

Integrated Housing Approach for Riyadh's hot arid Climate: solutions from the desert vernacular

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Abstract

Integrated Housing Approach for Riyadh's hot arid Climate: solutions from the desert vernacular

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The house is one of the purest forms of cultural reflection and it is the place where the design can have the most influence on people's life and daily practice. Thus the proposal for this thesis will look at exploring and introducing a different form of housing to the Saudi urban fabric. This form will be different than the typical Saudi house in the following aspects:

Firstly: it will look at the house as a living dynamic object. It will be dynamic in its spatial configuration giving the user the control on the uses and occupations of the space accommodating both conservative and less conservative users.

Secondly, It will also be dynamic in the way in which this house uses and produces energy. Like a living system this house would look at waste from one part of the system as an input for another part. In this case the use of grey water is optimize to be integrated with cooling towers. The cooling system here have three modes of operation and each mode

is designed to operate for a specific micro climatic condition. It uses both passive and active cooling techniques and lessons from both the Saudi vernacular architecture and precedents of high performance buildings in hot arid climates to optimize the cooling cycle within the system.

Thirdly: the proposal will look at the house as a system that is one part of a bigger system in terms of potential energy production and promoting green spaces in both the house structure and the urban fabric. It will look at the housing fabric, as a way to promote social justice and equal excess to green space with out clashing with people believes.

TABLE OF CONTENTS 1-3

LIST OF FIGURES	1
ACKNOWLEDGEMENTS	4
CHAPTER 1 INTRODUCTION	5
1.1 The necessity for energy efficient buildings in Saudi Arabia	6
1.2 Buildings energy usage in the Saudi context	7
1.3 The case for the single family house	8
CHAPTER 2 THEORETICAL FRAMEWORK	9
2.1 The Logic behind the contemporary single family neighborhoods and houses in Saudi Arabia	10
2.1.1 The Early Forms	10
2.1.2 Transitional period	13
2.1.3 The New House	14
2.2 Alternative approach for Housing	18
2.2.1 Housing Preferences	18
2.2.2 Saudi family life cycle and the house owning process today	18
2.2.3 an alternative approach	20
2.2.4 Feasibility	20
2.3 Case Study for Flexibility : ELEMENTAL (Half-House Typology)	22
CHAPTER 3 METHODOLOGY &DESIGN APPROACH	24
3.1 Case Study for a High-Performance House in the Desert	25
3.2 Water Management and treatment	28
3.3 The case for gray water in Saudi house	29

TABLE OF CONTENTS 2-3

3.4	Gray Water treatment	30
3.5	Passive Evaporative Cooling Approach	31
3.5.1	Review on wind towers in the vernacular context	33
3.5.2	Evaporative cooling and screen slides	35
3.5.3	Wind tower integration with the passive and active means	39
3.6	Proposed Design Concept	41
3.7	Site Location	44
3.7.1	Reasons for selecting the site	44
3.7.2	Site relations to the bigger context	45
3.7.3	Site relations to the Historical growth of riyadh	46
3.7.4	Site relations to the Transportation in Riyadh	47
3.7.5	Site relations to Riyadh's train	48
3.7.6	Site relations to Public plazas in Riyadh	49
3.8	Weather Data Riyadh	50
	CHAPTER 4 DESIGN & RESPONSE	54
4	Before Designing	55
4.1	Conventional logic	56
4.2	The Unit Design logic	57
4.3	Value Engineering Thinking	58
4.4	Pedestrian Shared Alley	59
4.5	Shades and Future Photovoltaic	60

TABLE OF CONTENTS 3-3

4.6	Site Plan	61
4.7	Urban Form	62
4.8	Unit Layout	65
4.9	System Integration	68
4.10	Three Moods of Operation	72
4.11	Summer Mood of Operation	73
4.12	Spring Mood of Operation	74
4.13	Winter Mood of Operation	75
	CHAPTER 5 CONCLUSION	76
5	Conclusion	77
	BIBLIOGRAPHY 	

