passive environmental strategies and integrated low-carbon technologies.



Note. Adapted from *Dune House*, by T. W. Ewing, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the author.

Figure 52

Wall construction details illustrating the use of compressed earth blocks and bio-based materials.



Note. Adapted from *Dune House*, by T. W. Ewing, House of the Future Competition 2023/24, Buildner. Copyright 2024 by the author.

Technology and Materials:

- Recycled palm wood is integrated into the cladding and timber framing, aiding in the overall reduction of the building's carbon footprint.
- The primary wall construction utilizes Compressed Earth Blocks (CEB), which are produced using local materials and a hydraulic press rather than kiln-firing. This

method significantly reduces both the embodied and operational carbon associated with the project.

4.3.2 Winning Projects 2024/25

House of Courts - 1st place winner

House of Courts, designed by Hamzeh Ahmad Hasan Al-thweib and Luzia Magdalena Stallmann (Jordan), received First Prize in the 2024/25 House of the Future Competition. The proposal organizes the dwelling around a central circulation spine and a sequence of courtyards, combining privacy and multigenerational flexibility with access to landscaped outdoor spaces. Traditional environmental elements, including wind catchers, mashrabiya screens, and thermal mass, are reinterpreted through contemporary forms and integrated with circular construction, passive cooling, and decentralized energy and water systems.

Figure 53

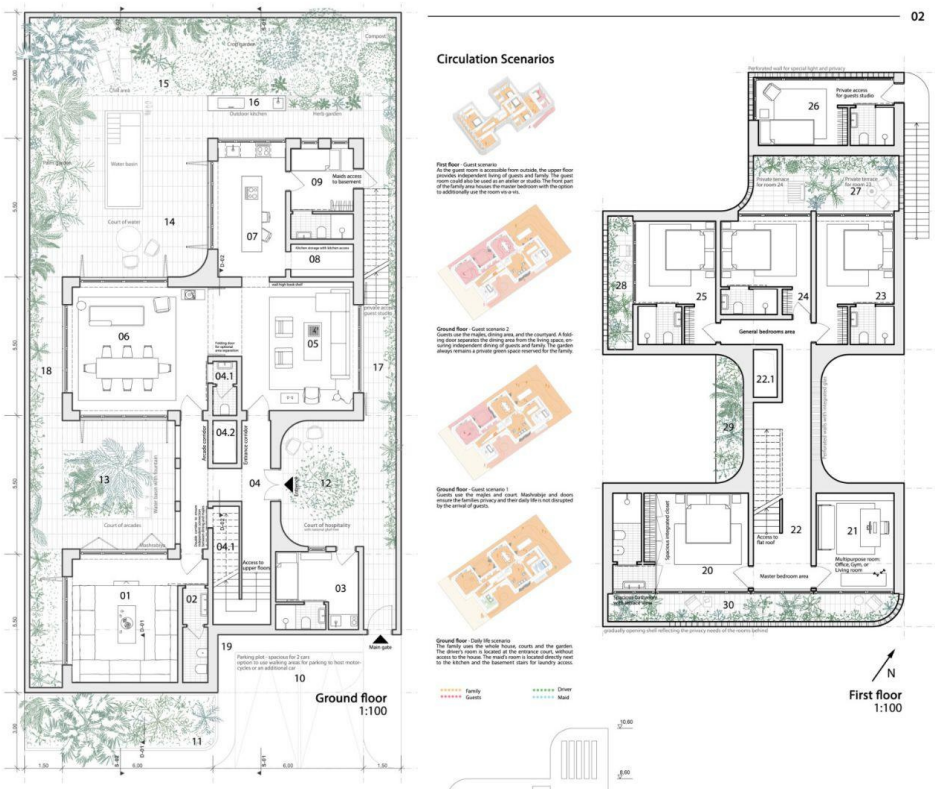
Exterior perspective of the House of Courts proposal.



Note. Adapted from *House of Courts*, by H. A. H. Al-thweib and L. M. Stallmann, House of the Future Competition 2024/25, Buildner.

Figure 54

Ground and first floor plans illustrating the organization of the dwelling around a central circulation spine and multiple courtyards.



Note. Adapted from *House of Courts*, by H. A. H. Al-thweib and L. M. Stallmann, House of the Future Competition 2024/25, Buildner.

Distribution:

- A series of courtyards serves to define the transitions between semi-public and private realms, establishing clear spatial thresholds throughout the plan.
- The layout establishes a direct spatial connection between the *majlis* and the dining area, facilitating the flow required for guests.

- The design incorporates the 3-meter rear buffer zone into the private courtyard to maximize usable outdoor space.
- The residence is bifurcated into two distinct wings, private and guest, separated by a central main entrance.
- The primary entrance is strategically positioned to provide direct and private access to the main functional areas of the home.
- An external staircase serves the guest room, allowing for a clear functional separation from the private areas.
- The water basin is designed as a swimmable feature to enhance the leisure utility for the residents.
- Building volumes are placed centrally on the site, utilizing the lateral pathways as buffer zones.
- The guest rooms are oriented toward the private residential area rather than being integrated with the semi-public zones.
- Most interior spaces overlook garden areas, improving the overall spatial comfort of the residential.
- The living area is secluded from the primary private courtyard.

Link with Tradition:

- The inclusion of a conversation pit in the *majlis* references traditional floor-level seating arrangements.

Figure 55

Relationship between the majlis and landscaped courtyard, illustrating the integration of indoor and outdoor spaces.



Note. Adapted from *House of Courts*, by H. A. H. Al-thweib and L. M. Stallmann, House of the Future Competition 2024/25, Buildner.

- The design incorporates water features and a wind tower, representing the fundamental elements of traditional housing.
- The use of an external staircase for guest access aligns with practices common with traditional housing.
- The modular units allow for customization according to family size, fostering architectural diversity and individual identities at the neighborhood scale.
- The units are organized in a cellular arrangement, mirroring the urban grain of traditional settlements.

- Privacy is maintained through the strategic use of multiple courtyards, shielding residents from both guests and neighboring properties.
- The facade's transparency and void patterns deviate from traditional norms.

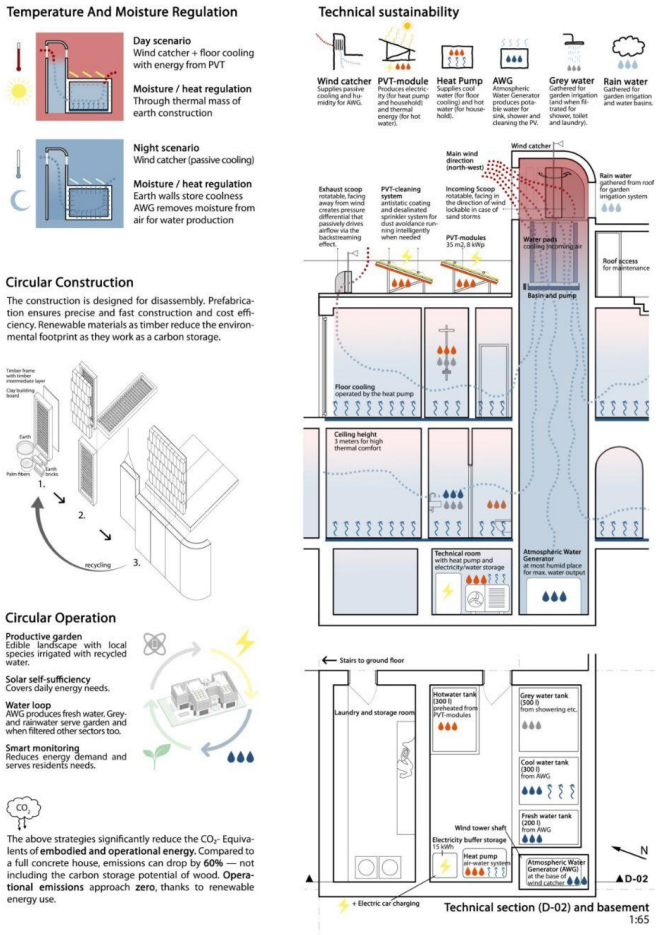
Energy Strategies:

- A water basin is placed in the courtyard to naturally cool the air and make the immediate surroundings feel more refreshed.
- Shared parks and green spaces are integrated into the neighborhood to filter and store greywater for resident use.
- Units are organized into a cellular system, enabling the implementation of decentralized energy and water infrastructure.
- Large, shaded openings ensure that all habitable rooms receive sufficient natural lighting and ventilation.
- An atmospheric water generator (AWG) is installed within the windtower to extract potable water from the air while simultaneously dehumidifying the air.
- The inclusion of Photovoltaic-thermal (PVT) systems provides combined electricity and heat production, allowing for solar self-sufficiency and a near-total reduction in operational CO2 emissions.
- By lowering the seating into a conversation pit, the design takes advantage of the cooler air that naturally settles at the floor level to improve comfort.
- The structure uses a solar-powered heat pump to drive a radiant floor cooling system.

- Adding a rotatable scoop, an air exhaust, and water pads improves the windtower's overall performance.

Figure 56

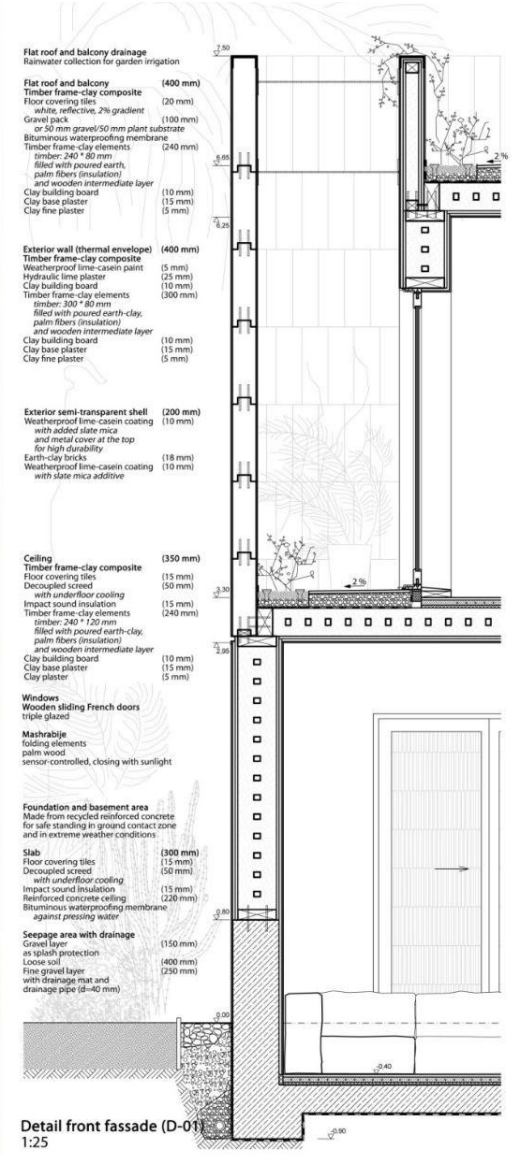
Integrated environmental systems combining passive cooling, renewable energy, and water management strategies.



Note. Adapted from *House of Courts*, by H. A. H. Al-thweib and L. M. Stallmann, House of the Future Competition 2024/25, Buildner.

Figure 57

Construction and material strategy illustrating the use of renewable materials and principles of circular construction.



Note. Adapted from *House of Courts*, by H. A. H. Al-thweib and L. M. Stallmann, House of the Future Competition 2024/25, Buildner.

Technology and Materials:

- The envelope relies on earth-clay bricks, timber, and palm fibers; these natural materials drastically reduce the project's embodied carbon.
- Adopting prefabrication speeds up the construction process and lowers costs while further cutting the project’s carbon footprint.

MODULOR - 2nd place winner

MODULOR: A Prototype for Evolving Homes , designed by Marc Izaguerri Serrano (United Kingdom), received Second Prize in the 2024/25 House of the Future Competition. The proposal develops a modular housing system capable of adapting to changing household needs through incremental expansion and spatial reconfiguration. Combining prefabricated construction with passive climate strategies, renewable energy, and water reuse, the project approaches sustainability not only through environmental performance but also through the long-term adaptability of the dwelling.

Figure 58

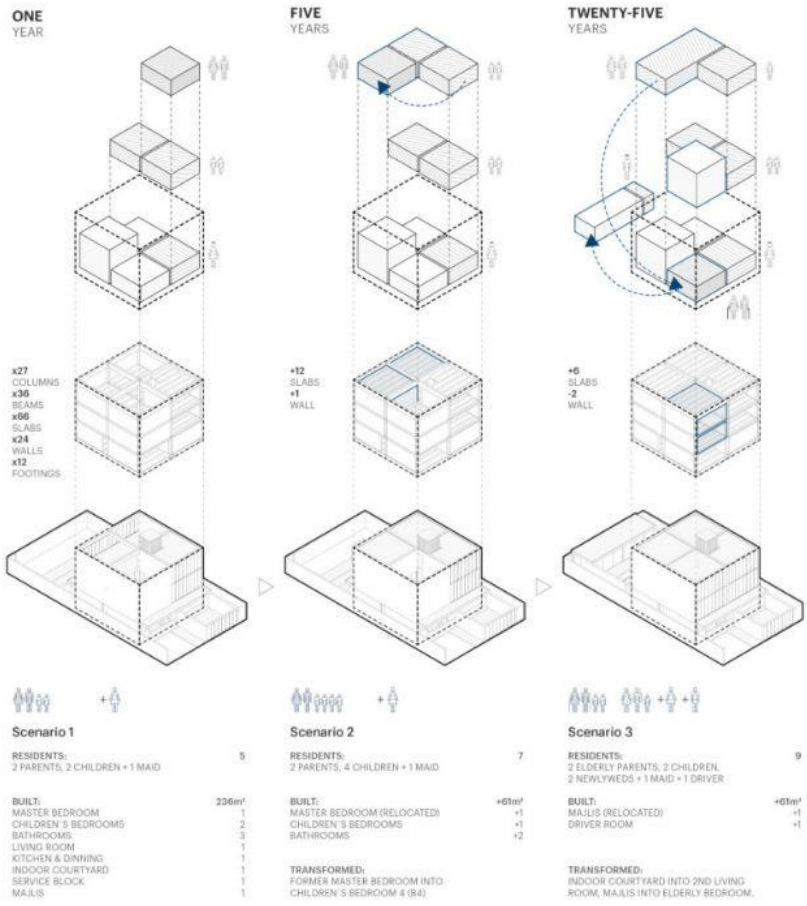
Exterior perspective of the MODULOR: A Prototype for Evolving Homes proposal.



Note. Adapted from *MODULOR: A Prototype for Evolving Homes*, by M. Izaguerri Serrano, House of the Future Competition 2024/25, Buildner.

Figure 59

Incremental housing strategy illustrating the adaptation and expansion of the dwelling over 1-, 5-, and 25-year scenarios.



Note. Adapted from *MODULOR: A Prototype for Evolving Homes*, by M. Izaguerri Serrano, House of the Future Competition 2024/25, Buildner.

Distribution:

- Opening the *majlis* toward the street encourages more frequent interaction with the neighborhood.
- Combining the rear setbacks with the terrace creates a large, unified private garden.

Figure 60

Ground, first, and second floor plans illustrating the modular spatial organization of the dwelling.



Note. Adapted from *MODULOR: A Prototype for Evolving Homes*, by M. Izaguerri Serrano, House of the Future Competition 2024/25, Buildner.

- The building layout incorporates a straightforward strategy for future horizontal or vertical expansion.
- The floor plan ensures that all spaces remain highly accessible.

- Using the side setback for service access provides a functional secondary entry point.
- The placement of two living areas overlooking one another is programmatically inefficient.

Link with Tradition:

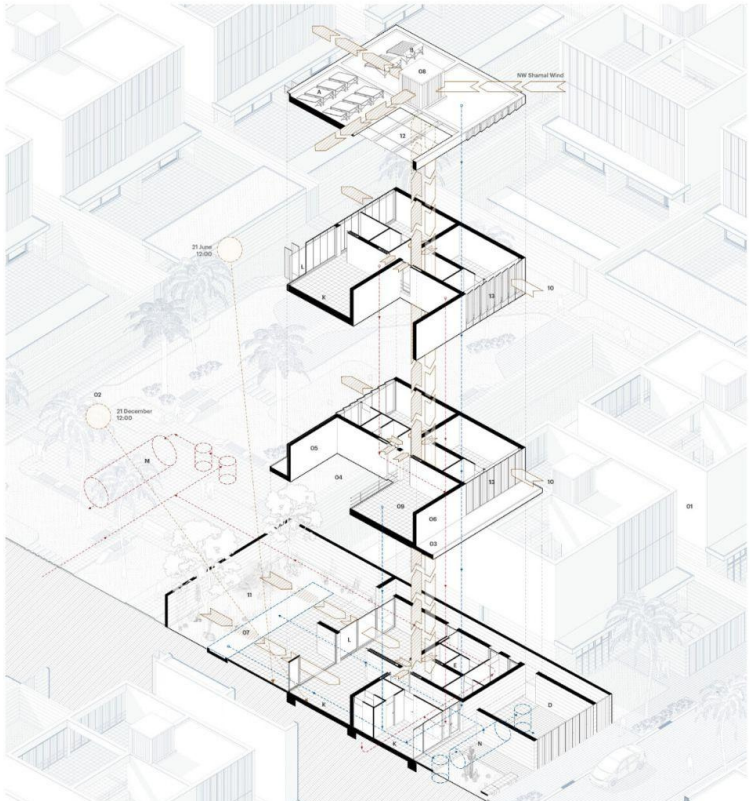
- The design incorporates water features and a windtower, representing the fundamental typological elements of traditional residential architecture.
- Social spaces are integrated directly into the building clusters and wider neighborhood fabric.
- Organizing the units in a cellular system mirrors the urban grain of traditional settlements.
- Operable shutters act as modern *mashrabiya* screens, allowing for adjustable privacy and light.
- Relying on a "copy-paste" strategy for the modules lacks the spatial diversity typical of traditional architecture.

Energy Strategies:

- A water basin in the main courtyard lowers the ambient temperature and refreshes the microclimate.
- Wind tower utilizes evaporative cooling to drive natural ventilation throughout the house.
- The neighborhood layout prioritizes pedestrian movement over vehicular access.

Figure 61

Environmental systems axonometric illustrating the integration of passive climate strategies, renewable energy, and water-management systems.



Note. Adapted from *MODULOR: A Prototype for Evolving Homes*, by M. Izaguerri Serrano, House of the Future Competition 2024/25, Buildner.

- Shared green spaces and parks serve as a neighborhood-scale system for filtering and storing greywater.
- The combination of photovoltaic and solar thermal panels reduces energy demand while significantly dropping operational CO2 emissions.
- A dedicated recycling system is built into the infrastructure to manage and reuse greywater.
- All rooms stay well-lit and ventilated thanks to large openings that are protected by integrated shading.
- Double-height spaces across different levels use the chimney effect to pull fresh air through the house and aid natural cooling.
- The terrace uses retractable shades to give the residents active control over solar gain throughout the day.

Technology and Materials:

- Choosing coral stone for the floors and roof helps lower the project's total embodied carbon.
- Most of the construction depends on concrete and other materials with high embodied carbon.

FlexiCourts - 3rd place winner

FlexiCourts, designed by GN Architects (Lijiang Shen and Yaoyao Yuan, China), proposes a courtyard-based housing prototype that combines regional spatial traditions with contemporary requirements for flexibility and environmental performance.

Distribution:

- By using both a semi-private and a private courtyard, the design creates a better balance between seclusion and thermal comfort.

Figure 62

Exterior perspective of the FlexiCourts proposal.



Note. Adapted from *FlexiCourts*, by GN Architects (L. Shen & Y. Yuan), House of the Future Competition 2024/25, Buildner.

- By giving the guest bedroom its own access and orienting it toward the road and semi-public courtyard, the design creates a clear and effective split between public and private spaces.
- With full-height openable doors, the living area can open up completely, allowing the interior to spill out into the courtyard both physically and visually.
- The layout includes several shaded outdoor environments, which are highly practical for the local climate.

- Using openable partitions to connect the *majlis* and the living room makes the layout flexible, allowing the communal space to open up whenever there is a need for more room during special events.
- The house entrance is a bit far from the main gate, leaving residents exposed for longer as they arrive, which takes away from their privacy.
- Some parts of the courtyards feel like dead zones that don't really have a clear use.

Figure 63

Ground- and first-floor plans illustrating the spatial organization of FlexiCourts around multiple courtyards and outdoor spaces.



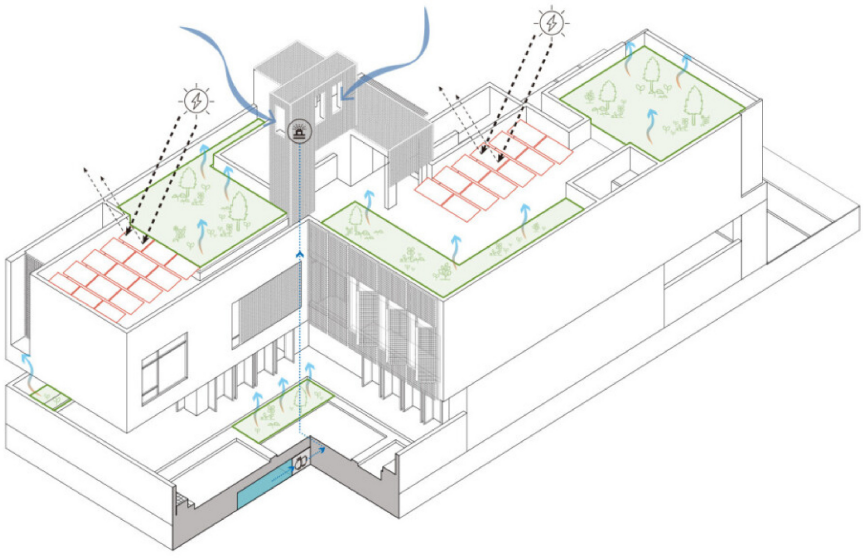
Note. Adapted from *FlexiCourts*, by GN Architects (L. Shen & Y. Yuan), House of the Future Competition 2024/25, Buildner.

Link with Tradition:

- The design incorporates water features and a windtower, representing the fundamental elements of traditional housing.
- The way the building heights vary from block to block gives the project that organic, almost random feel you see in traditional neighborhoods.
- The choice of adding an outside staircase for guests is a direct nod to traditional ways of keeping the family's private life separate.
- Openable shutters are used as modern mashrabiya screens, offering residents a flexible way to manage privacy and light.