LIST OF FIGURES 1-3

(Figure 1) Global electricity consumption map

(Figure 2.1) an example of the horizontal expansion of the house

(Figure 2.2) An Aerial image of Riyadh in the 1960's

(Figure 2.3) A schematic plan of Al-Malaz project master plan

(Figure 2.4) sample of houses from Al Malaz

(Figure 2.5) The Saudi family structure in relation to spatial needs

(Figure 2.6) Half house Typology in Tarapacá, Chile

(Figure 2.7) an illustration of the Half house Typology in Tarapacá, Chile

(Figure 3.1) The passive house Qatar next to the conventional house

(Figure 3.2) Passive house Qatar the conventional house wall assembly

(Figure 3.3) Water usage and consumption in Saudi Arabia

(Figure 3.4) Water usage in residential buildings Saudi Arabia

(Figure 3.5) Gray water filtering requirements in the Saudi building code

(Figure 3.6) Example of the wind towers in the Middle East

(Figure 3.7) To the top a traditional Baud-Geer with the four openings. on the bottom The improved model with evaporative cooling on top and clay conduits

(Figure 3.8) to the top photograph the full scale wind tower that was built and tested. on the bottom the wind tower showing the three embedded model units showing the air temperatures in each.

(Figure 3.9) the wind tower integrated with the solar fan

(Figure 3.10) a passive solar chimney and evaporative cooling integrated with wind tower

(Figure 3.11) Water circulation in relation to concept

LIST OF FIGURES 2-3

(Figure 3.12) On the top a typical relation between the windows in the ground floor and the house concrete fence. On the bottom an alternative relation between the two.

(Figure 3.13) The initial design concept with the evaporative cooling and ventilation system

(Figure 3.14) Site location

(Figure 3.15) site relation to the bigger context

(Figure 3.16) Historical growth of Riyadh

(Figure 3.17) Transportation in Riyadh

(Figure 3.18) Riyadh's train map

(Figure 3.19) Public plazas in Riyadh

(Figure 3.20) Temperature range and dry bulb temperature

(Figure 3.21) Sun chart

Figure 3.22) Wind chart

(Figure 3.23) Direct and diffused solar radiation

(Figure 3.24) Example of the dust storms

(Figure 4.1) Conventional logic for housing design in the Saudi context

(Figure 4.2) The housing unit design logic

(Figure 4.3) Value Engineering Thinking

(Figure 4.4) pedestrian shared alley

(Figure 4.5) shading system for pedestrian shared alley

(Figure 4.6) Comparison between the conventional and proposed design structure of relationships between the neighbors

(Figure 4.7) Connection between blocks

LIST OF FIGURES 3-3

(Figure 4.8) Site plan

(Figure 4.10) On the top a sample south elevation of the project and on the bottom an urban section perspective

(Figure 4.12) pedestrian shared alley

(Figure 4.13) ground floor axonometric

(Figure 4.14) Second floor axonometric

(Figure 4.15) complete house axonometric

(Figure 4.16) System Integration and components

(Figure 4.17) Internal courtyard with the shading system on

(Figure 4.18) Internal courtyard with the shading system of

(Figure 4.18) Internal perspective from the dining room

(Figure 4.19) Section axonometric that explains the Summer mood of operation

(Figure 4.20) Section axonometric that explains the Spring mood of operation

(Figure 4.21) Section axonometric that explains the Winter mood of operation

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**CHAPTER 1|
INTRODUCTION**

1.1 The necessity for energy efficient buildings in Saudi Arabia

Saudi Arabia's wealth as a nation depends completely on oil. However, Citigroup Inc along with other reports indicated that the Saudi oil reserves would be depleted before the end of this century. More accurately, by the year 2030 Saudi Arabia will use all its oil production to cover the domestic need, and there will be nothing to export. With a total population of 28 million in 2013, Saudi Arabia was ranked the 7th global oil consumer after Brazil and the 15th electricity producer after Mexico making the Saudi oil consumption the highest per capita.