Figure 64

Environmental systems axonometric graphic illustrating passive ventilation, wind-tower cooling, planted roofs, and solar-energy integration.



Note. Adapted from *FlexiCourts*, by GN Architects (L. Shen & Y. Yuan), House of the Future Competition 2024/25, Buildner.

Energy Strategies:

- A water basin is placed in the courtyard to naturally cool the air and make the immediate surroundings feel more refreshed.
- Adjustable shutters give residents a simple way to manage sunlight and heat, letting them dial in the right amount of daylight as the sun moves.
- The windtower creates passive cooling mechanisms to enhance natural ventilation and cooling.
- Photovoltaic panels are implemented to mitigate operational CO2 emissions and energy demand.
- The roof gardens are designed to support local biodiversity and contribute to the reduction of regional carbon emissions.
- All rooms stay well-lit and ventilated thanks to large openings that are protected by integrated shading.

Technology and Materials:

- Most of the structure is built with Autoclaved Aerated Concrete (AAC) because it's easier to recycle and takes much less energy to produce than the usual concrete.
- Beyond being a budget-friendly choice, AAC provides high insulating properties.

4.4 Overall Ranking

Figure 65

Overall ranking system

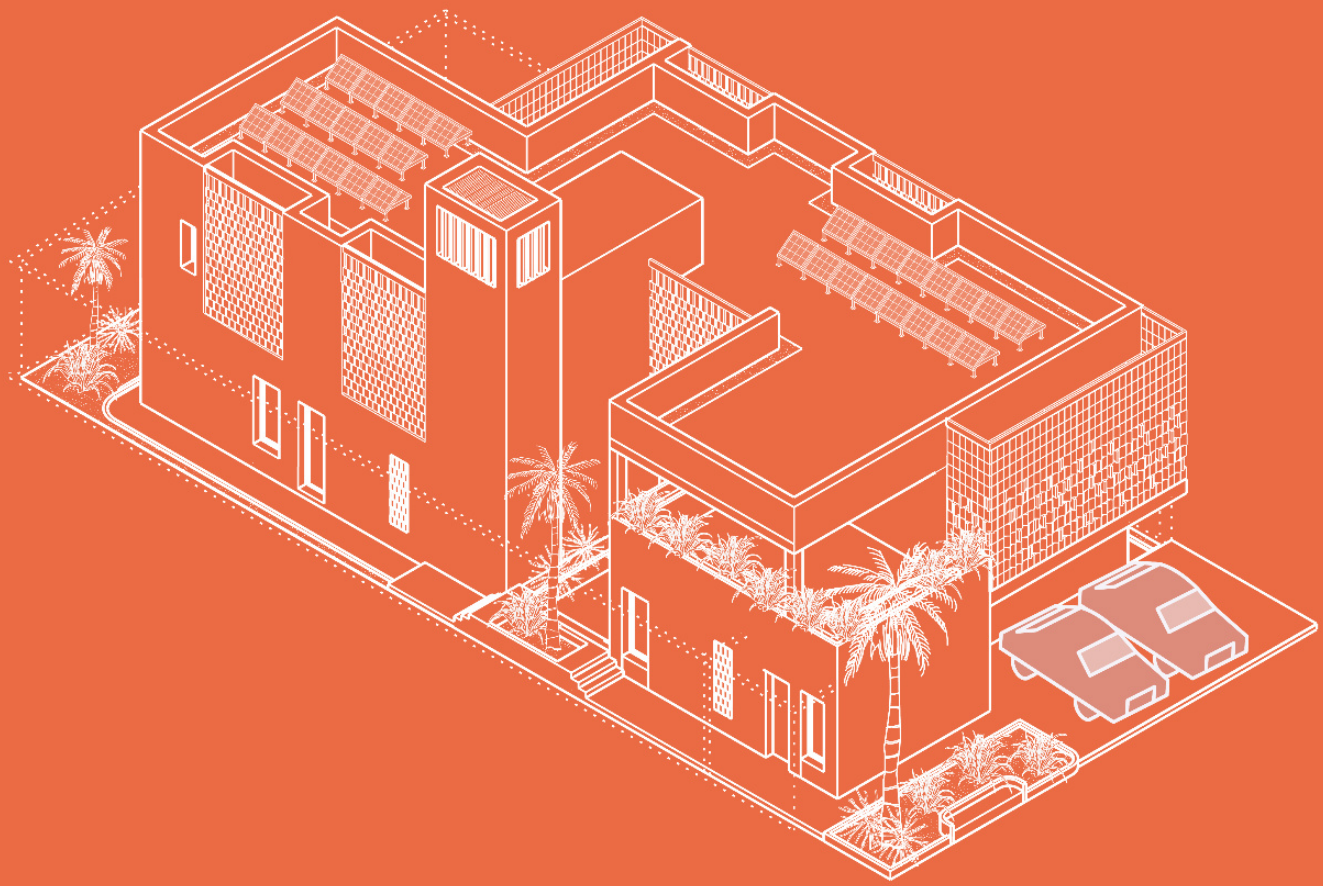
ORIGINAL RANKING	PERSONAL RANKING	TITLE	DISTRIBUTION	LINK WITH TRADITION	ENERGY STRATEGIES	TECHNOLOGY AND MATERIALS
1st	**1st**	House of Courts	○○○	○○	○○○	○○○
1st	**2nd**	AL DARA	○○○	○○○	○○	○
3rd	**3rd**	FlexiCourts	○○	○○○	○○	○○
2nd	**4th**	Block Yard	○○	○○	○○	○○○
2nd	**5th**	MODULOR	○○	○○	○○	○
3rd	**6th**	Dune house	○	○○	○	○○○

Strong ○○○
Moderate ○○
Limited ○

Note. Created by the author.

The comparative evaluation demonstrates that the strongest proposals are not necessarily those that maximize technological complexity, but those that achieve a balanced integration of spatial organization, cultural continuity, passive environmental strategies, and contemporary construction methods. House of Courts ranks highest overall due to its particularly strong combination of spatial distribution, environmental performance, and material strategies, while Al Dara stands out for its close relationship with traditional Emirati architectural principles. FlexiCourts follows closely, particularly through its reinterpretation of courtyards, privacy, adaptable spaces, and passive climatic strategies. Across the six projects, recurring elements—including courtyards, shaded outdoor spaces, wind towers, adaptable spatial configurations, natural ventilation, and locally responsive material systems—emerge as particularly relevant to the objectives of this thesis. These findings therefore provide a set of design principles that can be selectively reinterpreted in the development of the architectural proposal presented in the following chapter.

5. Design Proposal: House of the Future – UAE



5. Design Proposal: House of the Future – UAE

Building on the environmental, historical, and architectural analyses developed in the previous chapters, this chapter translates the identified principles into a contemporary residential design proposal for the United Arab Emirates. The project is developed within the framework of the House of the Future competition and explores how traditional Emirati spatial and climatic strategies can be reinterpreted through contemporary low-carbon design. The design process begins with the selection of an appropriate urban context and site, followed by an evaluation of accessibility, connectivity, environmental conditions, and surrounding land uses. The subsequent sections present the architectural concept, spatial organization, material and construction strategies, energy performance, and broader urban design approach of the proposed residence.

5.1 Site Analysis and Selection

Site selection forms an important part of the design process because the environmental performance and long-term viability of a residential project are strongly influenced by its wider urban context. The selection process was therefore carried out at two scales. First, Dubai was evaluated as the most appropriate city in which to locate the proposal. Second, a series of potential sites within Dubai were identified and comparatively assessed according to their development status, surrounding land uses, accessibility, and sustainability-related location criteria.

5.1.1 City Selection

Dubai was selected as the location for the proposed *House of the Future* because of the combined pressures of rapid population growth, increasing housing demand, limited family-oriented supply, affordability challenges, and demanding climatic conditions.

Dubai's population reached approximately 4.03 million residents in October 2025, representing year-on-year growth of 4.47%. This increase corresponded to approximately 470 additional residents per day, generating an estimated demand for nearly 150 new homes daily. At the same time, only around 44,000 residential units were expected to be delivered during 2025, indicating a growing mismatch between population growth and housing supply (The National, 2025).

The composition of new residential supply also reveals an imbalance in available housing typologies. Of the 152,402 units launched in Dubai during 2025, approximately 89% were apartments, while only 11% consisted of villas and townhouses. This is particularly significant for family-oriented housing, as villas and townhouses generally provide larger domestic spaces and longer-term residential options but remain comparatively limited within new development.

Housing affordability represents an additional challenge. Alawadi et al. (2018) found that only approximately 23% of Dubai's housing units, corresponding to just 7% of the total residential floor area, were affordable to middle-income households. This indicates that the increasing production of housing does not necessarily correspond to greater accessibility or diversity within the residential market.

These conditions make Dubai a relevant context for investigating a housing model that is not only environmentally responsive but also adaptable, family-oriented, and capable of accommodating changing household requirements. At the same time, Dubai's hot-arid climate, intense solar exposure, and high dependence on mechanical cooling provide a strong environmental basis for reconsidering passive strategies derived from traditional Emirati architecture.

The combination of rapid urban growth, housing demand, limited family-oriented supply, affordability pressures, and climatic constraints therefore makes Dubai an appropriate setting in which to test the proposed *House of the Future* residential model.

5.1.2 Site Selection

Following the selection of Dubai as the urban context, a preliminary search was conducted to identify undeveloped land that could potentially accommodate a residential compound. Google Earth was initially used to locate remaining vacant plots within the urban area and to examine their relationship with surrounding residential districts, road networks, and existing development.

The identified sites were subsequently examined using QGIS in order to determine whether the vacant areas were affected by land-use restrictions, protected areas, reserves, or other conditions that could limit their suitability for development. Historical satellite imagery and available street-level imagery were then used to verify whether construction activity had recently begun on any of the shortlisted sites and to assess changes in their physical condition over time.

Following this preliminary screening, the remaining sites were comparatively evaluated using principles derived from the Location and Transportation (LT) category of the LEED v5 rating system. The LT framework was used as an analytical tool rather than as a formal certification process, allowing the sites to be compared according to criteria related to location efficiency, access to existing infrastructure and services, transportation options, and their relationship with the surrounding urban fabric.

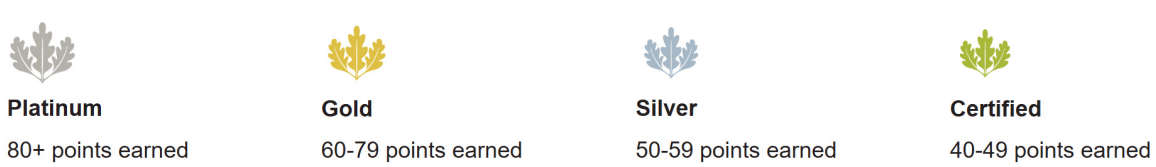
This combined process of spatial analysis, visual verification, and sustainability-based evaluation established the basis for selecting the final site for the architectural proposal.

5.1.3 LEED v5: Location and Transportation (LT)

LEED (Leadership in Energy and Environmental Design) is a green building rating system developed by the U.S. Green Building Council (USGBC). It provides a framework for evaluating the sustainability performance of buildings across areas including energy use, water efficiency, materials, indoor environmental quality, site conditions, and transportation. LEED can be applied to a wide range of project types, including new construction, interiors, existing buildings, and residential projects.

Figure 66

LEED Certification Levels Based on Points Achieved



Note. Adapted from *LEED rating system*, by U.S. Green Building Council (USGBC), n.d.

The current LEED v5 framework places particular emphasis on three broader impact areas: decarbonization, quality of life, and ecological conservation and restoration. Projects pursuing LEED certification must satisfy required prerequisites and can then earn points by achieving additional credits. The final number of points determines the certification level: Certified, Silver, Gold, or Platinum.

Figure 68

Points of the Location and Transportation (LT) Credit (LEED v5 Building Design and Construction Rating System)

Name	What it rewards	Potential points
LTc1 Sensitive Land Protection	Previously developed land, OR avoiding floodplain/habitat/water body/steep-slope land	1 point
LTc2 Equitable Development	Brownfield/historic-district location, housing-jobs proximity	1-2 points
LTc3 Compact and Connected Development	Surrounding density, transit access, walkability, infill status	1-6 points
LTc4 Transportation demand management	Reduced parking, bike infrastructure	1-4 points
LTc5 Electric Vehicles	EVSE / EV-ready parking	1-2 points

Note. Created by the author from *LEED rating system*, by U.S. Green Building Council (USGBC), n.d.

For new buildings, LEED Building Design and Construction (BD+C) provides the relevant rating framework. Within BD+C, the Location and Transportation (LT) category considers the relationship between a project and its wider urban context, recognizing that site selection can significantly influence transportation-related emissions, infrastructure demand,

accessibility, and patterns of urban development.

In this thesis, the LT category is used as a comparative framework for site selection rather than as a complete LEED certification assessment. Its criteria provide a structured method for evaluating the shortlisted sites according to their accessibility, connection to existing urban development, transportation opportunities, and proximity to relevant services. This allows site selection to become part of the broader sustainability strategy of the proposed House of the Future, rather than being treated solely as a question of available land.

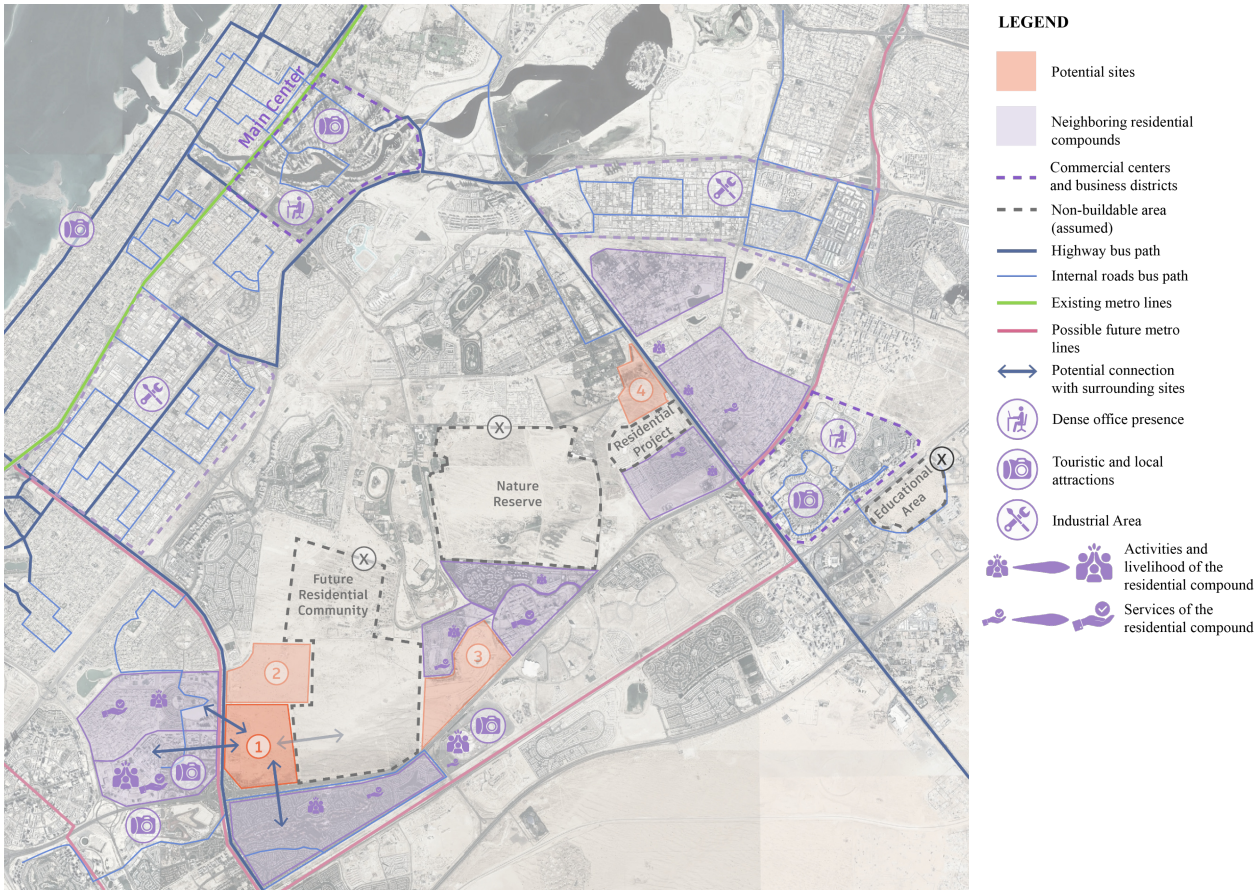
5.1.4 Available Sites

The availability of undeveloped land suitable for a residential compound in Dubai, while also maintaining good connections to public transportation and the city's main activity areas, was found to be relatively limited. For this reason, the site-selection process began with a broader analysis of the city to identify potential locations and progressively eliminate unsuitable areas.

The first stage examined the distribution of Dubai's main activity areas and patterns of daily movement. Particular attention was given to the locations where residents work, access services, and engage in leisure activities, as well as the principal business and tourist destinations. As illustrated in Figure 69, a major concentration of these activities occurs around Downtown Dubai and the adjacent business districts, while other important destinations are distributed across the wider urban area.

Figure 69

Potential Sites in Relation to Mobility, Services, and Major Urban Districts



Note. Adapted from Google Earth, OpenStreetMap, INAT, and Dubai.AL; modified by the author.

The transportation network was then analysed to understand the accessibility of potential sites. Existing and planned metro lines were considered together with the principal highways, secondary roads, and bus connections linking residential areas with the main activity districts. This analysis provided an initial indication of which undeveloped areas could potentially support residential development without being isolated from the existing urban and transportation network.

Potential vacant sites were subsequently identified through Google Earth and examined in QGIS to determine whether apparent undeveloped land was actually suitable for construction. This process revealed several constraints. One potential site was identified as part of a natural reserve, while another was located within an educational district surrounded predominantly by university facilities and was therefore considered unsuitable for the proposed residential use. A further area, identified in Figure 70 as the Future Residential Area, appeared as non-buildable land in the QGIS analysis. However, comparison of historical satellite imagery in Google Earth indicated recent site preparation consistent with future residential development. The same temporal analysis also showed the ongoing expansion of an existing residential compound located in the central-eastern part of the study area. These sites were consequently excluded from further consideration.

Through this progressive elimination process, the preliminary site search avoided environmentally sensitive and otherwise constrained land, supporting the principles established under LEED v5 LTc1: Sensitive Land Protection.

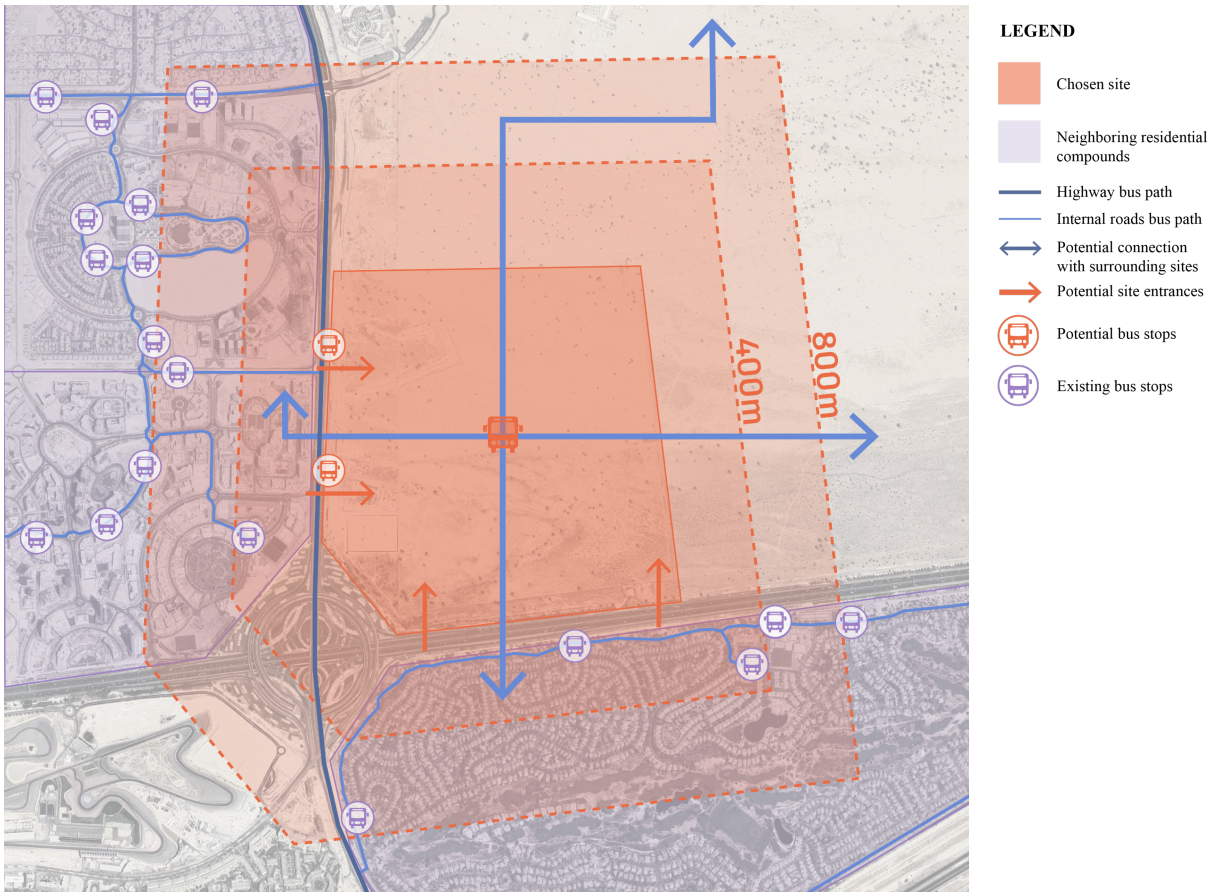
Following this initial screening, the remaining potential sites were evaluated according to their surrounding urban conditions. The analysis considered proximity and connectivity to everyday activities, services, employment areas, transportation networks, and existing development. This second stage was used to identify which sites offered the strongest potential to support the principles of LEED v5 LTc3: Compact and Connected Development, particularly by locating new housing within an accessible and connected urban context rather than contributing to isolated residential expansion.

5.1.5 Selected Site Analysis

After choosing the site based on the previously mentioned analysis, a deeper study was conducted to the surroundings of the site according to the LEED credits.