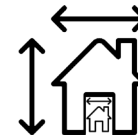
(Figure 1) Global electricity consumption map
(source: U.S. Energy Information Administration)

1.2 Buildings energy usage in the Saudi context

Similar to other places all around the world the urban built environment is accounted for more than two thirds of the energy usage. The population boom and the extraordinary process of urbanization in the last few decades led to consuming today almost 50% of the national oil production to generate electricity, and 80% of the previous number is used for air conditioning and refrigeration purposes. The factors listed below are some of the reasons behind such high consumption.



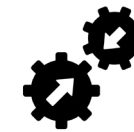
Abandoning the passive vernacular form and depending completely on active systems in the today's forms



The increased size of the Saudi dwelling



The absence of green building codes and incentives



The lack of integrated green technologies in the built environment



The subsidized price that the user pays for the electricity



The lack of experienced architectural practices leaving the space for develop-govern the built environment outcomes

(Taleb & Sharples 2011)

1.3 The case for the single family house

The single-family homes in Saudi Arabia are responsible for more than 50 % of the nation electricity consumption and it is the place where the design can have the most influence on people's life and daily practice. Given that the housing model that was developed in the early 60's became the typical prototype that we see today, this thesis argues that that model was not appropriate then, and less appropriate today. A more sustainable model can be adopted once it proves its practicality, not only from an environmental point of view, but from an economic one also. Since this approach is a fairly new and yet to be explored one in the housing market, such approach can open new opportunities for developers and entrepreneurs in the construction industry. With more than half of the population under 30 years old, the need for housing is bigger than ever, and with it the young population is more open and expecting to change than ever.

**CHAPTER 2|
THEORETICAL
FRAMEWORK**

2.1 The Logic behind the contemporary single family neighborhoods and houses in Saudi Arabia

2.1.1 The Early Forms

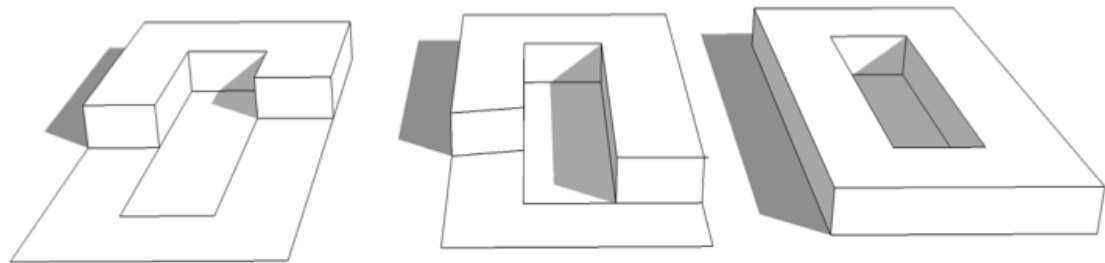
The traditional Saudi house varied in its form, characteristics and building material from one region of Saudi Arabia to the other. The way in which each form evolved was directly related to climate and the culture that took place in that region. In this context the main focus is on Riyadh for two reasons: first, the models that were initially developed in Riyadh, were the foundation from which the typical Saudi villa were established, and later spread all over the map in the kingdom. The second reason, Riyadh is the city with highest density in Saudi Arabia, and the need there for housing solutions is more critical.

The traditional house in Riyadh had either a square or a rectangle form that surrounded one or two opened courtyard-s in the center of the house. The courtyards had a significant value in the traditional house in the Islamic architecture in general, and the Middle Eastern architecture in specific. Addition to their role in cooling the surrounding space, they provided daylight to the house spaces with maintaining the privacy of the house occupants. In the hot arid climate when the temperature drops at night the hot air rises from the courtyard to be gradually replaced with a colder one. The cool air accumulates in the courtyard and then flows in to the surrounding rooms cooling them. During the day the process is reversed and the surrounding rooms shade most of the courtyard slowing the cumulative change in temperature and deflecting the airflow from the outside.

CHAPTER 2| THEORETICAL FRAMEWORK

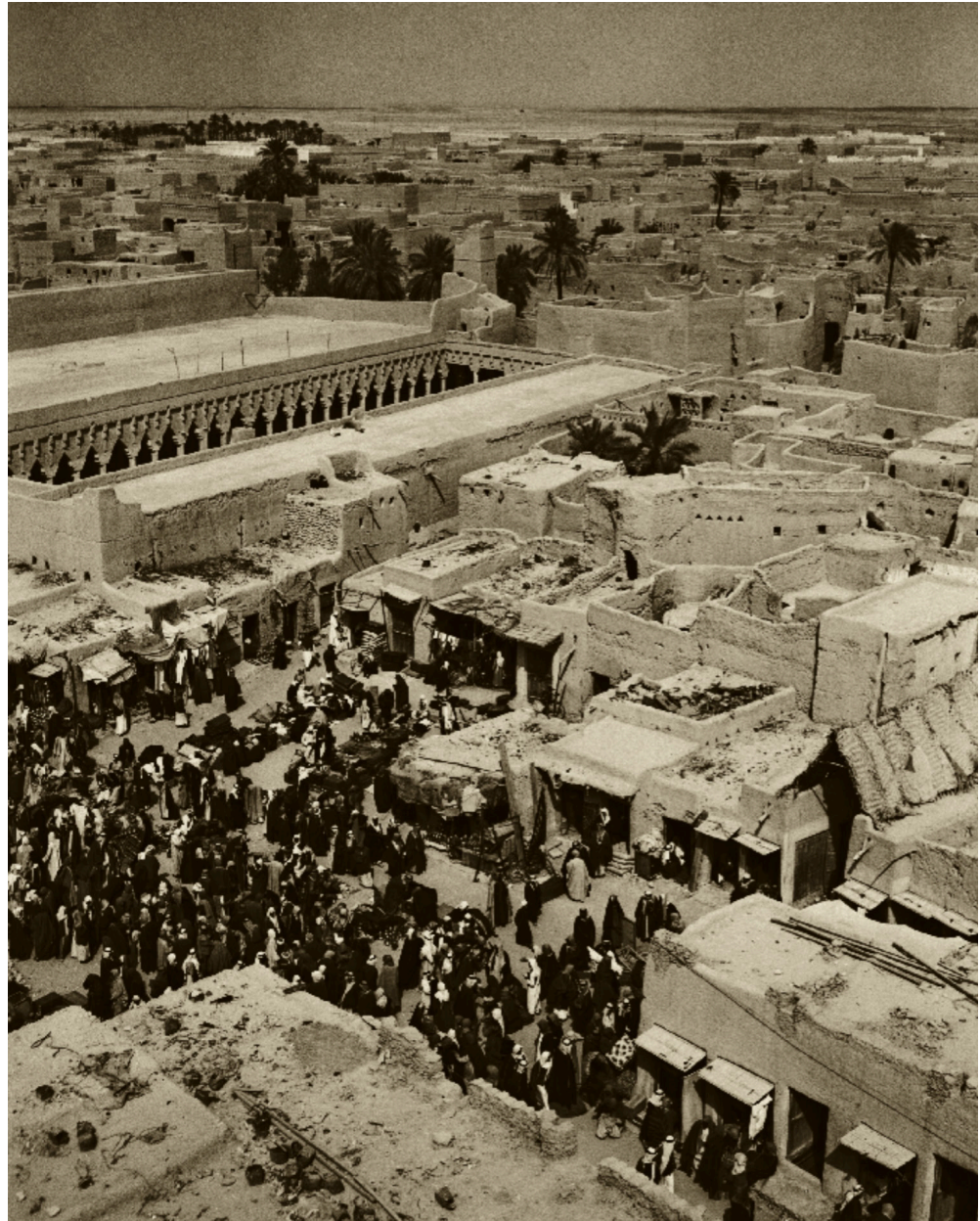
Houses were then open to the inside to minimize the intrusion of outsiders on the house and, to allow women to move freely in the house without any worry of being seen by strangers. In addition, the courtyard at the time connected the house occupant, especially women who spent most of their time in the house, with nature and the outside world. Moreover, courtyards were used by the families for gatherings and celebrations in the case of special events.