Figure 70

Proximity of the Selected Site to Existing Mobility Networks and Proposed Connections within 400 m and 800 m Walking Radii



Note. Adapted from Google Earth, INAT; modified by the author in accordance with LEED Location and Transportation (LT) criteria.

5.1.6 Compact and Connected Development

Following the selection of the site, a more detailed analysis of its surrounding urban context was conducted according to LEED v5 LTc3: Compact and Connected Development. The credit evaluates the relationship between a project and the existing urban fabric, with the aim of encouraging development in locations that provide access to infrastructure, public transportation, and everyday services while reducing dependence on private vehicles (U.S. Green Building Council [USGBC], n.d.).

Of the different achievement options established under the credit, three were considered particularly relevant to the proposed site: Surrounding Density, Access to Transit, and Walkable Location. These criteria were used to evaluate the site's relationship with existing development, public transportation, and nearby everyday services.

Surrounding Density

This criterion evaluates the density of existing development surrounding the project site. The surrounding built environment was examined within a 400 m (0.25-mile) radius, consistent with the LEED assessment method for surrounding density. In the case of the selected site, two of its four principal edges currently face vacant or undeveloped land. The calculated surrounding density was approximately 230 m²/ha, substantially below the 5,050 m²/ha threshold required under this option. Consequently, the site does not qualify for points through the Surrounding Density pathway.

Access to Transit

The second criterion evaluates pedestrian access to public transportation according to

the proximity and frequency of available services. As illustrated in Figure 70, existing bus stops are located within the analysed 400 m and 800 m walking distances from the site. The combined services provided by these stops were assessed against the minimum transit-service requirements of the credit. The proposed future metro connection identified in the wider mobility analysis was considered separately as a potential improvement to the site's future accessibility rather than as an existing condition.

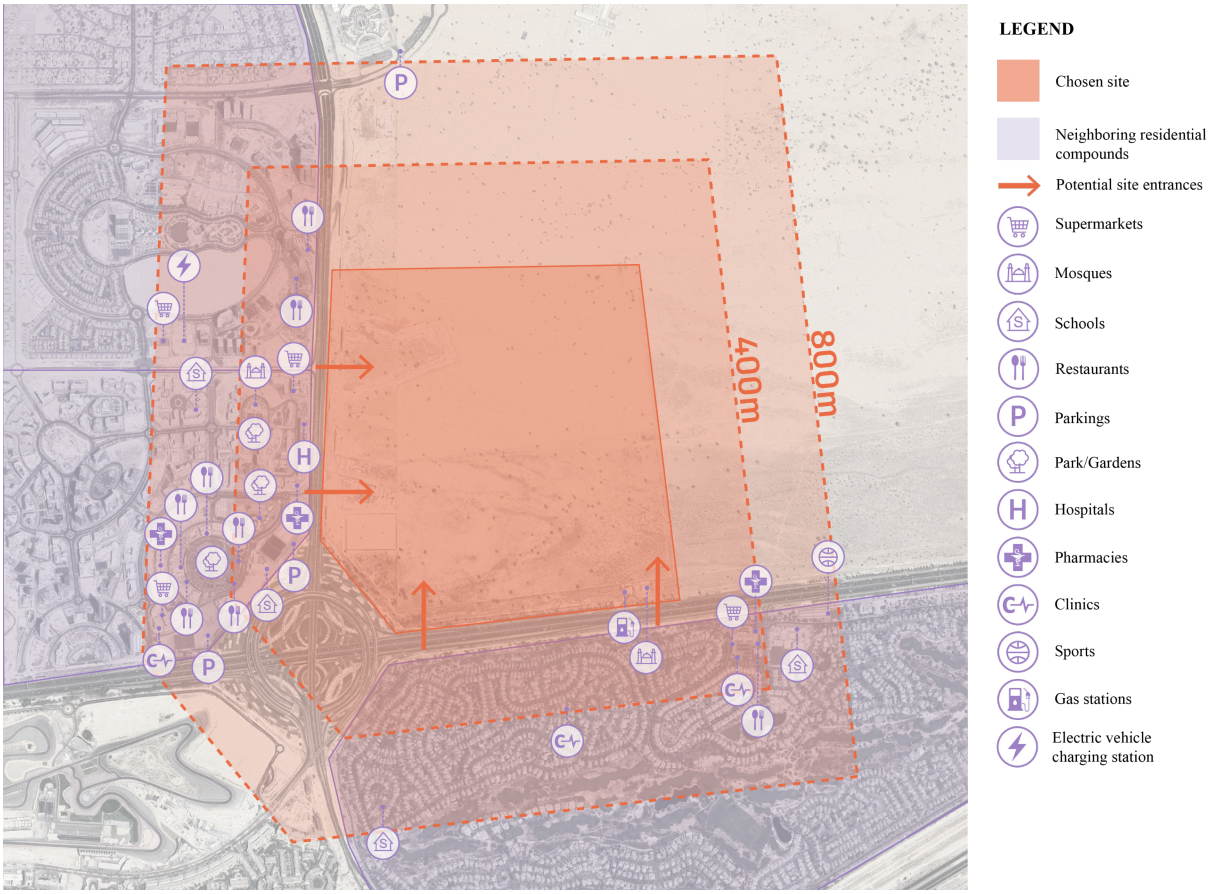
In addition to the existing network, Figure 70 identifies proposed connections between the project and its surroundings, including additional bus connections and new site entrances. These interventions are intended to strengthen pedestrian access between the residential compound and existing public transportation and support the project's broader objective of reducing dependence on private vehicles.

Walkable Location

This option rewards proximity to a diversity of everyday amenities within an 800 m walking distance, with 1–3 points awarded according to the number of qualifying uses. A maximum of two establishments of the same use type may be counted, and the qualifying uses must represent at least three of the five designated use categories (USGBC, n.d.). As shown in Figure 71, the area within 800 m of the selected site includes fuel and EV charging stations, restaurants, parks, retail facilities, supermarkets, parking facilities, schools, mosques, a sports field, healthcare facilities, and pharmacies. Following the LEED counting criteria, 21 qualifying uses were identified across the surrounding area, placing the site within the highest scoring tier for Walkable Location.

Figure 71

Existing Services and Activities within 400 m and 800 m Walking Radii of the Selected Site



Note. Adapted from Google Earth; modified by the author in accordance with LEED v5 LTc3: Compact and Connected Development criteria.

Together, these three sub-criteria position the site as strongly transit- and amenity-connected despite its low surrounding density, a combination that supports the thesis's argument for a location where daily needs are met largely on foot, reducing reliance on private vehicles in line with the courtyard house's broader passive, low-carbon design intent

Figure 72

Number Counted Amenity Uses Within 0.5 mile (800m) walking distance - LTc3 Option 3, Walkable Location Site

Use type	Your count	Counted (cap 2)
Gas station	1	1
EV charging station	1	1
Restaurants	2+	2
Parks	2+	2
Clothing store	2+	2
Supermarkets	2+	2
Parking facilities	2+	2
Schools	2+	2
Mosques	2	2
Sports field	1	1
Hospital/clinic	2+	2
Pharmacy	2+	2
Total		**21**

Note. Created by the author after counting the stores from Google earth based on *LEED rating system*, by U.S. Green Building Council (USGBC)

5.2 Architectural Design Proposal

Following the site selection and urban analysis, the design proposal was developed in response to the spatial, environmental, and programmatic requirements established by the House of the Future competition.

5.2.1 Competition Requirements

The competition brief establishes the main spatial, dimensional, functional, and environmental requirements that form the basis for the development of the architectural proposal.

Figure 73

House of The Future Competition Requirements Summary

Requirement	Details
Competition	House of the Future (Buildner, in partnership with Sheikh Zayed Housing Programme and Mohammed bin Rashid Centre for Government
Site location	No fixed site; participant selects a plot in the UAE
Max plot size	450 m² (recommended 15 m x 30 m, 15 m side facing the street)
Setbacks (suggested)	Approx. 3 m front and back, 1.5 m sides (may be broken with strong rationale)
Building height	Minimum G+1, maximum G+2
Recommended floor area	300 m² total building floor area
Number of occupants	Family of 4 to 6 members
Budget	Should not exceed 800,000 AED, with possible expansion up to 1,200,000 AED (estimate only, no detailed cost list required)
Expandability	Design must allow affordable future expansion/additions without harming original function or aesthetic
Bedrooms	3 bedrooms minimum, expandable up to 5
Parking	2 cars minimum
Must-have areas	Bedrooms (3, expandable to 5); 2-car parking; garden; pantry (indoor prep kitchen); living room; washroom + WC for each bedroom and living room; laundry & ironing room; maid room + washroom; kitchen; storage
Optional/recommended areas	Dining area; office; majlis (private social hosting area); driver room + washroom (segregated); dressing area per bedroom or shared family
Materials	Innovative, sustainable, and ideally locally sourced materials, chosen to reduce cost and energy use in construction and maintenance
Sustainability / energy	Power-efficient design to minimize running costs and environmental
Compliance	Must meet UAE insurance standards and building requirements; must account for climatic and environmental durability/comfort
Design criteria (jury)	Overall design aesthetic; harmony of design and function; innovation in materials; expandability; sustainability; innovation in design

Requirement	Details
Cultural fit	Must align with Emirati aesthetic (per Pinterest/insight documents) and reflect UAE societal culture
Submission format	4 A2 landscape presentation boards (max 10MB per jpg each); no video files; all text in English; anonymous (no identity markers)
Team size	Individual or team, maximum 4 members
Eligibility	Open to all; no professional qualification required
Total prize fund	250,000 EUR (4 winning proposals + 6 honorable mentions; includes a dedicated Innovation Award for sustainable/innovative materials)

Note. Created by the author based on the competition brief, by Buildner House of the Future Competition 2023/24.

The jury may reward projects demonstrating exceptional creativity even when specific requirements are not strictly followed, provided that any deviation is clearly justified.

5.2.2 Design Concept

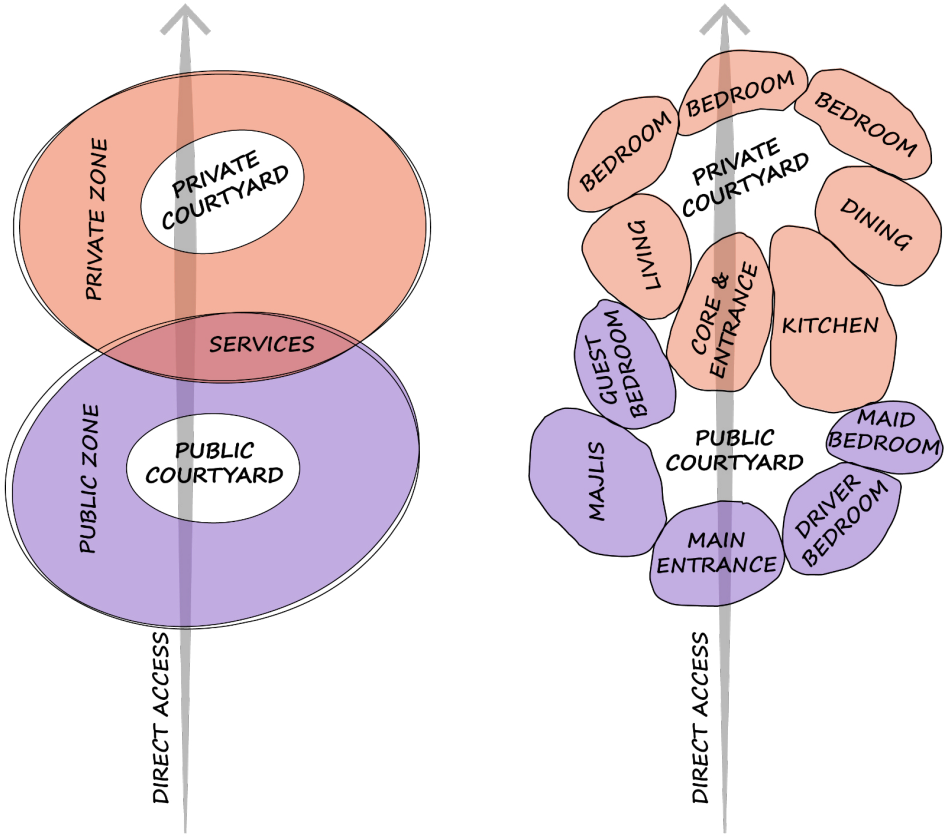
Based on these requirements, the design concept reinterprets the traditional Emirati courtyard house through a contemporary approach focused on climatic responsiveness, spatial flexibility, privacy, and family life.

The bubble diagram (figure 74), which is created based on the competition requirements (figure 73), establishes the spatial and programmatic organization that the massing (Figure 75) later translates into built form. At the diagrammatic level, the private and public zones are each organized as a ring around their respective courtyards, with the services zone acting as the overlapping hinge between them, and a single line of direct access threading vertically through both. This logic is then developed at the detailed scale: the private zone wraps its courtyard with bedrooms, living, dining, and kitchen spaces, anchored by a shared core and entrance, while the public zone wraps its courtyard with the majlis, guest and staff bedrooms, and the main entrance. This bifurcated, courtyard-centric logic becomes the generative diagram for the massing, since the program distribution, the separation into

distinct volumes around private and public courtyards, and the circulation spine all follow directly from the relationships first established here.After designing the bubble diagram (figure 74) according to the requirements of the competition and by developing a circulation strategy, the concept was applied on the volume (figure 75) that follows the dimensions required by the competition: (site: 15x30m, 2 storey) (Figure 73).

Figure 74

Bubble diagrams showing the generic and function distribution strategy



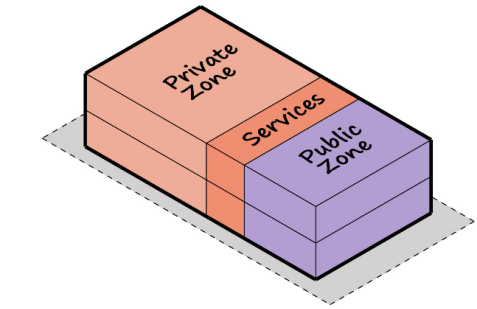
Note. Created by the author

The design concept develops through three sequential moves. It begins with Program, where the massing is organized into three primary zones, private, services, and public, establishing a clear functional hierarchy within a single volume. The Separation stage then breaks this mass apart, carving the block to let private and public courtyards emerge; this cut simultaneously improves the microclimate and physically disconnects the private and public realms, while the services volume is deliberately retained as the connective link serving both sides.

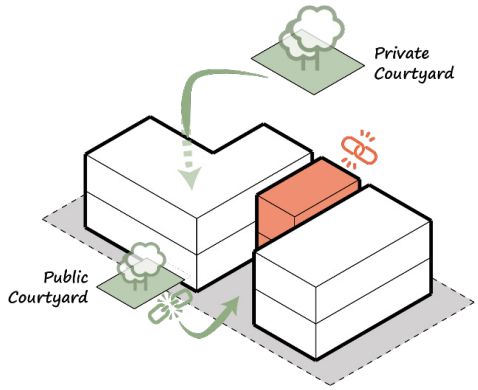
Finally, Circulation resolves access: a public staircase is placed adjacent to the entrance for visitors, while a private staircase is embedded within the private volume, and an overhead spine ties all the fragmented blocks together with a single line of direct access running through the entire scheme.

Figure 75

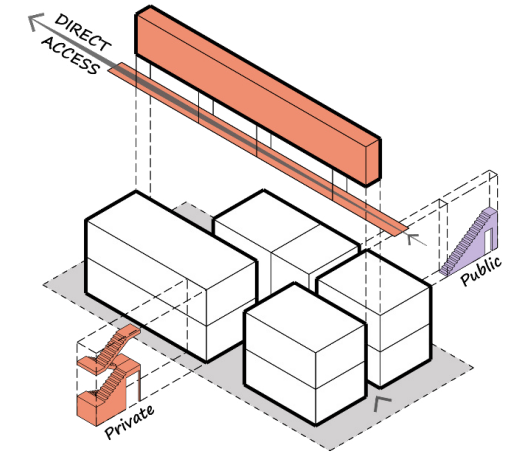
Volumetric diagrams showing the Concept development process based on the bubble diagram



Program
The volume is distributed to 3 main Zones



Separation
Volumes are cut, and courtyards emerge to enhance the microclimate and seperate zones. The services block serves both sides

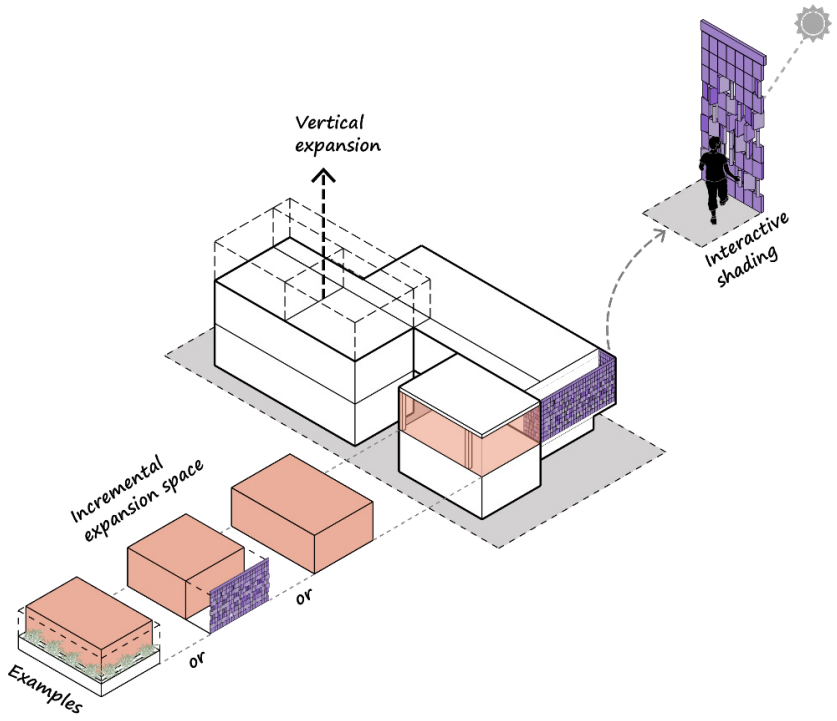


Circulation
A public staircase next to the entrance and a private one inside, with a direct access going through all volumes

Note. Created by the author

Figure 76

Diagrams showing the architectural strategy to establish diversity



Note. Created by the author

As an initial strategy to establish architectural identity and diversity within the residential compound, the design aims to avoid the repetition of identical housing units and instead support a stronger sense of belonging for residents. Two complementary strategies were developed: an architectural strategy, illustrated in Figure 76, and an urban strategy, presented later in the chapter.

The architectural strategy for creating diversity is based on three parameters: interactive shading, vertical expansion, and incremental expansion. Interactive shading allows residents to manually adjust the vertical shading elements according to changing solar conditions and individual needs. Vertical expansion is enabled by designing the structural

system to accommodate an additional floor in the future. Incremental expansion is provided through a first-floor terrace with a prepared structural frame and roof, allowing the space to function initially as an outdoor terrace and later to be enclosed through the addition of walls according to changing household requirements.

Together, these three strategies allow individual dwellings within the compound to develop different configurations over time, reducing visual and spatial repetition and giving each residence a greater degree of identity and adaptability.

5.2.3 Spatial Layout

The spatial layout develops the public–private organization established in the initial concept diagram into a two-storey residential plan. The ground floor accommodates the principal communal, guest, and service functions, while the upper floor is primarily dedicated to private family spaces. This vertical distribution establishes a clear hierarchy of privacy while maintaining strong visual and spatial connections with the courtyards.

On the ground floor, the house is structured around two distinct courtyards. The public courtyard is associated with the majlis and entrance sequence, allowing guests to access the social areas of the house without passing through the family's private domestic spaces. The private courtyard, by contrast, is connected to the living and dining areas and forms the principal outdoor space for everyday family use. The separation of these two courtyards allows the house to maintain the environmental benefits of courtyard living while responding to contemporary requirements for privacy and differentiated social use.

The service spaces including the kitchen, laundry, storage, maid's room, and vertical circulation are concentrated between and alongside the principal living zones. Their position creates a functional transition between public and private areas while allowing the main

family spaces to remain directly connected to the courtyards. Parking and the driver's room are positioned close to the street edge, reducing the need for service movement through the private areas of the residence.

The first floor forms the more private level of the house and contains the principal bedrooms and additional family-use spaces. Bedrooms are organized around the central circulation and are positioned to maintain access to daylight and ventilation while limiting direct exposure to the street. A shared balcony provides an additional outdoor area at the upper level, while the terrace is conceived as an incremental expansion space that can initially function as an outdoor terrace and later accommodate additional enclosed rooms if the family's needs change.

The circulation strategy reinforces this hierarchy. Movement from the main entrance progresses from the more public areas toward the private domestic spaces, while the staircase establishes a direct connection to the bedroom level. This organization allows guest circulation, family circulation, and service functions to overlap where necessary without eliminating the distinction between them.

The courtyard arrangement also contributes to the environmental performance of the plan. By placing the principal living spaces around shaded internal open areas, the design increases opportunities for controlled daylight, cross-ventilation, and visual connection with vegetation. Together with the wind tower, these spaces form part of the broader passive cooling strategy of the house, translating principles identified in traditional Emirati courtyard houses into a contemporary residential layout.