The house had a small amount of light movable furniture, which made it easy for the occupant to shift rooms' uses in different weather conditions. Flexibility and the ability to grow were among the main factors to be taken in consideration when placing the house layout, and the main factor that guided the house construction. Houses were constructed over an extended period of time and grow over with the growing needs of the occupants. That means if a family member got married, or the number of the rooms did not match the needs of the family needs, an additional room or rooms can be easily added either vertically or horizontally depending on the house structure and land (Fadan 1983)



(Figure 2.1) an example of the horizontal expansion of the house
(source: (© Alhumaid)

CHAPTER 2| THEORETICAL FRAMEWORK



(Figure 2.2) An aerial image of Riyadh in the 1960's
(source: (Arriyadh Development Authority)

CHAPTER 2| THEORETICAL FRAMEWORK



(Figure 2.3) A schematic plan of Al-Malaz project master plan
(source: (Alhathloul)

2.1.2 Transitional period

The first transformation between the traditional built environment and the contemporary one in Saudi Arabia started in the Eastern parts of the kingdom 250 Miles from Riyadh, and was first introduced by ARAMICO . The activities and industrialization that took place in that part of Saudi Arabia required a new form of organization. Thus, the grid street pattern structure first took place in that area before the system has been exported to Riyadh and the other parts of Saudi Arabia.

In the beginning of the 1950's the Saudi government moved from Mecca to Riyadh and with it all government agencies and ministries. With this move, there was an urgent need for providing housing units for government officials and workers that moved into Riyadh. Using the same grid street patterns that were first used by ARAMICO in the Eastern region, Al-Malaz neighborhood was chosen to embrace the first housing project in Riyadh. With 754 detached villa-type and 180 apartment units divided on three buildings were built by the government and sold to the workers for long-term, with no or low interest loan. Later the principles and Methods that were applied in this project were generalized on other developments all around the map in Saudi Arabia. (Alhathloul 1981)

Two main reasons were behind making Al-Malaz project a prototype from which other development used as their basic starting point. First of all, this project was built and financed by the government for the government employees. Thus it represented the official point of view and vision on how the new urban setting should be. The other reason is that Al-Malaz project was looked upon as the transformation from what was considered then obsolete to what is then modern and civilized.

2.1.3 The New House

The new villa form contrasted the traditional one in more than one aspect. However, the limitation on the land, and the loss of the courtyard along with the introduction of new building techniques, were the key restraints on the new design. Moreover, the new modern houses would not be looked at as a complete product without replacing the “old-fashioned” traditional furniture with the modern a western one. In contrast to the traditional furniture, the modern furniture was heavy and hard to move, and as a result, the uses of most of the spaces in the house were fixed.

This sudden lack of flexibility led to a clear repetition in some of the houserooms. In most cases the two or two and a half story house was divided into two main functional spaces. The first floor, containing: the kitchen, one or two dining rooms, one or two guests reception rooms, a family living room, and the bathrooms. The second floor or in other words the family floor, containing: the main family living room and the bedrooms (S. Akbar1998) (Bahammam1998). The following comparison by (Bahammam1998) summarizes the main different points between the traditional and contemporary house in terms of the constructing of the building. However, the sudden change in the building process seems to be the most profound factor to today's housing culture and the socio-cultural changes that came with it.