Figure 77

Ground floor plan

Note. Created by the author

Ground Floor - Interior

1. Driver's room
2. Majlis
3. Majlis WC
4. Maid's room
5. Laundry room
6. Storage
7. Kitchen
8. Dining
9. Entrance hall
10. WC
11. Windtower
12. Living Area

Ground Floor - Exterior

13. Public courtyard
14. Private courtyard
15. Parking

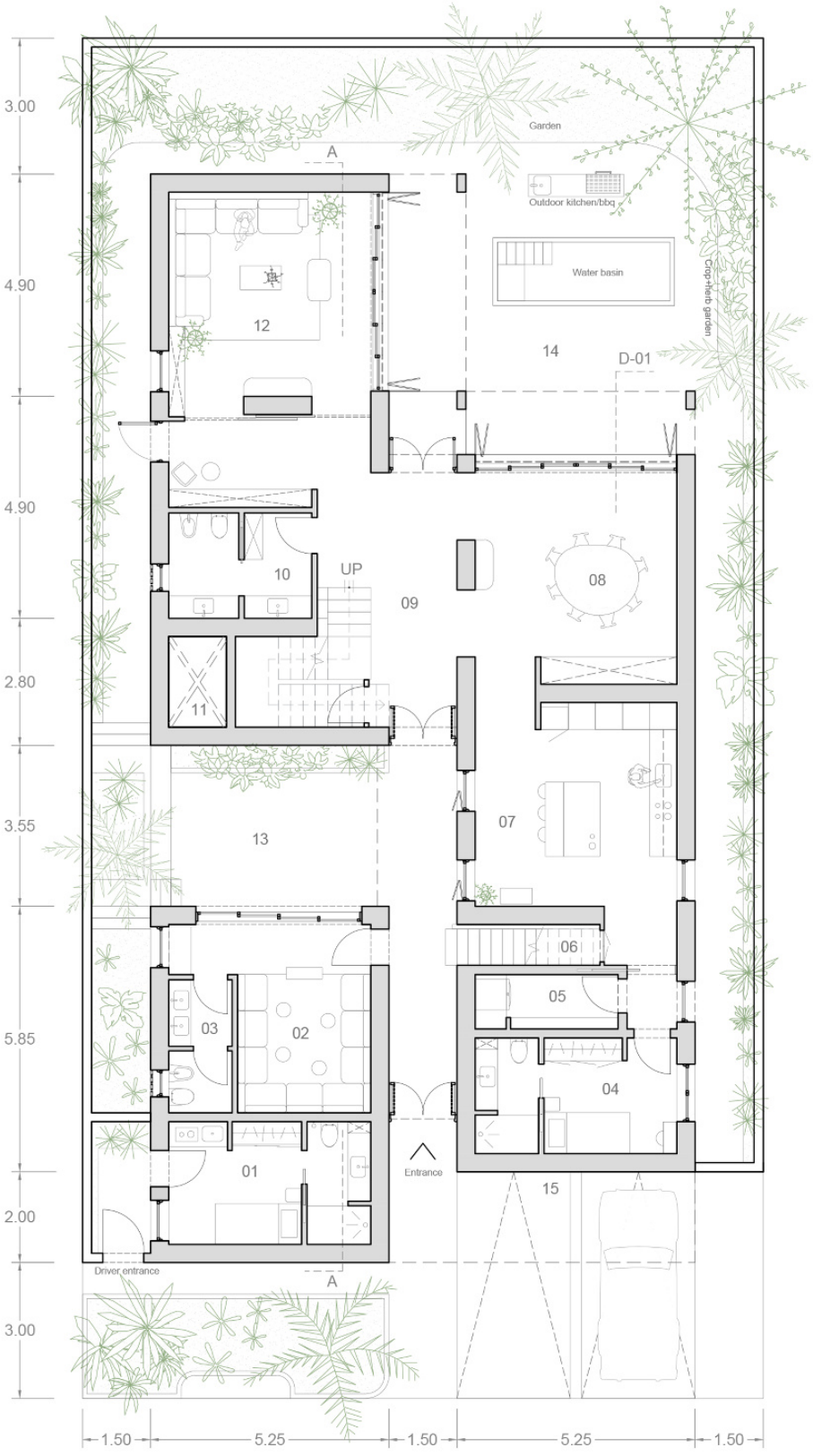
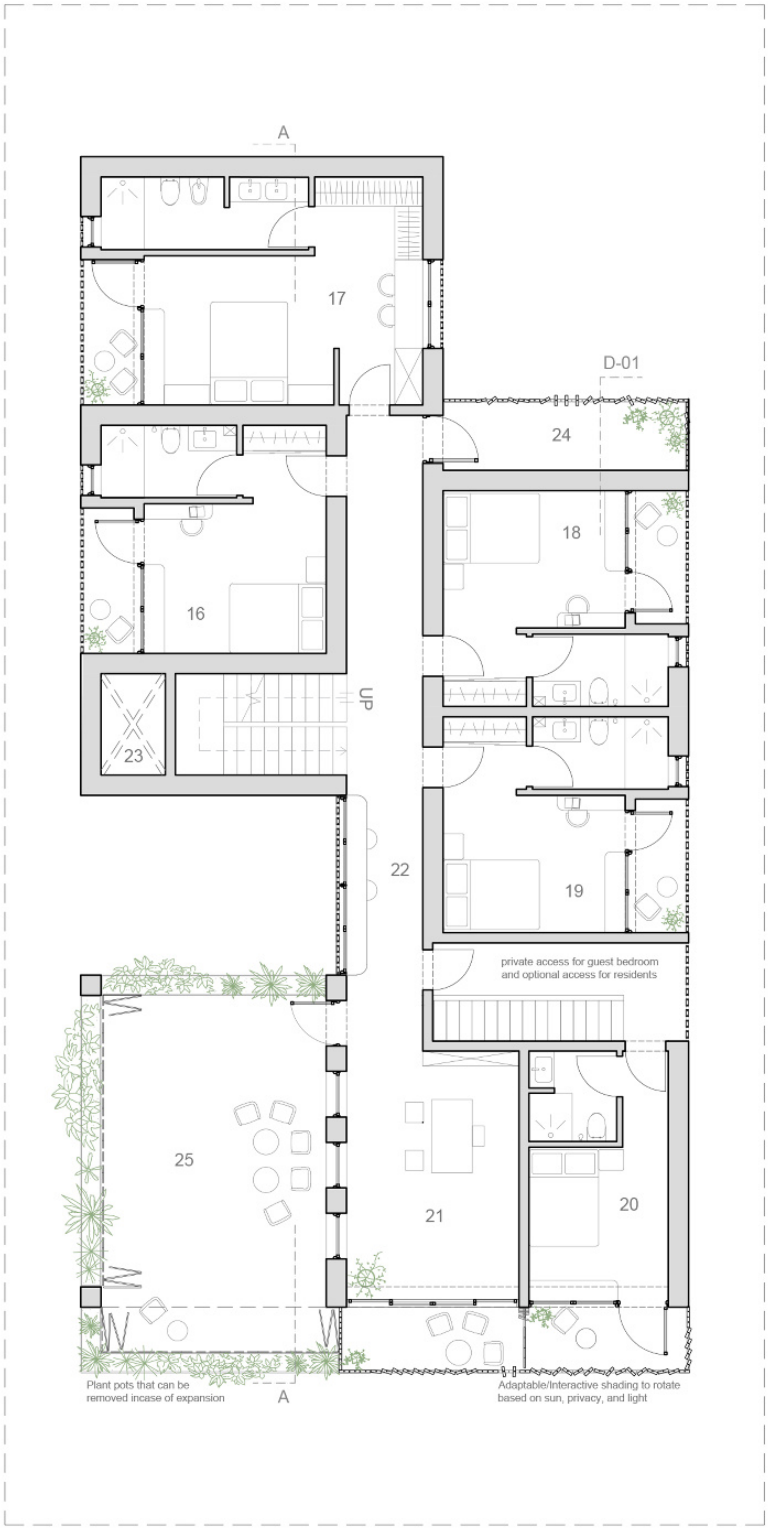


Figure 78

1st floor plan



First Floor - Interior

16. Bedroom 1
17. Master bedroom
18. Bedroom 2
19. Bedroom 3
20. Guest bedroom
21. Office/ Living/ Sports
22. Study/Corridor
23. Windtower

First Floor - Exterior

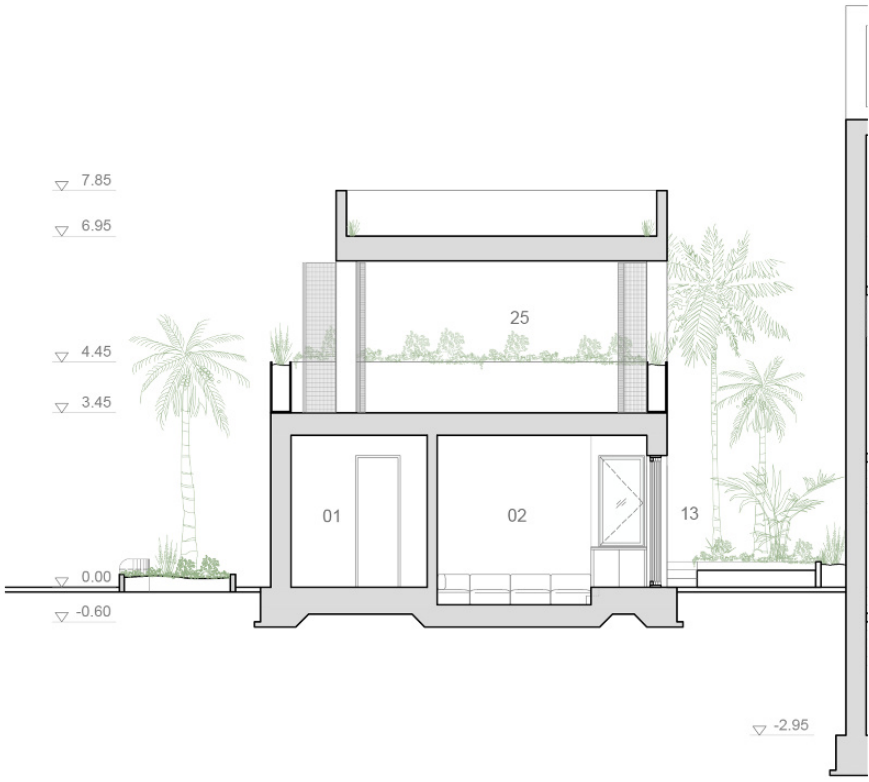
24. Shared balcony
25. Terrace/Incremental space (ex. additionaş bedroom)

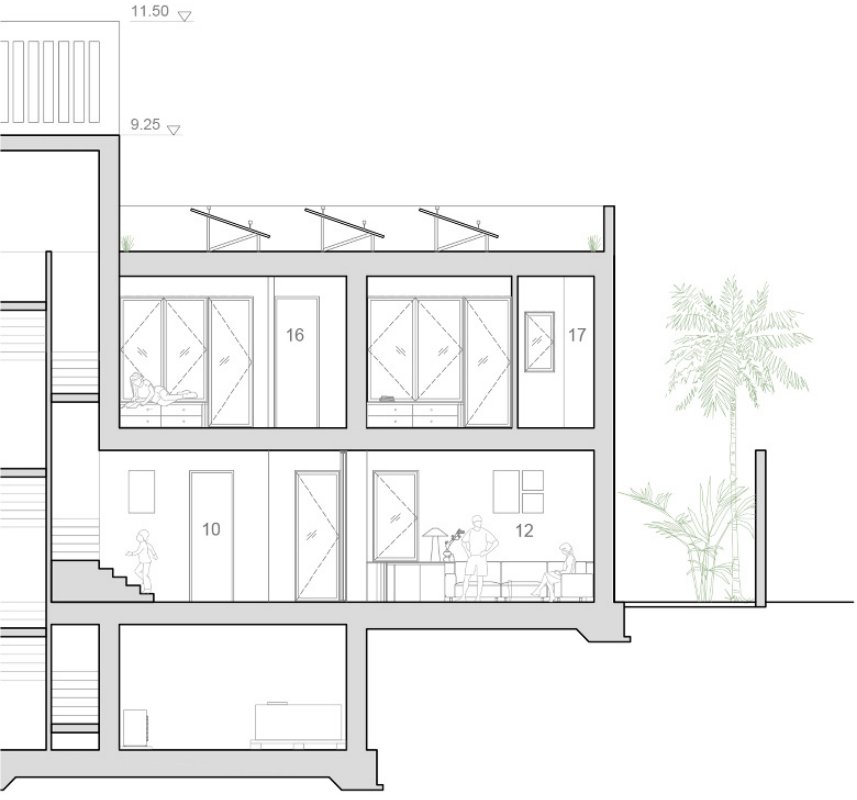


Figure 79

Lateral section showing the interior and the circulation

Note. Created by the author




11.50
9.25
16
17
10
12


0 1 2 3 4 5 10m

5.2.4 Materials and Building Systems

Building Envelope Strategy

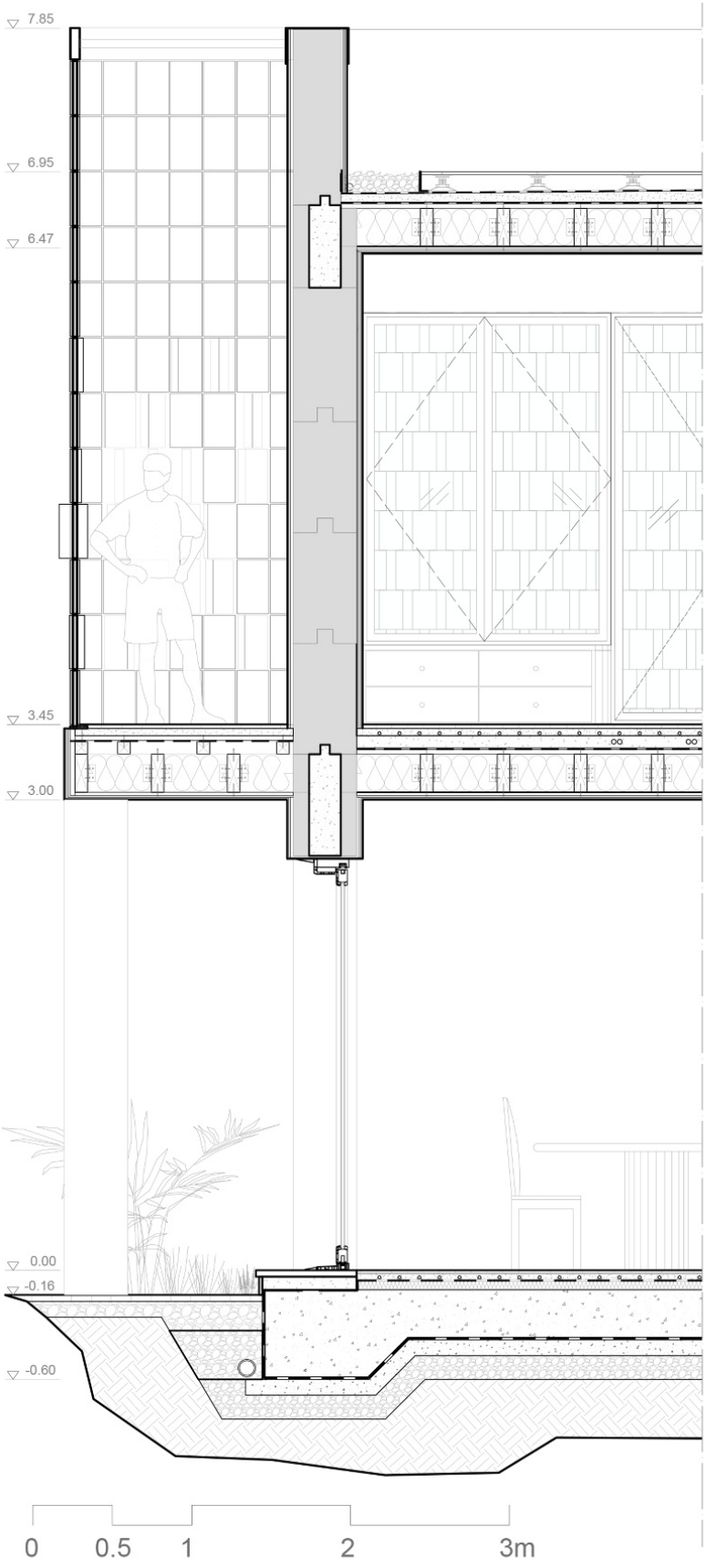
The building envelope for the proposed courtyard house is developed as a continuous, hygroscopic, timber and earth-based system, addressing Dubai's mandatory Al Sa'fat Green Building Regulations while advancing a passive, climatically responsive design logic rooted in Gulf vernacular construction. Each assembly, wall, roof, internal floor, and foundation, is evaluated against its corresponding thermal transmittance (U-value) requirement established under the Dubai Green Building Regulations and Specifications (Dubai Municipality, 2011).

External Wall Assembly

The external wall (thermal envelope), totaling 470mm, is composed, from interior to exterior, of limewash, fine hydraulic lime plaster, hemp-lime, a 400mm stabilized compressed earth block (CEB) core, hemp-lime, fine hydraulic lime plaster, and an exterior limewash finish. This assembly achieves a calculated U-value of 0.55 W/m²K. Dubai Municipality (2011) mandates a maximum external wall U-value of 0.57 W/m²K, the minimum compliance threshold for all new buildings in Dubai. The proposed wall therefore meets this mandatory requirement, though with a comparatively narrow margin, reflecting the deliberate decision to retain the CEB core at full 400mm thickness specifically to satisfy this threshold rather than optimize for spatial efficiency. Beyond the steady-state U-value, the wall's dynamic thermal behavior, a thermal lag of approximately 18.5 hours and an attenuation factor of 0.017, offers a more complete account of its performance in a hot-arid climate, where diurnal temperature swing, not constant heat flow, is the dominant thermal driver.

Figure 80

D-01: Detail section showing the structure and materials of the buildings



Flat Roof - (480mm)
U=0.16 W/m²K

1. UAE limestone slabs on pedestals – 30-100mm (Gravel ballast – 100mm, non-walked zones)
2. Bituminous waterproofing membrane – doubles as vapor barrier
3. Screed - 50mm – laid to falls
4. Separation/slip membrane
5. Timber board – 30mm
6. Timber joists 80x240mm filled with rockwool – 240mm
7. Timber board – 30mm
8. Clay building board – 10mm (plaster substrate)
9. Clay base plaster – 15mm
10. Clay fine plaster – 5mm
11. Limewash (final ceiling finish coat)

External Wall (thermal envelope) - (470mm)
U=0.55 W/m²K

1. Limewash (interior finish)
2. Fine hydraulic lime plaster – 5mm
3. Hemp-lime – 30mm
4. Stabilized earth block (CEB) – 400mm, primary structural wall
5. Hemp-lime – 30mm
6. Fine hydraulic lime plaster – 5mm
7. Limewash – 2mm (exterior finish)

Ceilling (internal) - (470mm)
U=0.15 W/m²K

1. Tiles – 30mm
2. Screed + floor cooling – 50mm
3. Pipes + light concrete with foam – 80mm
4. Waterproof membrane
5. Timber board – 30mm
6. Rockwool – 240mm (within timber joists, 80x240mm)
7. Timber board – 30mm
8. Clay building board – 10mm (plaster substrate)
9. Hydraulic lime base coat plaster
10. Hydraulic lime fine coat plaster
11. Limewash (ceiling finish, underside)

Vertical shading elements

1. Compressed earth blocks (CEB) : weatherproof lime-casein coating with slate mica additive 340x200x60mm
2. Fixed metal rod passes through the center of the blocks that are stacked vertically
3. Metallic coating is put inside a central hole in the rotatable blocks (up until 2.1 meters, humanly accessible) to prevent deterioration when blocks are rotated
4. spacers are placed between each block

Timber-Aluminum windows

Uw=1.2W/m²K

Double glazed timber windows with external aluminum face and frame

Raft Foundation and floor- (680mm)

1. U=0.47 W/m²K
2. Tiles – 30mm
3. Screed + floor cooling – 50mm
4. Waterproof membrane
5. XPS Thermal Insulation - 50mm
6. Reinforced concrete Raft foundation - 300mm (footings under the walls - 550mm)
7. Bituminous waterproofing membrane against pressing water
8. Lean concrete - 100mm
9. Gravel - 150mm

Note. Created by the author

Roof Assembly

The flat roof assembly, totaling 480mm, is designed as an accessible terrace using UAE limestone slabs on adjustable pedestals over a bituminous waterproofing membrane, which functions simultaneously as the vapor barrier given its continuous, fully-adhered, vapor-closed composition. Beneath this, a screed laid to falls, a separation membrane, and a timber joist structure (80x240mm) filled with rockwool insulation complete the thermal envelope, finished internally with a clay board substrate, clay plasters, and a limewash coat. This assembly achieves a calculated U-value of 0.16 W/m²K, substantially exceeding the mandatory roof maximum of 0.3 W/m²K set by Dubai Municipality (2011), performing at roughly half the regulatory ceiling. This margin supports the roof's role as the building's primary thermal buffer, consistent with Al Sa'fat's own naming convention, Sa'fat referring to the traditional use of palm fronds as a cooling roofing technique in Gulf construction (Dubai Municipality, 2011).

Internal Floor and Ceiling Assembly

The internal floor separating ground and first-floor levels follows a comparable timber-joist logic, adapted from standard light-frame floor construction methods (Ching, 2014), with UAE limestone tile flooring, an integrated floor cooling screed, light concrete infill, and a waterproof membrane above a rockwool-insulated timber joist cavity (80x240mm), finished on its underside with a clay board substrate, hydraulic lime plasters, and a limewash coat. This assembly achieves a calculated U-value of 0.15 W/m²K. As an internal separation between two conditioned levels rather than an external envelope element, this floor is not subject to a mandatory Al Sa'fat threshold (Dubai Municipality, 2011), but its performance is reported for consistency, demonstrating that the same rockwool-timber logic

applied at the roof produces comparable thermal resistance when repeated at an internal horizontal plane.

Foundation

The raft foundation and ground floor assembly, totaling 680mm, addresses Dubai's sabkha soil conditions and shallow water table through a layered strategy: limestone tile flooring and a floor-cooling screed above a waterproof membrane, XPS thermal insulation, a 300mm reinforced concrete raft (thickened to 550mm beneath load-bearing walls), a bituminous waterproofing membrane resisting rising groundwater pressure, a lean concrete blinding layer, and a granular gravel sub-base acting as a capillary break against sulfate-laden groundwater. This assembly achieves a calculated U-value of 0.47 W/m²K, meeting the mandatory ground floor requirement of 0.57 W/m²K (Dubai Municipality, 2011) with reasonable margin.

Windows

Openings are specified as double-glazed timber-aluminum composite windows, with an internal timber face for thermal comfort and material continuity with the building's earth-timber envelope, and an external aluminum cladding face providing weather resistance and reduced maintenance, a configuration widely used in high-performance European glazing systems (Finestre, n.d.). The specified assembly achieves Uw = 1.2 W/m²K, comfortably below the glazing requirement of 2.0 W/m²K with a maximum Solar Heat Gain Coefficient of 0.25 mandated by Dubai Municipality (2011), reflecting a deliberate over-performance strategy to offset solar heat gain risk given the extensive courtyard-facing glazing typical of this typology.

Precedent Grounding

These material decisions extend directly from precedent analysis conducted on the 2024 and 2023 competition-winning courtyard house designs, House of Courts and Block Yard respectively (Architecture Competitions, n.d.), which demonstrated the viability of timber-frame earth composite envelopes and CEB monolithic construction within comparable hot-arid, high-sustainability design briefs.

Wind Tower and Water/Energy Systems Integration

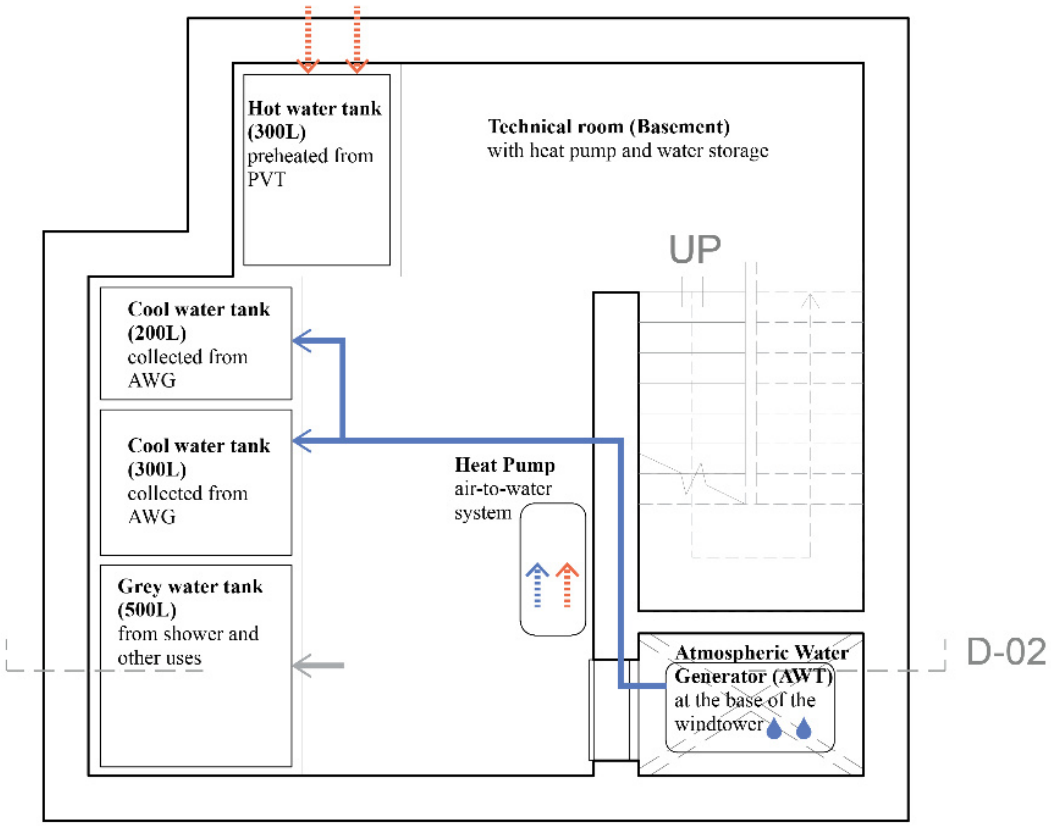
Figure 81 shows the wind tower in section, drawing air from the north-west through a fixed internal X-blade, a mosquito net, and a removable dust filter before passing over PeriCool-type evaporative water pads that cool the incoming air (Pericoli, n.d.). Excess water droplets are collected by a pump and basin below the pads. At the top of the shaft, an insulated roller shutter opens occasionally to allow drying and cleaning of the pads for hygiene purposes. Cooled air is distributed to habitable rooms through air vents connected to the wind tower via a corridor false ceiling, supplemented by floor cooling operated by a heat pump. PV and PVT panels are placed on the roof, generating electricity and preheating domestic hot water, with an automated antistatic coating and desalinated water spray system cleaning the panels when dust builds up. The passive and active systems used in this design draw on the strategies developed by the winning entries of the House of the Future competition (House of the Future , 2023/24 and 2024/25).

Figure 81 shows the basement technical room in plan, where an atmospheric water generator (AWG) is positioned at the base of the wind tower, in the most humid part of the system, to maximize water yield (Aquaria, n.d.). The building's main water source is the

municipality network, while potable water is fully operated by the AWG, which feeds two cool water tanks (200L and 300L). A separate 500L grey water tank stores water from showers and other household uses, and a 300L hot water tank is preheated by the PVT panels. An air-to-water heat pump serves the floor cooling and hot water systems. Battery storage is kept separate from the technical room, located instead in dedicated storage rooms on the ground floor.

Figure 81

Total energy loads per year obtained from the Honeybee-Grasshopper energy model

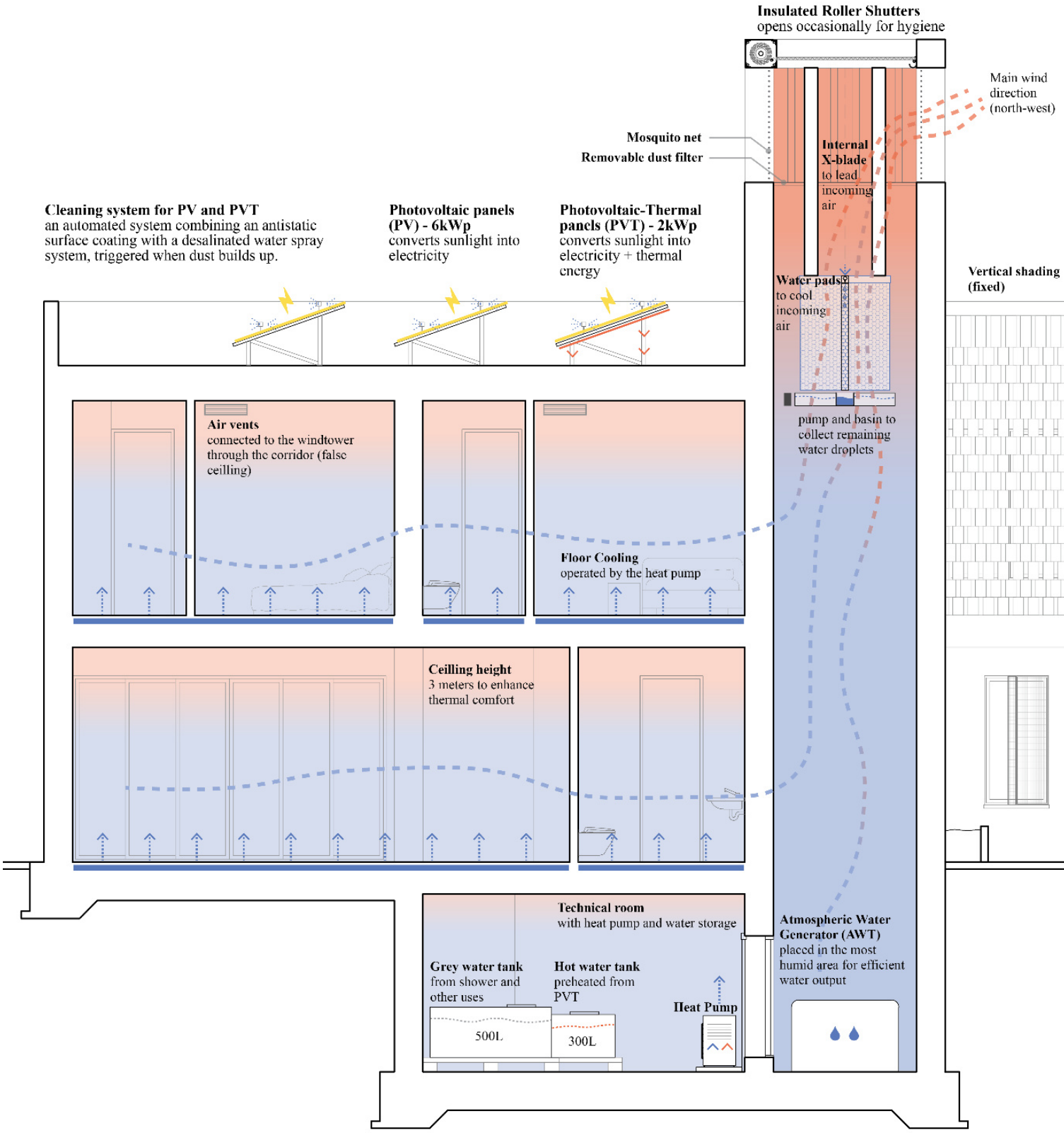


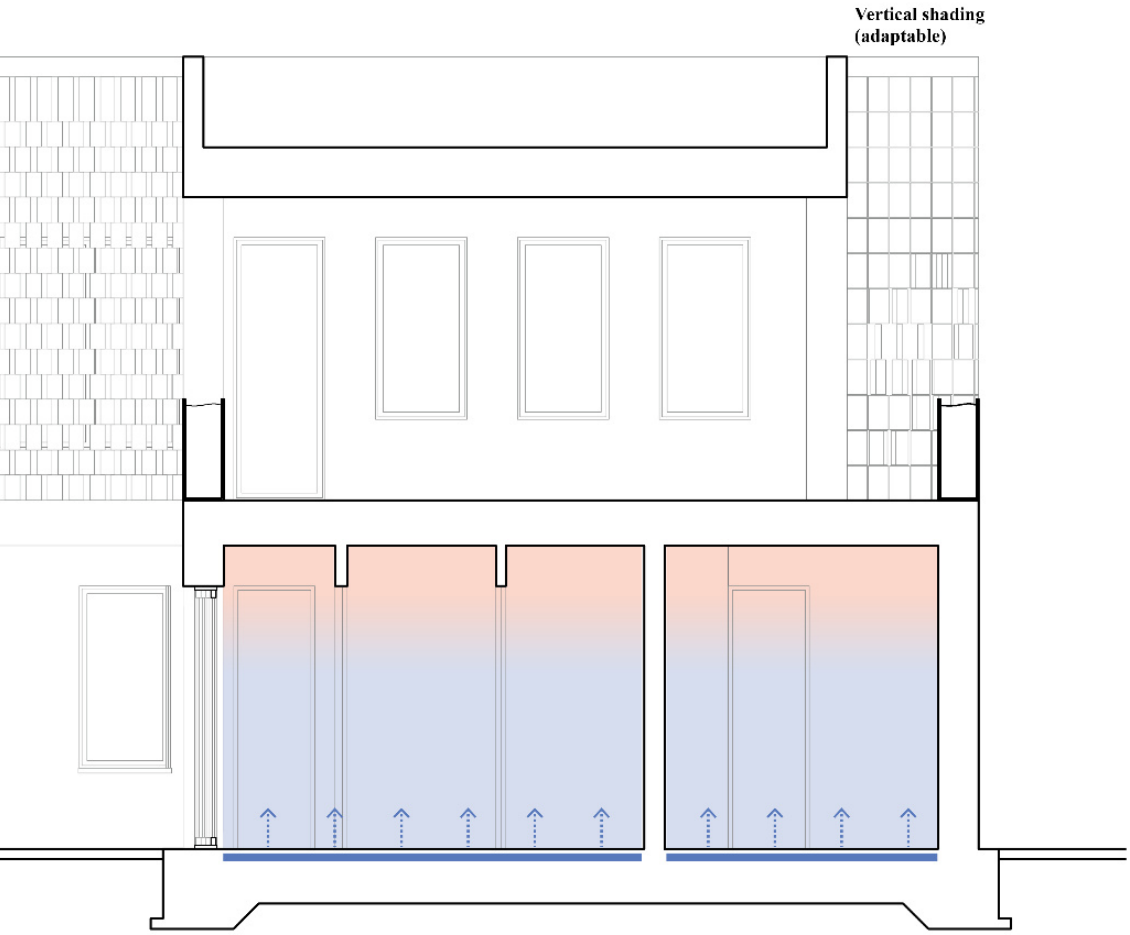
Note. Created by the author

Figure 82

Detail Section showing the Cooling Systems, Wind Tower and Water/Energy Systems Integration

Note. Created by the author




Vertical shading
(adaptable)


0
1
2
3
4
5m

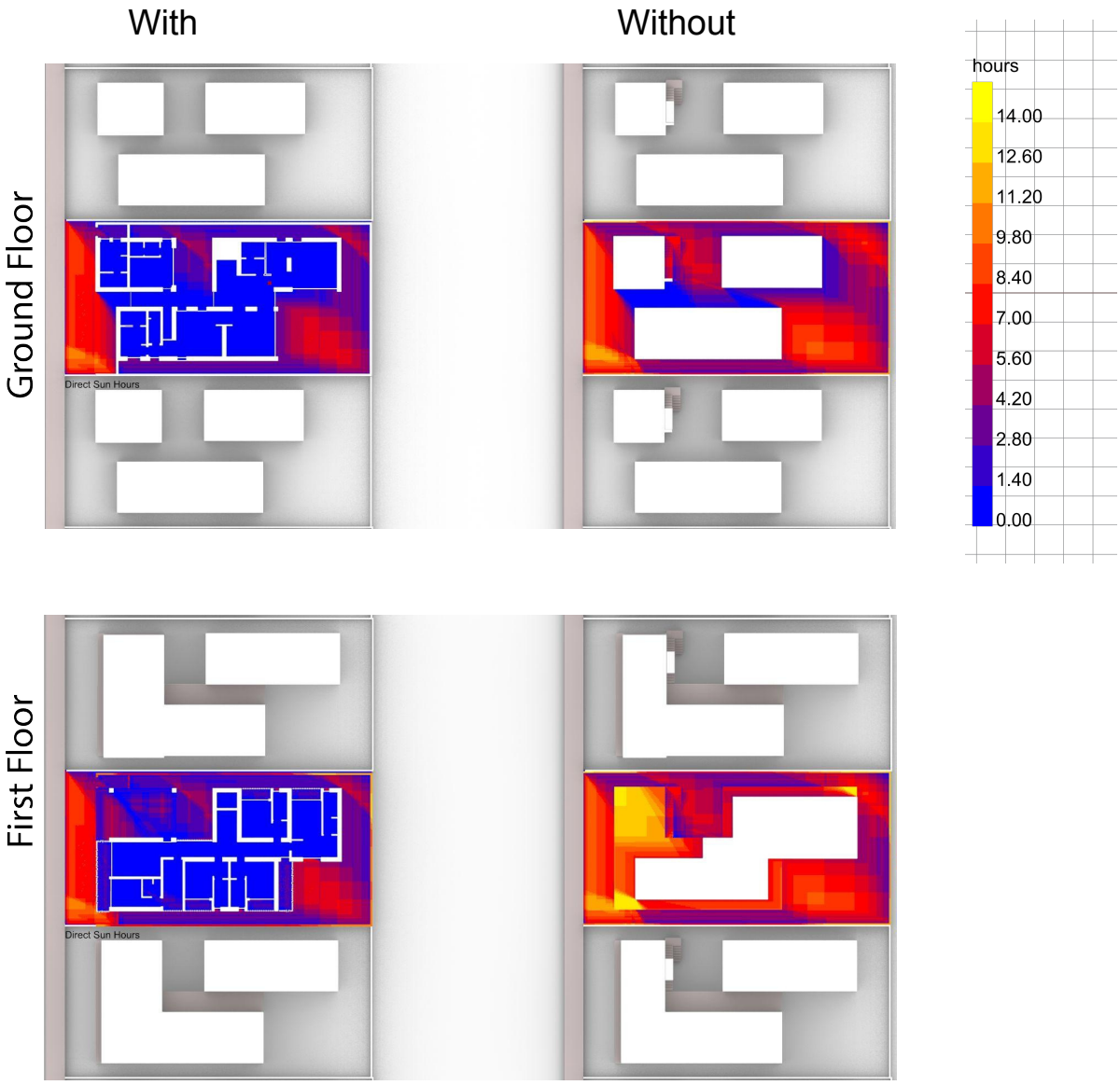
5.2.5 Cooling Energy Demand

Direct Sun Hours During the Summer Solstice

The direct sun hours reaching the building's interior were analyzed during the summer solstice to evaluate the effectiveness of the vertical shading elements described (Figure 83). Without shading, the ground- and first-floor interiors receive approximately 8 to 14 hours of direct sunlight across most of their footprint, with the highest exposure concentrated along the west- and south-facing edges. With the shading elements in place, direct sun exposure is reduced to approximately 0 to 1.4 hours across the majority of the interior on both floors, while higher exposure remains largely limited to the building perimeter rather than the occupied interior spaces. The results demonstrate the contribution of the rotatable CEB shading system to reducing solar heat gain before reliance on mechanical cooling, supporting the passive-first design approach established throughout the thesis.

Figure 83

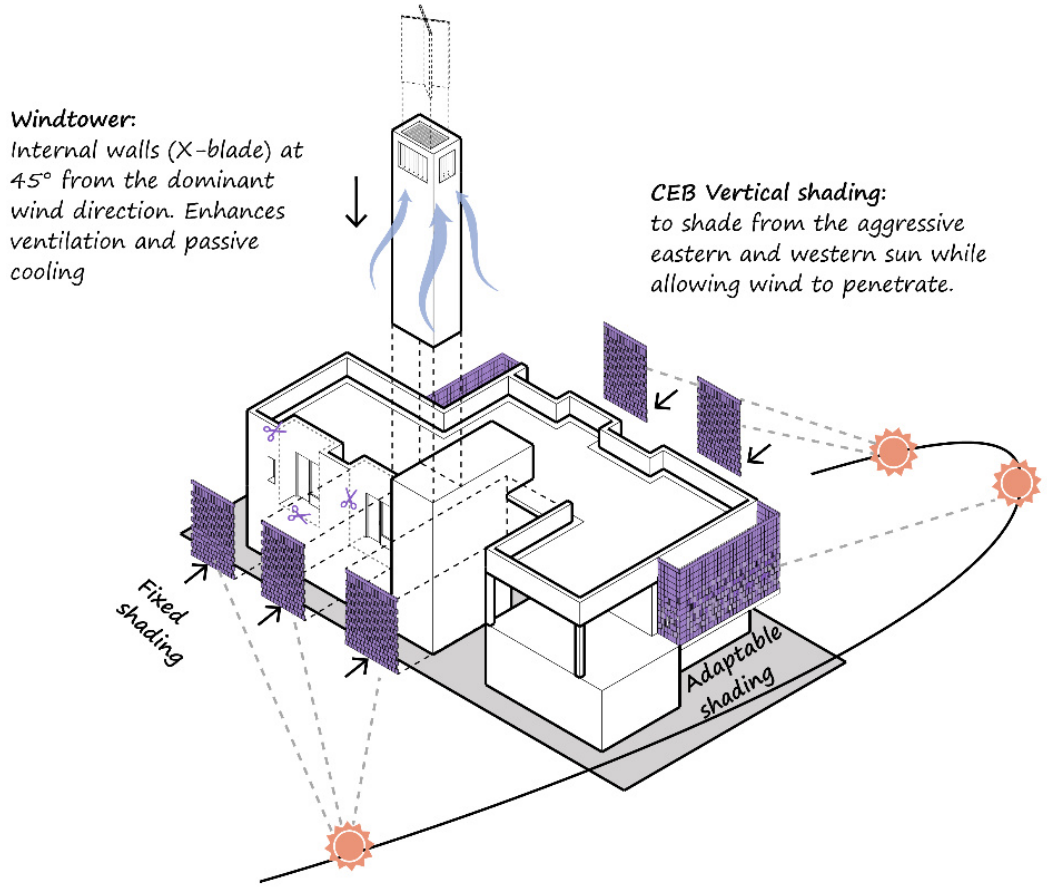
Direct Sun Hours During Summer Solstice



Note. Created by the author

Figure 84

Diagram showing the integration of passive solutions on the building volume.



Note. Created by the author

The building's passive strategies are shown integrated on the massing in Figure 84, illustrating how the wind tower and shading system operate together on the same volume. The wind tower's internal X-blade is set at 45° from the dominant north-west wind direction to maximize capture and enhance passive ventilation and cooling. Alongside it, fixed and adaptable CEB vertical shading elements are positioned to intercept the low-angle eastern and western sun, the most aggressive exposure condition on site, while their perforated arrangement still allows wind to pass through toward the tower. This combination illustrates

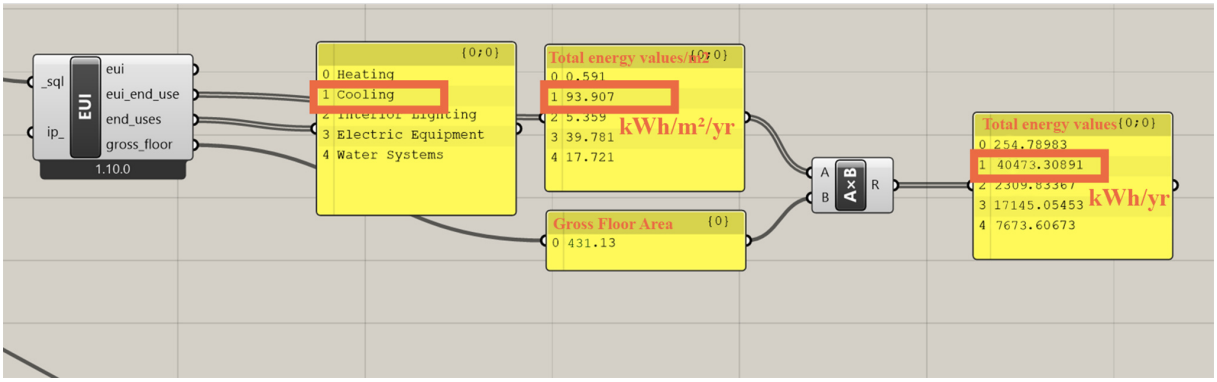
the design's passive-first logic at the volumetric scale, with the wind tower and shading system positioned to work together rather than as separate, independently resolved elements.

Simulation methodology

The building's cooling energy demand was quantified using a parametric energy model developed in Honeybee (Ladybug Tools) within Grasshopper for Rhino, with EnergyPlus as the simulation backend and the Al Minhad TMYx weather file representing the site's climate. The reported figures include the corrected material assemblies (400mm CEB wall, hemp-lime and lime plaster layers, roof and floor buildups) and the shading strategy, but do not yet include the ventilation contribution of the wind tower.

Figure 85

Total energy loads per year obtained from the Honeybee-Grasshopper energy model.



Note. Created by the author

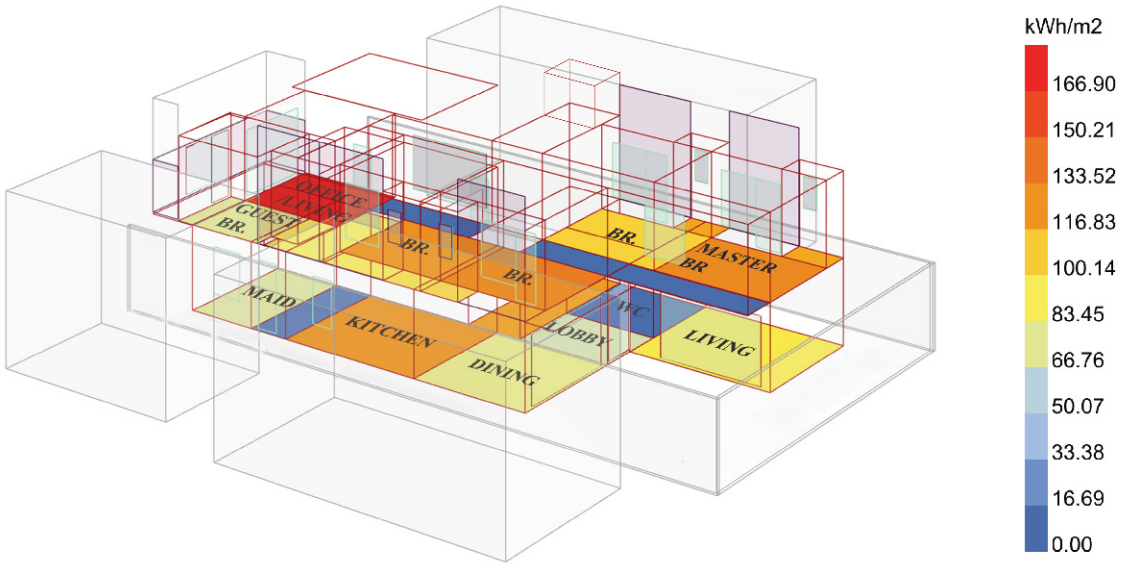
Simulated result

Across a gross floor area of 431 m2, the model returns an annual cooling energy demand of 40,473.31 kWh, equivalent to an intensity of 93.91 kWh/m2/year (Figure 85). This result sits alongside four other end uses returned by the same simulation: heating (0.591 kWh/

m2/yr), interior lighting (5.359 kWh/m2/yr), electric equipment (39.781 kWh/m2/yr), and water systems (17.721 kWh/m2/yr), giving a combined building energy use intensity of approximately 157.4 kWh/m2/year across all end uses.

Figure 86

Total energy loads per year of each room, obtained from the Honeybee-Grasshopper energy model .



Note. Created by the author

The zone-level distribution of this cooling demand (Figure 86) is consistent with the building's massing and program logic. The highest-intensity zone is the first-floor office/ living space, a result of its position directly beneath the roof without the buffering of a floor above, combined with longer occupancy schedules, higher equipment density, and view-oriented glazing relative to sleeping and service spaces. The lowest-intensity zones correspond to circulation and service spaces, including the corridor route connecting rooms to

the wind tower via the false ceiling, which carry minimal internal gains and reduced glazing exposure. Most habitable rooms across both floors fall within a mid-range band, indicating broadly consistent envelope performance across the plan.

Comparison with reference case

The project's cooling load was compared against a regulation-compliant villa case study in Dubai's Jumeirah Park, modeled under current Dubai Green Building Regulations and Specifications (GBRS) using IESVE. Thermal simulation for this base case recorded the villa's annual cooling load as 45.9019 MWh across a case study villa in Dubai Jumeirah Park with a total built-up area of 262 m2 (Abu-Hijleh & Jaheen, 2019), normalizing to approximately 175 kWh/m2/year. As this is a code-compliant rather than a conventional baseline, it represents current mainstream regulatory practice in Dubai rather than an unregulated legacy villa.

Figure 87

Table comparing the results obtained, with the results from Jumeirah Park villa, (Abu-Hijleh & Jaheen, 2019)

Case	Basis	Cooling load (kWh/m2/yr)
Jumeirah Park villa, GBRS-compliant (Abu-Hijleh & Jaheen, 2019)	Cooling load only, thermal	~175
Project result	Cooling load only, thermal, shading included, wind tower not yet included	**~93.91** **(46.3% reduced)**

Note. Created by the author

Against this baseline, the project's simulated cooling load represents a reduction of approximately 46.3%. This reduction is achieved through the combination of the 400mm stabilized CEB wall assembly, whose dynamic thermal lag and attenuation performance contributes materially to reducing peak and cumulative cooling demand beyond what a steady-state comparison captures (Figure 87), a constrained window-to-wall ratio of approximately 20% against the 14% recorded in the Jumeirah Park case, and an integrated shading strategy, achieved before the wind tower's ventilation contribution is accounted for.

5.2.6 Embodied Carbon Calculation

The embodied carbon of the proposed dwelling was assessed following the RICS *Whole Life Carbon Assessment for the Built Environment* Professional Standard (2nd edition) (RICS, 2023), aligned with the EN 15978 lifecycle module structure. Given the constraints of a single researcher working within a thesis timeline, the assessment was limited to the upfront carbon stages, product stage (A1-A3, raw material extraction, transport to manufacturer, and manufacturing) together with transport to site (A4) and construction-stage impacts (A5, comprising material wastage and site construction energy). Later lifecycle stages, in-use replacement (B), operational carbon (B6), and end-of-life (C), fall outside the scope of this study and are identified as an area for further research. This scope, commonly referred to as "upfront carbon" or A1-A5, is the primary metric against which current UK and international benchmarks (LETI, RIBA 2030 Climate Challenge) are calibrated, allowing the result to be compared directly against established industry targets.

Material quantities were derived from a layer-by-layer take-off of each building assembly. Carbon factors were sourced from the Inventory of Carbon and Energy (ICE) Database where available, supplemented by literature-derived values for vernacular materials,

stabilized earth block and hemp-lime, that lack standard database entries. Transport distances and modes were assigned per material based on reasoned assumptions of local United Arab Emirates sourcing (for stabilized earth block, limestone, and reinforced concrete) versus imported components (for timber, mineral wool insulation, and clay-based boards), following the RICS default distance-category approach (RICS, 2023). Construction waste rates were applied per material category, and site construction energy (A5.1) was estimated using RICS's own published baseline default of 25 kgCO2e per square meter of gross internal area, in the absence of contractor-specific site energy data.

Figure 88

Tables of each building element, showing the layer-by-layer material quantities along with the Embodied carbon assessment of each layer

External Wall (thermal envelope) | Total thickness: 470mm | U = 0.55 W/m2K								
Net wall area (gross wall area minus window/door openings), m2:						**587.5**	*m^2 (input net area)*	
Layer #	**Material**	**Thickness (m)**	**Volume (m3)**	**Density (kg/m3)**	**Carbon Factor A1-A3 (kgCO2e/kg)**	**Mass (kg)**	**Embodied Carbon A1-A3 (kgCO2e)**	**Source / Notes**
1	Limewash (interior finish)	**0.002**	1.175	**1600**	**0.75**	1,880.0	**1,410.0**	*CF: lime binder ECF ~0.78 kgCO2e/kg (thewoodlouse.blogspot.com, Embodied and Disembodied Carbon)*
2	Fine hydraulic lime plaster	**0.005**	2.938	**1600**	**0.35**	4,700.0	**1,645.0**	*CF: finished NHL plaster estimate (CAT/Pritchett, Building with Hemp and Lime)*
3	Hemp-lime (interior side)	**0.030**	17.625	**450**	**0.11**	7,931.3	**872.4**	*CF: hempcrete gross A1-A3 estimate, pre-biogenic credit (Hempshed/Limetechnology datasheet 2011)*
4	Stabilized earth block (CEB) - primary structural wall	**0.400**	235.000	**1900**	**0.05**	446,500.0	**22,325.0**	*CF: CSEB LCA literature estimate (ScienceDirect, low-cement stabilized earth) - not in ICE default DB, cite source*
5	Hemp-lime (exterior side)	**0.030**	17.625	**450**	**0.11**	7,931.3	**872.4**	*CF: hempcrete gross A1-A3 estimate, pre-biogenic credit (Hempshed/Limetechnology datasheet 2011)*
6	Fine hydraulic lime plaster	**0.005**	2.938	**1600**	**0.35**	4,700.0	**1,645.0**	*CF: finished NHL plaster estimate (CAT/Pritchett, Building with Hemp and Lime)*
7	Limewash (exterior finish)	**0.002**	1.175	**1600**	**0.75**	1,880.0	**1,410.0**	*CF: lime binder ECF ~0.78 kgCO2e/kg (thewoodlouse.blogspot.com, Embodied and Disembodied Carbon)*
	TOTAL						**30,179.9**	
	Embodied Carbon per m2 of element (kgCO2e/m2)						**51.4**	

Flat Roof | Total thickness: 480mm | U = 0.16 W/m2K								
Roof area (inside face, excluding open courtyard), m2:						**174**	*m^2 (input net area)*	
Layer #	**Material**	**Thickness (m)**	**Volume (m3)**	**Density (kg/m3)**	**Carbon Factor A1-A3 (kgCO2e/kg)**	**Mass (kg)**	**Embodied Carbon A1-A3 (kgCO2e)**	**Source / Notes**
1	UAE limestone slabs on adjustable pedestals (walked zones)	**0.065**	11.310	**2500**	**0.06**	28,275.0	**1,696.5**	*CF: natural dimension stone A1-A3 estimate (Engine Shed / Historic Environment Scotland, Embodied Carbon of Natural Stone). Thickness ranges 30-100mm on drawing; 65mm used as average*
2	Screed, laid to falls	**0.050**	8.700	**2000**	**0.2**	17,400.0	**3,480.0**	*CF: cement-sand screed/mortar estimate, general literature range*
3	Timber board	**0.030**	5.220	**500**	**0.07**	2,610.0	**182.7**	*CF: softwood A1-A3 (Arup/IStructE, Embodied Carbon Timber guide)*
4	Timber joists 80x240mm, filled with rockwool	**0.240**	41.760	**60**	**1.5**	2,505.6	**3,758.4**	*CF: stone/mineral wool A1-A3 estimate (Historic England, range 1.4-4.2 kgCO2eq/FU). Rockwool fill only - report joist timber volume as a separate minor line if required for accuracy*
5	Timber board	**0.030**	5.220	**500**	**0.07**	2,610.0	**182.7**	*CF: softwood A1-A3 (Arup/IStructE, Embodied Carbon Timber guide)*
6	Clay building board (plaster substrate)	**0.010**	1.740	**700**	**0.1**	1,218.0	**121.8**	*CF: estimate for unfired clay/earth board, low-processing natural material - no dedicated EPD found, flagged as estimate*
7	Clay base plaster	**0.015**	2.610	**1800**	**0.1**	4,698.0	**469.8**	*CF: estimate for unfired clay plaster, low-processing natural material - no dedicated EPD found, flagged as estimate*
8	Clay fine plaster	**0.005**	0.870	**2000**	**0.1**	1,740.0	**174.0**	*CF: estimate for unfired clay plaster, low-processing natural material - no dedicated EPD found, flagged as estimate*
9	Limewash (final ceiling finish coat)	**0.002**	0.348	**1600**	**0.75**	556.8	**417.6**	*CF: lime binder ECF ~0.78 kgCO2e/kg (thewoodlouse.blogspot.com)*
	TOTAL						**10,483.5**	
	Embodied Carbon per m2 of element (kgCO2e/m2)						**60.3**	

Ceiling (internal) / Intermediate Floor | Total thickness: 470mm | U = 0.15 W/m2K								
Floor area for this level (excluding courtyard), m2:						**242**	*m^2 (input net area)*	
Layer #	**Material**	**Thickness (m)**	**Volume (m3)**	**Density (kg/m3)**	**Carbon Factor A1-A3 (kgCO2e/kg)**	**Mass (kg)**	**Embodied Carbon A1-A3 (kgCO2e)**	**Source / Notes**
1	Tiles (UAE limestone)	**0.030**	7.260	**2500**	**0.06**	18,150.0	**1,089.0**	*CF: natural dimension stone A1-A3 estimate (Engine Shed / Historic Environment Scotland)*
2	Screed + floor cooling pipework	**0.050**	12.100	**2000**	**0.2**	24,200.0	**4,840.0**	*CF: cement-sand screed/mortar estimate, general literature range; pipework carbon reported separately if required*
3	Pipes + light concrete with foam	**0.080**	19.360	**800**	**0.2**	15,488.0	**3,097.6**	*CF: lightweight foamed concrete estimate, similar order to standard screed per kg*
4	Timber board	**0.030**	7.260	**500**	**0.07**	3,630.0	**254.1**	*CF: softwood A1-A3 (Arup/IStructE, Embodied Carbon Timber guide)*
5	Rockwool (within 80x240mm timber joists)	**0.240**	58.080	**60**	**1.5**	3,484.8	**5,227.2**	*CF: stone/mineral wool A1-A3 estimate (Historic England, range 1.4-4.2 kgCO2eq/FU)*
6	Timber board	**0.030**	7.260	**500**	**0.07**	3,630.0	**254.1**	*CF: softwood A1-A3 (Arup/IStructE, Embodied Carbon Timber guide)*
7	Clay building board (plaster substrate)	**0.010**	2.420	**700**	**0.1**	1,694.0	**169.4**	*CF: estimate for unfired clay/earth board, low-processing natural material - flagged as estimate*
8	plaster	**0.005**	1.210	**1600**	**0.35**	1,936.0	**677.6**	*CF: finished NHL plaster estimate (CAT/Pritchett)*
9	plaster	**0.005**	1.210	**1600**	**0.35**	1,936.0	**677.6**	*CF: finished NHL plaster estimate (CAT/Pritchett)*
10	Limewash (ceiling finish, underside)	**0.002**	0.484	**1600**	**0.75**	774.4	**580.8**	*CF: lime binder ECF ~0.78 kgCO2e/kg (thewoodlouse.blogspot.com)*
	TOTAL						**16,867.4**	
	Embodied Carbon per m2 of element (kgCO2e/m2)						**69.7**	

Raft Foundation and Ground Floor | Total thickness: 680mm | U = 0.47 W/m2K								
Ground floor footprint area (raft area, excluding courtyard), m2:						209	m^2 (input net area)	
Layer #	Material	Thickness (m)	Volume (m3)	Density (kg/m3)	Carbon Factor A1-A3 (kgCO2e/kg)	Mass (kg)	Embodied Carbon A1-A3 (kgCO2e)	Source / Notes
1	Tiles (UAE limestone)	0.030	6.270	2500	0.06	15,675.0	940.5	CF: natural dimension stone A1-A3 estimate (Engine Shed / Historic Environment Scotland)
2	Screed + floor cooling	0.050	10.450	2000	0.2	20,900.0	4,180.0	CF: cement-sand screed/mortar estimate, general literature range
3	XPS thermal insulation	0.050	10.450	35	3.3	365.8	1,207.0	CF: XPS A1-A3, standard ICE-range value for extruded polystyrene
4	Reinforced concrete raft foundation (footings under walls - 550mm)	0.300	62.700	2500	0.15	156,750.0	23,512.5	CF: RC32/40-class concrete, mid-range of ICE 124-176 kgCO2e/t by strength (IStructE, A short guide to embodied carbon). 300mm typical slab; footings under walls thicker at 550mm - model as separate line if footing volume is significant
5	Lean concrete	0.100	20.900	2100	0.11	43,890.0	4,827.9	CF: lower-strength/lower-cement blinding concrete, ICE RC20/25-class range
6	Gravel	0.150	31.350	1600	0.005	50,160.0	250.8	CF: virgin aggregate/gravel, standard ICE low value for extraction-only processing
	TOTAL						34,918.7	
	Embodied Carbon per m2 of element (kgCO2e/m2)						167.1	

Note. Created by the author

Building Elements Assessed

The 470 mm external wall thermal envelope assembly (Figure 88), consisting of limewash, hydraulic lime plaster, hemp-lime, and a 400 mm stabilized compressed earth block (CEB) core, was assessed as the primary structural and thermal element of the dwelling. The CEB core, sourced from a local Dubai precast supplier, represents the largest proportion of both the mass and carbon performance of the assembly, while benefiting from a substantially lower carbon factor than conventional masonry alternatives.

The flat roof assembly consists of UAE limestone paving on pedestals, a timber-joist cavity insulated with rockwool, and a clay plaster ceiling finish. Regionally sourced stone and screed represent the dominant contribution to the transport and waste profile, while imported timber and mineral wool account for a smaller proportion of the overall mass. The intermediate floor and basement ceiling assemblies incorporate integrated floor-cooling pipework, foamed lightweight concrete, and a timber-joist cavity insulated with rockwool.

The roof parapet and boundary wall were modelled as single-material stabilized earth block construction (Figure 88), consistent with the external wall core and reflecting the continuation of the primary vernacular material strategy across both the building envelope and

site boundary. Similarly, the vertical CEB shading elements, which form a secondary passive design feature, were assessed as compressed earth block construction precast locally in Dubai alongside the primary wall blocks.

The reinforced concrete foundation and retaining walls were assessed using the same material assumptions as the raft foundation due to their shared structural role and likely use of the same concrete mix. The internal staircase was assessed as precast reinforced concrete fabricated locally in Dubai, benefiting from the lower waste rate associated with factory-controlled precast production compared with in-situ concrete.

Finally, the double-glazed timber-aluminium composite window and door system, with a total area of 102 m², was assessed using a literature-derived carbon intensity per square metre of window area (Figure 88). The value was interpolated between published benchmarks for timber-framed and aluminium-framed glazing systems to reflect the intermediate carbon performance of the composite system.

Results

The assessed dwelling returned a total embodied carbon of 118,365 kgCO2e for the product stage (A1-A3), equivalent to a carbon intensity of 274.6 kgCO2e per square metre of gross floor area (431 m²) (Figure 89). Extending the assessment to include transport (A4) and construction impacts (A5) raised the total to 141,856 kgCO2e (A1-A5), equivalent to an intensity of 329.1 kgCO2e/m². The addition of A4 and A5 increased the upfront carbon total by approximately 20 percent relative to A1-A3 alone, consistent with the proportional uplift typically reported in comparable whole-life carbon studies.

Figure 89

Embodied Carbon Assessment of Building Elements, Including Material Quantities, Transport, and Construction Waste

WHOLE-BUILDING SUMMARY (A1-A5)								
Gross Floor Area (GFA), m2 (input):					431			
Element Workings								
Building Element	**Thickness (m)**	**Mass (kg)**	**Density (kg/m3)**	**Embodied Carbon per m2 (kgCO2e/m2)**	**Volume (m3)**	**A4 Transport (kgCO2e)**	**A5 Construction Waste (kgCO2e)**	**Notes**
External Wall (thermal envelope) + internal walls	**0.47**	475,522.5	1,722	**51.4**	276.125	**2,139.9**	**1,509.0**	*Composite assembly - see External Wall table above. A4/A5 use dominant material (CEB) transport profile: 30km road (Dubai precast/local), WR 5% (masonry)*
Flat Roof	**0.48**	61,613.4	738	**60.3**	83.520	**1,386.3**	**524.2**	*Composite assembly - see Roof table above. A4/A5 use dominant material (UAE limestone/screed) transport profile: 150km road (regional UAE quarry), WR 5% (stone)*
Ceilings (internal) / Intermediate Floors	**0.47**	74,923.2	659	**69.7**	113.740	**1,123.8**	**1,012.0**	*Composite assembly - see Ceiling-Floor table above. A4/A5 use dominant material (screed/tiles) transport profile: 100km road (regional UAE), WR 6% (mortar/render)*
Raft Foundation and Ground Floor	**0.680**	287,740.8	2,025	**167.1**	142.120	**1,294.8**	**1,745.9**	*Composite assembly - see Foundation table above. A4/A5 use dominant material (RC) transport profile: 30km road (local Dubai batching plant), WR 5% (concrete in-situ)*
Roof Parapet	**0.300**	56,430.0	1,900	**28.5**	29.700	**169.3**	**141.1**	*CEB, precast Dubai. Volume 29.7 m3, thickness 0.30m. CF 0.05 kgCO2e/kg embedded. A4: 20km road, WR 5%*
Boundary Wall	**0.200**	79,800.0	1,900	**19.0**	42.000	**239.4**	**199.5**	*CEB, precast Dubai. Volume 42 m3, thickness 0.20m. CF 0.05 kgCO2e/kg embedded. A4: 20km road, WR 5%*
RC Foundation Walls	**0.400**	81,250.0	2,500	**150.0**	32.500	**365.6**	**609.4**	*RC, local Dubai batching. Volume 32.5 m3, thickness 0.40m. CF 0.15 kgCO2e/kg embedded. A4: 30km road, WR 5% (concrete in-situ)*
Vertical Shading Bricks (CEB)	**0.050**	11,590.0	1,900	**4.8**	6.100	**34.8**	**11.6**	*CEB, precast Dubai (per drawing: rotatable 340x200x60mm blocks). Volume 6.1 m3, thickness 0.05m. CF 0.05 kgCO2e/kg embedded. A4: 20km road, WR 2% (precast, lower waste)*
Precast Concrete Staircase	**0.165**	8,250.0	2,500	**61.9**	3.300	**24.8**	**12.4**	*Precast RC, Dubai. Volume 3.3 m3, thickness 0.165m. CF 0.15 kgCO2e/kg embedded. A4: 20km road, WR 1% (RICS precast concrete category)*
Windows and Glass Doors	*n/a*	4,080.0	*n/a*	**50.0**	*n/a (area-based)*	**18.4**	**153.0**	*Double-glazed timber-aluminium sliding/lift-slide (finestre.com product line), 102 m2 total. Mass estimated 40 kg/m2 (typical double-glazed timber-alu composite). EC/m2 A1-A3 = 50 kgCO2e/m2, interpolated between timber (40) and aluminium (76) frame benchmarks (Circular Ecology/ICE research). Assumed sourced/available locally in Dubai (not imported from country of manufacture) - A4: 30km road, WR 3% (specialist manufactured units, low waste) - all figures are literature-based estimates, no project-specific EPD available*
TOTAL						**6,797.0**	**5,918.1**	

Note. Created by the author

Figure 90

Summary of Embodied Carbon Results by Building Element for A1–A3 and A1–A5 (W*ith Their Intensity Per Square Meter)*

Results Summary		
Building Element	**Total EC A1-A3 (kgCO2e)**	**TOTAL A1-A5 (kgCO2e)**
External Wall (thermal envelope) + internal walls	30,179.9	33,828.7
Flat Roof	10,483.5	12,394.0
Intermediate Floors	16,867.4	19,003.3
Floor	34,918.7	37,959.4
Roof Parapet	2,821.5	3,131.9
Boundary Wall	3,990.0	4,428.9
RC Foundation Walls	12,187.5	13,162.5
(CEB)	579.5	625.9
Precast Concrete Staircase	1,237.5	1,274.6
Windows and Glass Doors	5,100.0	5,271.4
TOTAL (A1-A3 only)	**118,365.5**	
Energy (RICS default, 25 kgCO2e/m2 GIA)		**10,775.0**
GRAND TOTAL EMBODIED CARBON (A1-A5)		**141,855.5**

Embodied Carbon Intensity A1-A3 (kgCO2e / m2 GFA)	**274.6**	
Embodied Carbon Intensity A1-A5 (kgCO2e / m2 GFA)		**329.1**

Benchmark reference (LETI / RIBA 2030, A1-A5): < 600 kgCO2e/m2

Methodology notes

A4 formula (RICS WLCA 2nd ed.): mass (t) x distance (km) x [outbound factor + 0.5 x return factor]. Road freight factor 0.10 kgCO2e/t.km (DEFRA-style average); sea freight 0.02 kgCO2e/t.km (GLEC-style average); effective one-way-equivalent factor = base factor x 1.5

A5.3 (construction waste) approximated as: waste rate x element A1-A3 total (i.e. wasted material embodies carbon at the same intensity as installed material) - a standard simplification of RICS Table 10 default waste rate approach

A5.1 (site energy) applied once at whole-building level as a literature default (kgCO2e/m2 GFA), not per element, since site plant/energy use is not material-specific

Distances/modes are reasoned UAE-context assumptions (local Dubai/UAE sourcing for CEB, limestone, screed, RC, and windows; sea freight import assumed only for rockwool, timber, clay board, hemp-lime binder within the composite assemblies) - not measured supplier data. Refine with actual supplier locations for final submission

A4/A5 for the four composite assemblies (Wall/Roof/Ceiling/Foundation) are applied using each element's dominant-mass material as a representative transport/waste profile, not per individual layer

Note. Created by the author

Both results fall substantially below the LETI and RIBA 2030 Climate Challenge target of 500-600 kgCO2e/m² (A1-A5) (Figure 90) for residential buildings (LETI, 2020), and below the current best-practice benchmark of approximately 500 kgCO2e/m² reported by RICS's Net Zero Carbon Building Standard call-for-evidence dataset (RICS, 2023). This result substantiates the central thesis argument that passive, vernacular-derived construction strategies, centred on stabilized earth block and hemp-lime assemblies, can deliver a

measurable embodied carbon advantage over conventional construction, while remaining compatible with contemporary regulatory and rating-system benchmarks.

It is acknowledged that the assessment scope excludes mechanical, electrical, and plumbing systems, structural reinforcement within concrete elements, and later lifecycle stages beyond A5, and that several carbon factors for vernacular materials rely on literature estimates in the absence of dedicated Environmental Product Declarations. These limitations are identified as areas for refinement should project-specific data become available

5.2.7 Urban Design Strategy

Modular typology and adaptation. The urban strategy is built from a family of residential modules scaled to household size and social configuration. One-family modules (A, A', B, B') are oriented and mirrored to face the back road while preserving privacy between adjacent units, their orientation derived directly from the sun path and prevailing north-west wind. Two-family modules (C, C') merge pairs of one-family units, and four- and six-family modules (D, E) extend this logic further, incorporating ground-floor services to support higher-density clusters. Exterior finishes (white finish, clay, exposed CEB) are distributed across the modules to differentiate typologies while maintaining a coherent material palette rooted in vernacular construction. (Figure 91)

Clustering around water. Modules are grouped into clusters that orient around a shared water-collection space, drawing on the courtyard logic of the individual dwellings and reproducing it at urban scale. This shared space consolidates rainwater collection and grey

water natural filtering while acting as a cooler, shaded microclimatic anchor for each cluster, reinforcing passive cooling strategies beyond the building envelope. (Figure 91)

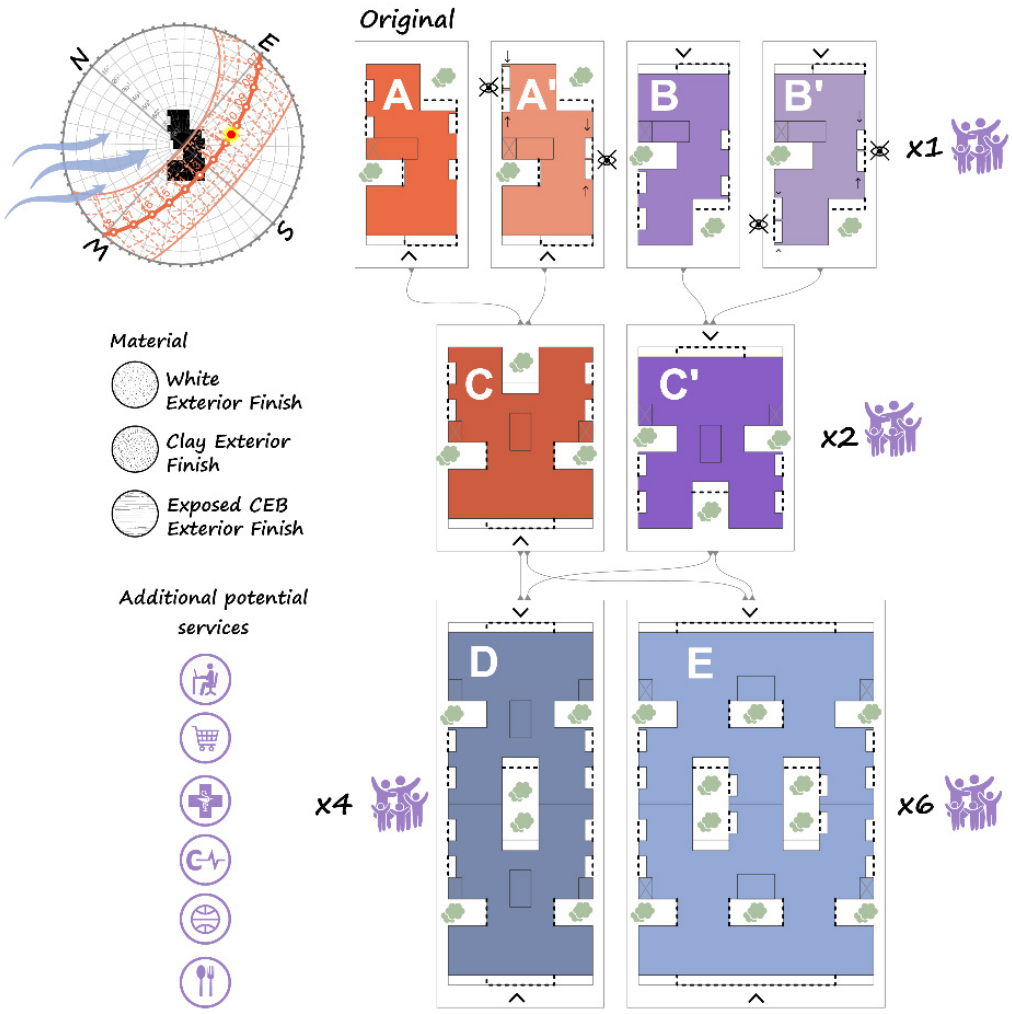
Incremental urban space. Four clusters are arranged around a central incremental urban space, a flexible void that can accommodate a saha, a mosque, additional clusters, or standalone buildings as the settlement grows. This space functions as the primary socializing and public realm of the group, introducing programmatic diversity while allowing the urban fabric to expand organically rather than through a fixed masterplan. (Figure 91)

Distribution and circulation. Groups of four clusters and their shared incremental space combine like puzzle pieces, generating further incremental spaces at the seams between groups. Vehicular roads run only longitudinally, aligned with the prevailing wind direction, so that buildings face the car routes while all other passages remain pedestrian-only. This hierarchy limits vehicular penetration into the fabric, prioritizes walkability, and ensures the road network itself reinforces passive ventilation at the urban scale, extending the wind-responsive logic of the individual dwelling to the settlement as a whole. (Figure 92)

Figure 91

Diagrams of the module types on an urban scale

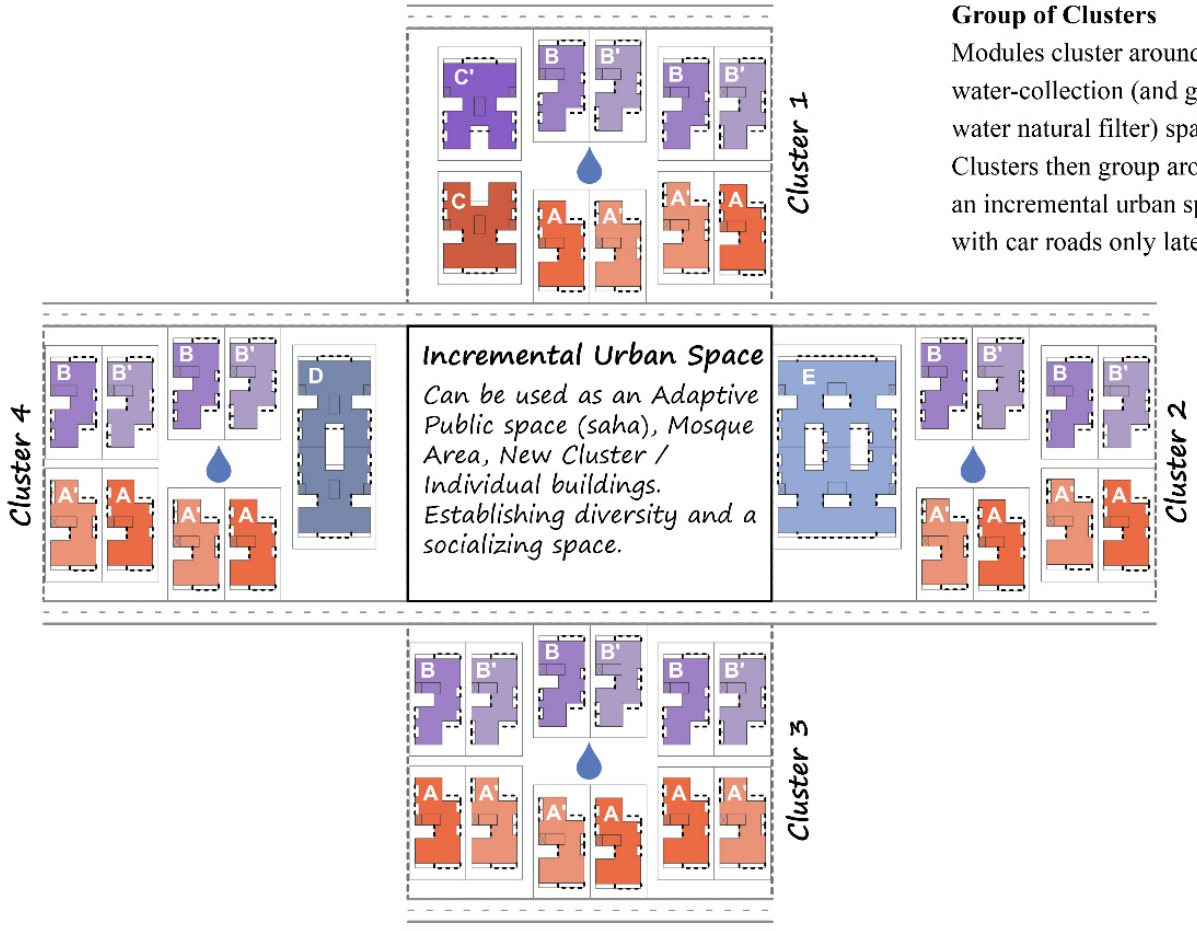
Note. Created by the author



One-Family Modules
Module B is a flipped version of module A to face the back road, adapted to sun and wind. Modules A' and B' are modified for privacy between buildings.

Two-Family Modules
Modules C and C' are merged verions of modules A-A' and B-B', adapted to the sun and wind direction

Four and Six-Family Modules
Modules D and E merge C and C', adapted to sun and wind. Unlike the other single-purpose modules, they're residential with added ground-floor services.

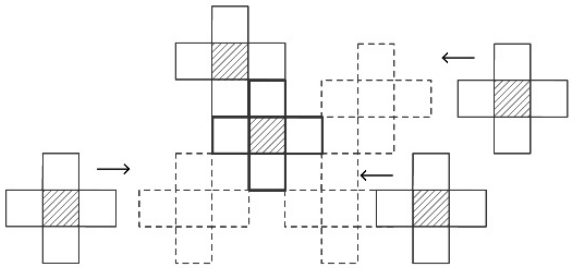


Group of Clusters
Modules cluster around a water-collection (and grey water natural filter) space. Clusters then group around an incremental urban space, with car roads only laterally.

Figure 92

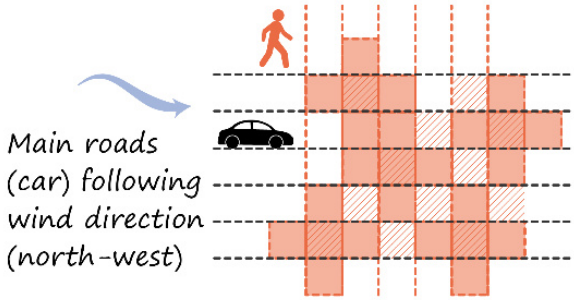
Diagrams of the urban design strategy and the urban distribution plan

Note. Created by the author



Urban Distribution Strategy

Groups(4 clusters + saha) are put together like a puzzle, forming more incremental spaces



Urban Routes

Internal roads run only longitudinally, with buildings facing them, to limit car movement. All other passages and spaces are pedestrian-only.



Urban Distribution

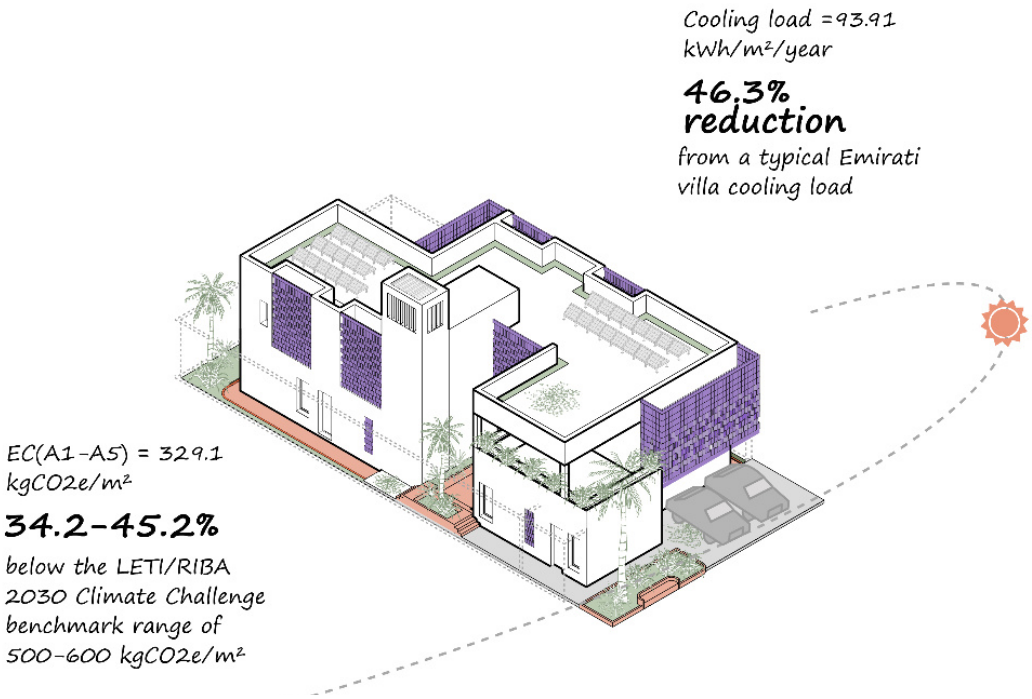
Groups of clusters form a puzzle-like shape that can combine flexibly with other groups, generating further incremental urban spaces for additional clusters, standalone buildings, a mosque with its saha, and more.

5.2.8 Goals Achieved

The design's key performance outcomes are summarized together in Figure 93. The proposal achieves a simulated cooling load of 93.91 kWh/m²/year, a 46.3% reduction relative to a typical Emirati villa cooling load, alongside an embodied carbon result of 329.1 kgCO2e/m² (A1-A5), 34.2-45.2% below the LETI/RIBA 2030 Climate Challenge benchmark range of 500-600 kgCO2e/m². Presenting both results together on the completed massing reinforces that the vernacular-derived envelope and shading strategy reduce operational cooling demand and upfront carbon simultaneously, rather than trading one for the other. The sections below evaluate the design proposal against the six research objectives established in the introduction, of which these results are the central evidence.

Figure 93

Summary of Key Design Performance Results



Note. Created by the author

The first objective, examining the UAE's climatic characteristics and their influence on residential design, informed the wind tower orientation and courtyard massing developed in the design concept (Figures 74-76). The second objective, investigating the spatial organization and passive strategies of traditional Emirati houses, was translated into the design through the courtyard-centric bubble diagram (Figure 74), the resulting plans and section (Figures 77-79), the reworked wind tower (Figure 82), and the CEB thermal mass envelope (Figure 80). The third objective, analyzing the transformation of residential architecture from traditional settlements to contemporary compounds, informed the urban diversity strategy: interactive shading, vertical and incremental expansion (Figure 76), and the cluster-based settlement growth strategy (Figures 91-92) were developed specifically to counter the repetitive compound logic identified in Chapter 3.

The fourth and fifth objectives, identifying adaptable vernacular principles and developing a low-carbon design proposal integrating them with modern technologies, are substantiated by the performance results themselves. The external wall, roof, and foundation assemblies meet Al Sa'fat's mandatory U-value thresholds (Dubai Municipality, 2011), with the wall's thermal lag of approximately 18.5 hours and attenuation factor of 0.017 demonstrating that the vernacular CEB logic performs beyond what steady-state compliance alone captures (Figure 80). The parametric energy model returned a cooling intensity of 93.91 kWh/m²/year, a 46.3% reduction against a GBRS-compliant reference villa (Abu-Hijleh & Jaheen, 2019), achieved before the wind tower's ventilation contribution is included (Figures 88-90). The embodied carbon assessment returned 329.1 kgCO2e/m² (A1-A5), well below the LETI and RIBA 2030 Climate Challenge benchmark of 500-600 kgCO2e/m² (LETI, 2020) (Figures 85-87).

The sixth objective, evaluating the proposal's environmental performance, cultural responsiveness, and contribution to sustainable residential architecture, is addressed across the chapter as a whole and is discussed further in the Conclusion. The site selection process additionally supported LEED v5 LT objectives, scoring within the highest tier for Walkable Location and demonstrating strong Access to Transit despite low surrounding density (Figures 70-72), reinforcing the design's low-vehicle-dependency intent at the urban scale.

5.3 Summary

Chapter 5 translated the findings of the previous chapters into a contemporary residential proposal for Dubai. The design combines traditional Emirati spatial and environmental principles, including courtyard organization, wind-tower ventilation, shading, thermal mass, and privacy, with contemporary construction systems, renewable energy technologies, and low-carbon design strategies.

The final proposal demonstrates how these principles can be adapted rather than reproduced, resulting in a climate-responsive family residence that addresses both operational energy demand and embodied carbon. The architectural strategy is further extended to the urban scale through adaptable housing modules, incremental growth, and shared spatial organization, creating a residential model that responds to environmental performance, cultural identity, and changing household needs.

Conclusion

Conclusion

This thesis set out to test whether the passive logic of traditional Emirati houses, the courtyard, the wind tower, thermal mass, could be reinterpreted rather than replicated to meet the performance demands of a contemporary low-carbon residence in the UAE. Traditional Emirati architecture developed in direct response to a harsh climate, limited resources, and a specific social structure, producing a set of passive strategies that were highly effective but progressively abandoned as Dubai shifted toward mechanically conditioned, repetitive compound housing. The central argument of this thesis is that these strategies were not made obsolete by that shift; they were simply displaced by a construction model that prioritized speed and standardization over climatic responsiveness. By returning to courtyard massing, wind tower ventilation, and earth-based thermal mass, and pairing them with contemporary technologies such as PV/PVT, atmospheric water generation, and heat pump floor cooling, this thesis proposes a residence that meets present-day regulatory benchmarks (Al Sa'fat, LEED v5, LETI/RIBA 2030) without severing the design from its vernacular origins (Figures 80-87). The following sections summarize the specific findings that support this argument, outline the thesis's broader contribution, and identify where further research would strengthen or extend the work.

Figure 94

Exterior perspective of the project proposal

Note. Created by the author





Summary of Findings

The research moved from a climatic and historical grounding, through a critical reading of how contemporary compound housing eroded vernacular passive logic, to a design proposal tested against measurable performance criteria. The proposed courtyard house, built around a 400mm stabilized CEB wall, a rockwool-timber roof and floor system, and a reworked wind tower integrating evaporative cooling, atmospheric water generation, and floor cooling (Figures 80-81), meets Al Sa'fat's mandatory envelope thresholds while returning a cooling intensity 46.3% below a regulation-compliant reference case (Figure 87) and an embodied carbon result comfortably under LETI and RIBA 2030 benchmarks (Figures 88-90). These results were obtained without yet crediting the wind tower's ventilation contribution, suggesting the design's passive performance is understated rather than overstated by the current model. The urban-scale strategy, modular typologies clustered around shared water-collection spaces and organized around incremental public voids (Figures 91-92), extends the same courtyard and wind-responsive logic beyond the single dwelling, directly answering the identity and repetition concerns raised by the contemporary compound analysis.

Contribution to Sustainable Architecture in Arid Regions

The thesis contributes a documented case that vernacular Gulf construction logic, specifically CEB thermal mass and wind-tower ventilation, can be quantified and verified against present-day regulatory and rating-system benchmarks rather than treated as a purely historical or aesthetic reference. By pairing steady-state U-value compliance with dynamic thermal lag and attenuation (Figure 80), the work also argues methodologically that diurnal desert climates are better represented by dynamic thermal performance than by steady-state

metrics alone, a distinction with relevance beyond this single project. The embodied carbon methodology, built around literature-sourced factors for materials absent from standard LCA databases (Figures 88-90), offers a transparent, reproducible approach for other vernacular-material assessments in similar hot-arid contexts.

Recommendations for Future Research

Three extensions follow directly from this work. First, the parametric energy model should incorporate the wind tower's ventilation contribution, currently excluded from the results shown in Figures 85-86, to establish the design's full passive cooling potential. Second, the embodied carbon assessment (Figures 88-90) should be extended beyond the A1-A5 upfront stages to include in-use replacement (B) and end-of-life (C) modules, and vernacular material carbon factors should be replaced with project-specific Environmental Product Declarations as they become available. Third, the urban-scale strategy (Figures 91-92) would benefit from a comparative environmental assessment, testing whether the cluster and incremental-space logic delivers measurable performance gains at settlement scale, not only the qualitative diversity and identity benefits argued here

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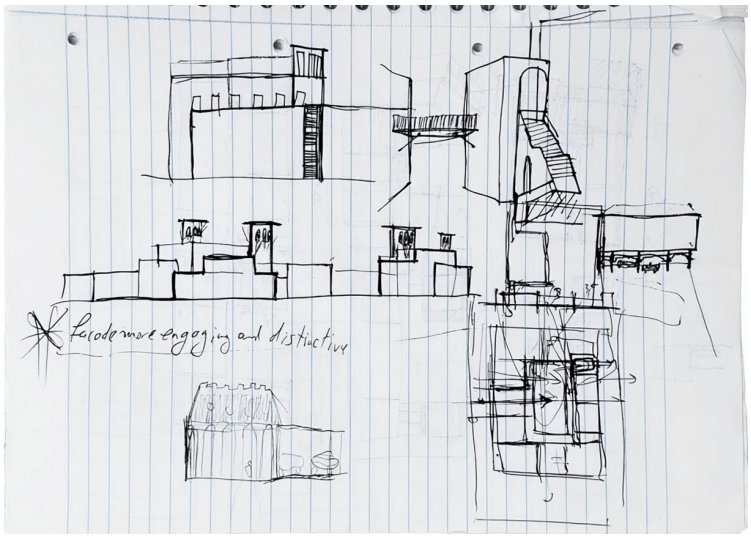
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Appendix A Design Sketches and Diagrams

Figure A1

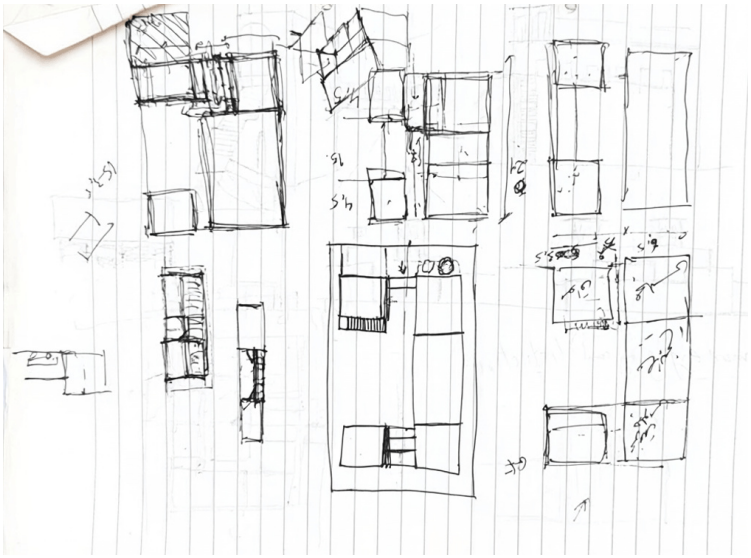
Early Studies of Building Massing, Section, and Spatial Organization



Note. Created by the author.

Figure A2

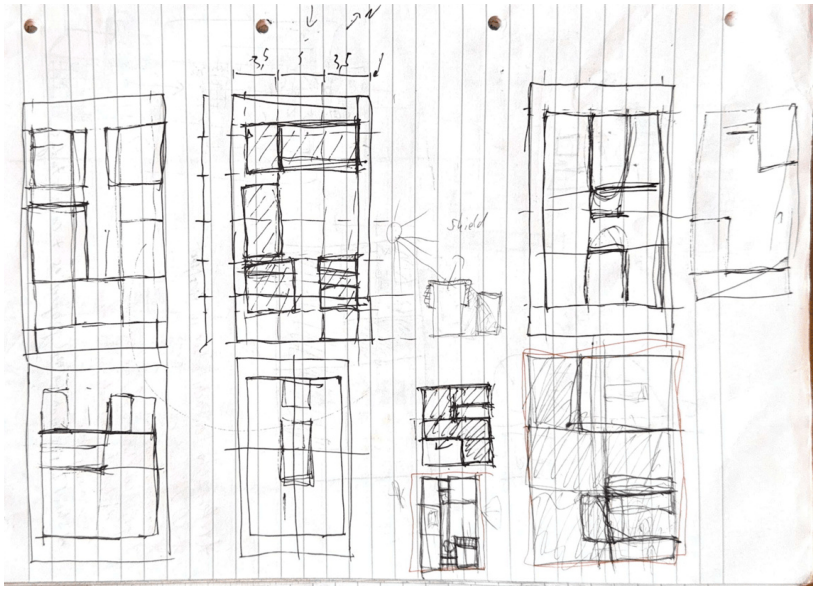
Early Plan and Spatial Layout Development Studies



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Figure A3

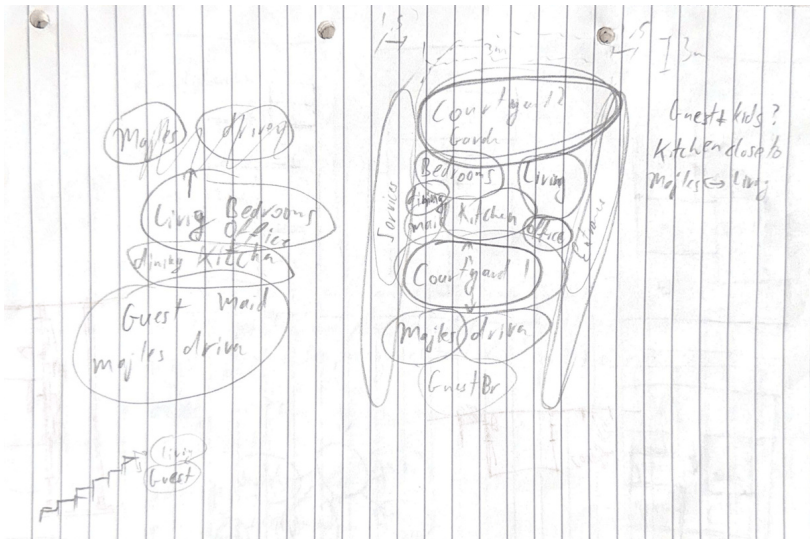
Plan Configuration and Courtyard Organization Studies



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Figure A4

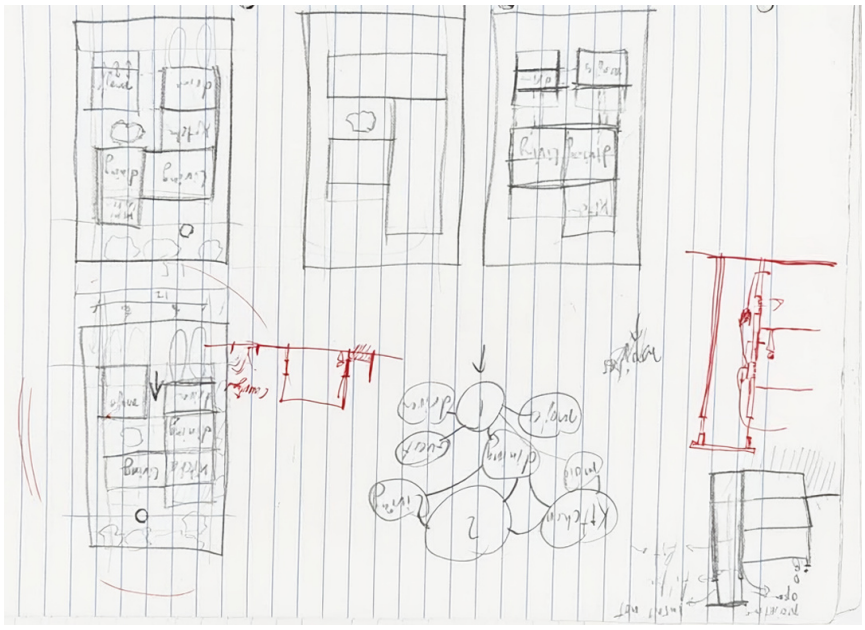
Early Functional Zoning and Spatial Relationship Diagrams



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Figure A5

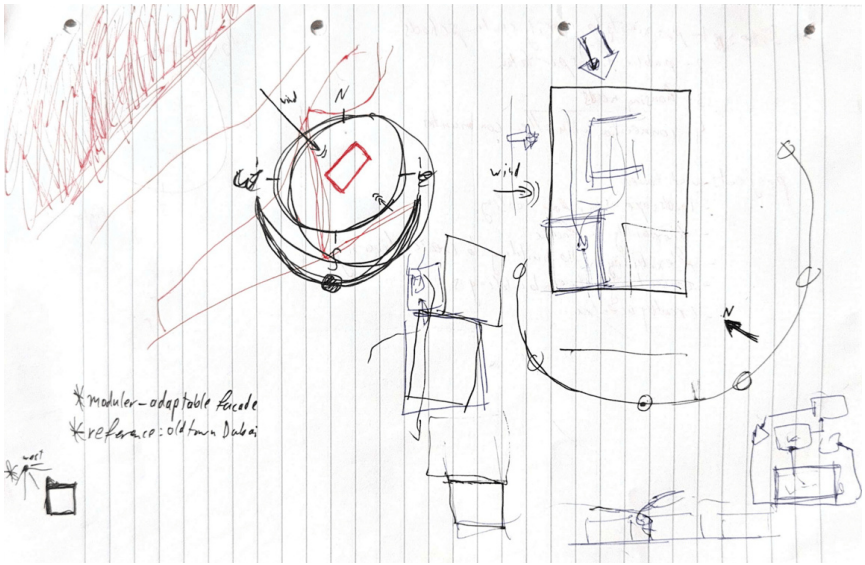
Development of Courtyard-Based Spatial Organization and Circulation



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Figure A6

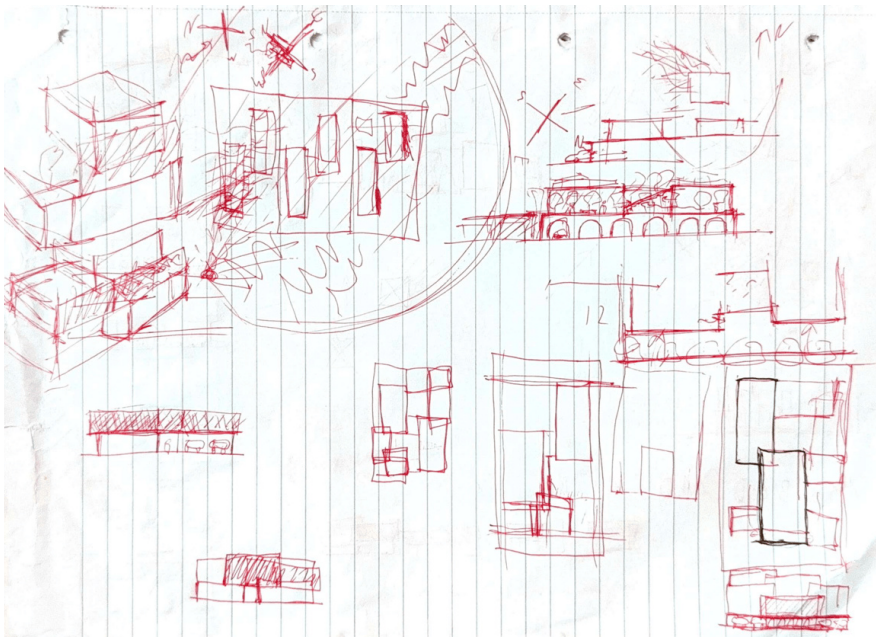
Studies of Building Orientation, Sun path Diagram



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Figure A7

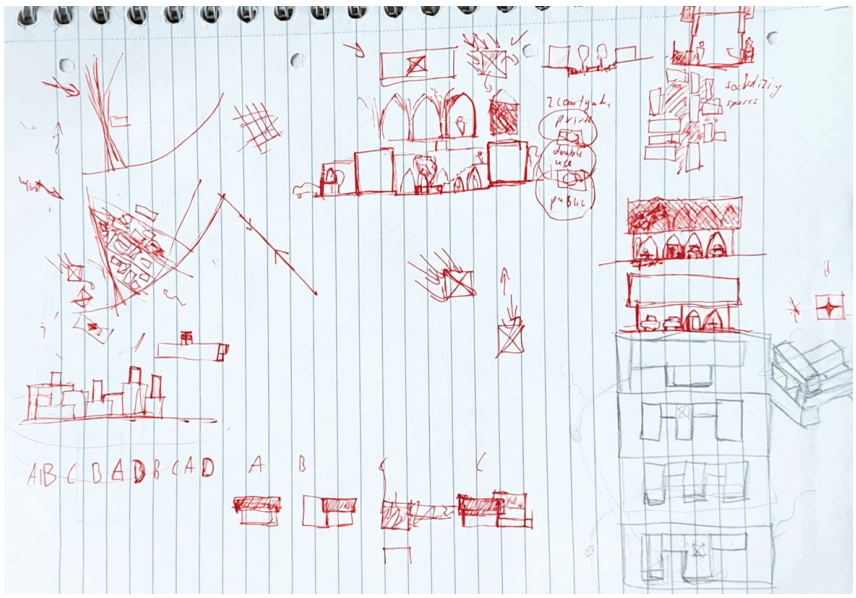
Massing, Façade, and Architectural Identity Studies



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Figure A8

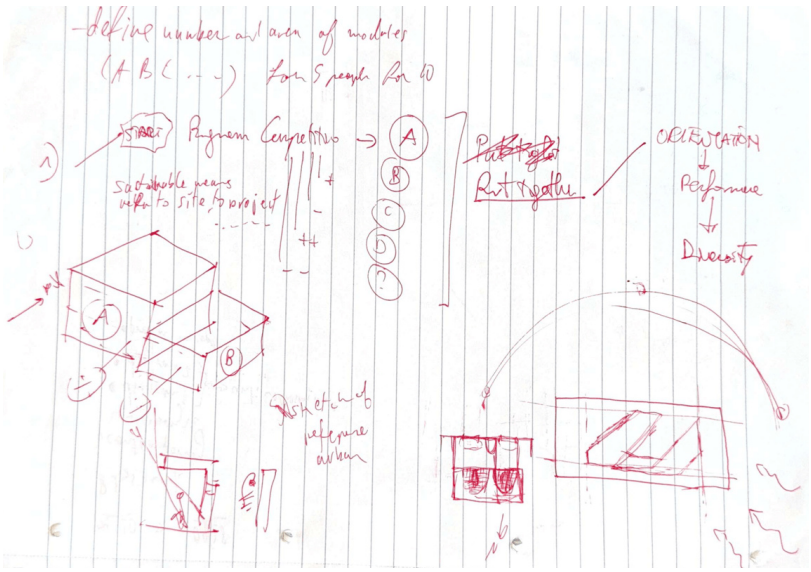
Early Urban Composition and Residential Module Studies



Note. Created by the author.

Figure A9

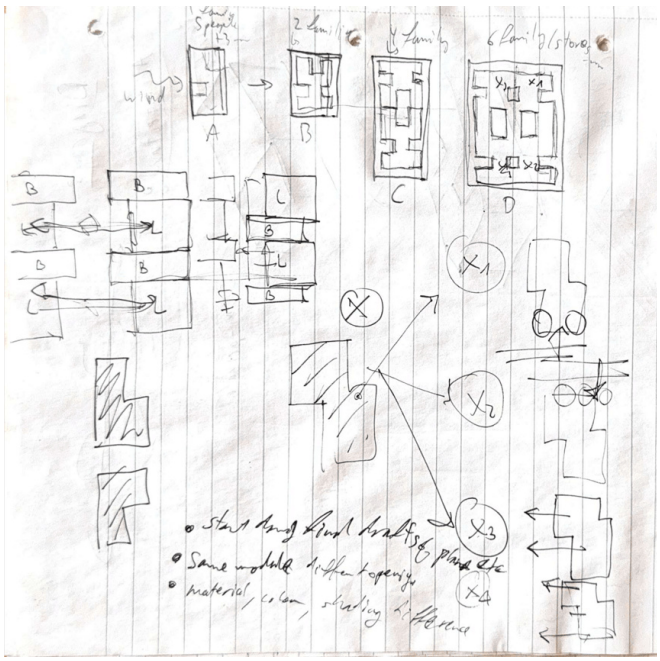
Development of Modular Housing Typologies and Incremental Growth Strategies



Note. Created by the author.

Figure A10

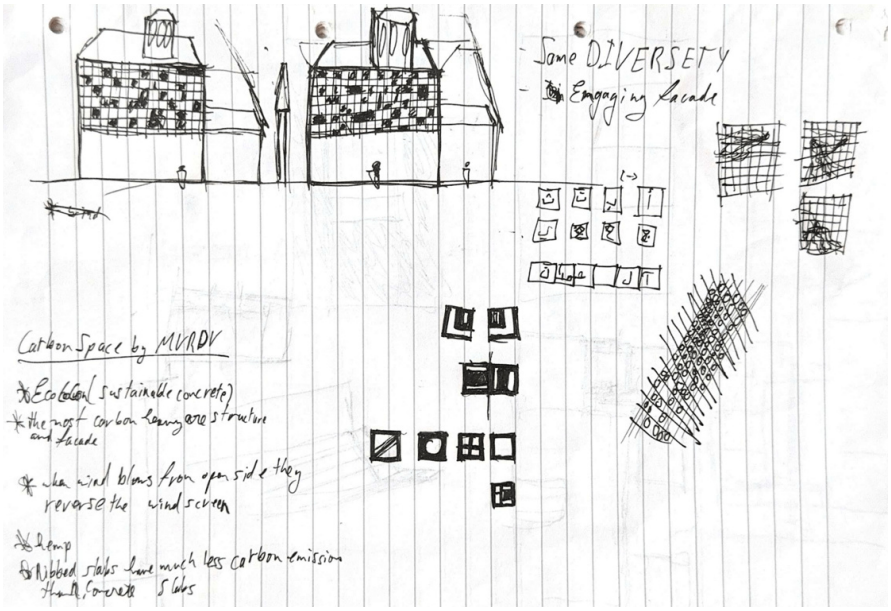
Development of Residential Module Types and Cluster Configurations



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Figure A11

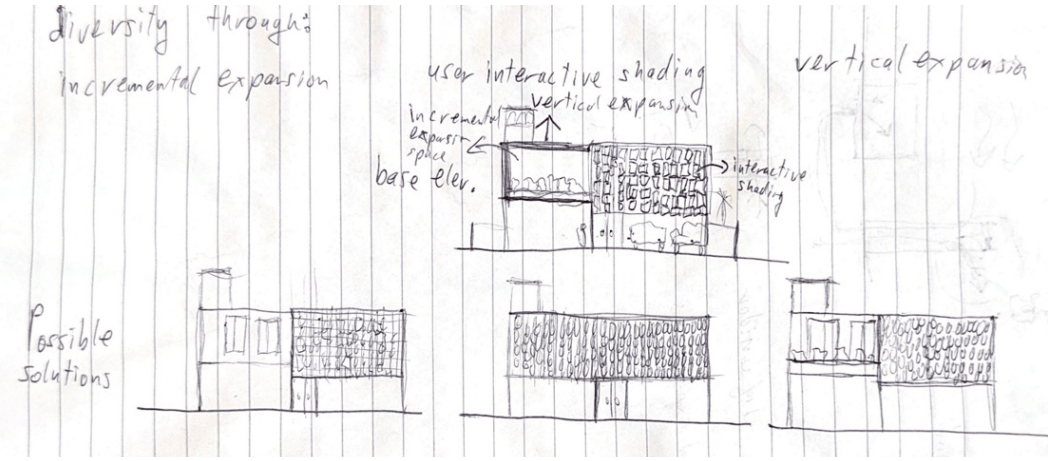
Façade Shading, Material Expression, and Incremental Expansion Studies



Note. Created by the author.

Figure A12

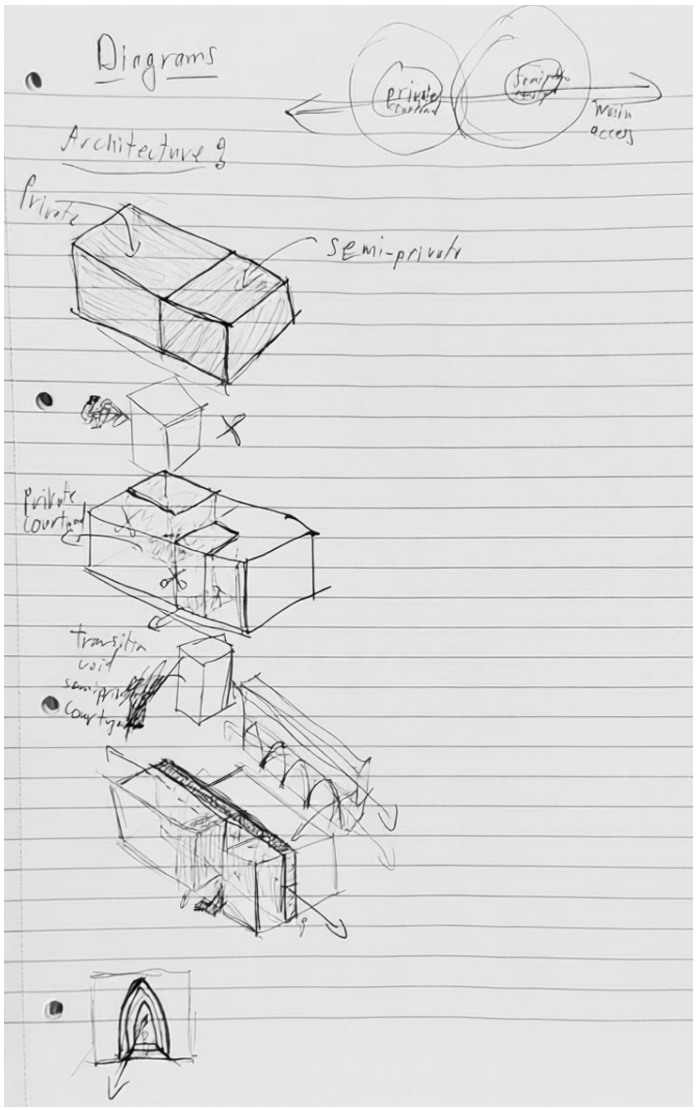
Early Studies of Adaptable Shading and Vertical Expansion



Note. Created by the author.

Figure A13

Courtyard, Privacy, and Transitional Space Concept Studies



Note. Created by the author.