CHAPTER 2| THEORETICAL FRAMEWORK

Factors	Traditional dwelling	Contemporary dwelling
Plot size	Land is almost free and people can build as much as the need.	The land is subdivided into plots of 400 square meters or more, bought and sold as a commodity.
Rules and regulations	People can build as much as they need and as they wish without harming the community or the individual interests.	Built area should not exceed a certain percentage within a certain setback from all four sides and building should not be more than two stories.
Construction budget	As much as the household can afford from their income at different stages of their life cycle.	In many cases, a long-term interest-free loan can be acquired if the family built a dwelling with size not less than (300 m ²).
Technology	The short span of the available local roofing materials and building technology produced small spaces (rooms).	New imported roofing materials and technology allow for longer spans and bigger spaces (rooms).
Building process	Accumulative process, building expands with the family size and needs throughout the years.	Building is viewed as an end product to be delivered complete to the family.

With the new economic boom people started racing to show that they are a part of the new civilized society. Thus they build their house according to what they knew or what they saw in established examples. This takes us back to the question: what were established examples at the time? The answer for this question falls into two parts. The first one is the projects that were done by the government. The other one, were the examples that were done by Arabic Mediterranean architects who came from a developed built environment to a virgin one.

CHAPTER 2| THEORETICAL FRAMEWORK



(Figure 2.4) sample of houses from Al Malaz
(source: (Alhathloul)

Those architects and engineers came to a climate and a culture that they do not fully understand and with good faith they assumed that the Saudi householder would be open to some new elements and changes in the design as they were opened to the shift toward modernity. One example of a borrowed element that did not seem to be acceptable from the Saudi occupant is the balcony. From the designer point of view the balcony seemed a good solution to replace the courtyard. Especially, with the need to build more in less space .

However from the occupant point of view, that space did not more than expos the house occupants to outsiders. Or in a more broad since make the neighbors' houses exposed by the balcony. Therefor, most if not all balconies were closed and used as rooms or storage areas. The balcony it self is not a bad idea to replace the courtyard, but for it to be acceptable it should have been adjusted to fit the needs of the Saudi culture and climate.

Houses in the new contemporary urban fabric were not opened to the inside as they were in the traditional one. The new Saudi house, had windows facing the streets and overlooking the neighbors' yards or in some cases overlooking the interior of the house. In a conservative Islamic culture, similar forms that violate the privacy of the residents will never be acceptable. Therefor people started adding a plastic or mettle sheets that were in a way an extension of the 9-10 feet concrete fence that was surrounding the house (Alhathloul 1981)

CHAPTER 2| THEORETICAL FRAMEWORK

This act may seem to be a harmless one. However, with more careful analysis, a different result may emerge. Those sheets may create a false sense in the community that the main goal of a neighbor is to spy on their neighbor, or in a reversed scenario, to protect the house from them. It is hard to distinguish which is more negative than the other. In addition, in a neighbor where most houses “protected” their privacy with those sheets, the house that did not follow, would be distinguish as the less-conservative one . The one who broke the tradition!

In a different manner, the small windows that were supposed to bring sunlight and fresh air in to the space were interrupted by those sheets. This means a decrease in the little amount of sunlight and fresh air that were supposed to reach the house, and increase dependence on electricity. This practice varies from neighbor to another however it still takes place in today’s houses.

These example among many shows that that architects can not always anticipate peoples behavior toward a given design. Likewise, if that design did not meet the occupants’ need, the rational respond is to change it. This change may not always be in apposite context.

2.2 Alternative approach for Housing

2.2.1 Housing Preferences

Through a self-administered structured survey, (Opoku A.Robert) started an investigation about the dwellings type and preference among the low income Saudis who do not live in a home owned by them. The respond showed that about 43% of that population slide favored living in a private small house if they had the chance in the future. Followed by 27% preferring a Duplex house. Unfortunately it is hard to accept alternative prototypes when those are the only ones they have seen. Moreover, among ten different factors that may influence their choice, cost, and the house privacy of the space were the top two on the list. Such respond is not surprising knowing that the study's scope is the low-income Saudis.

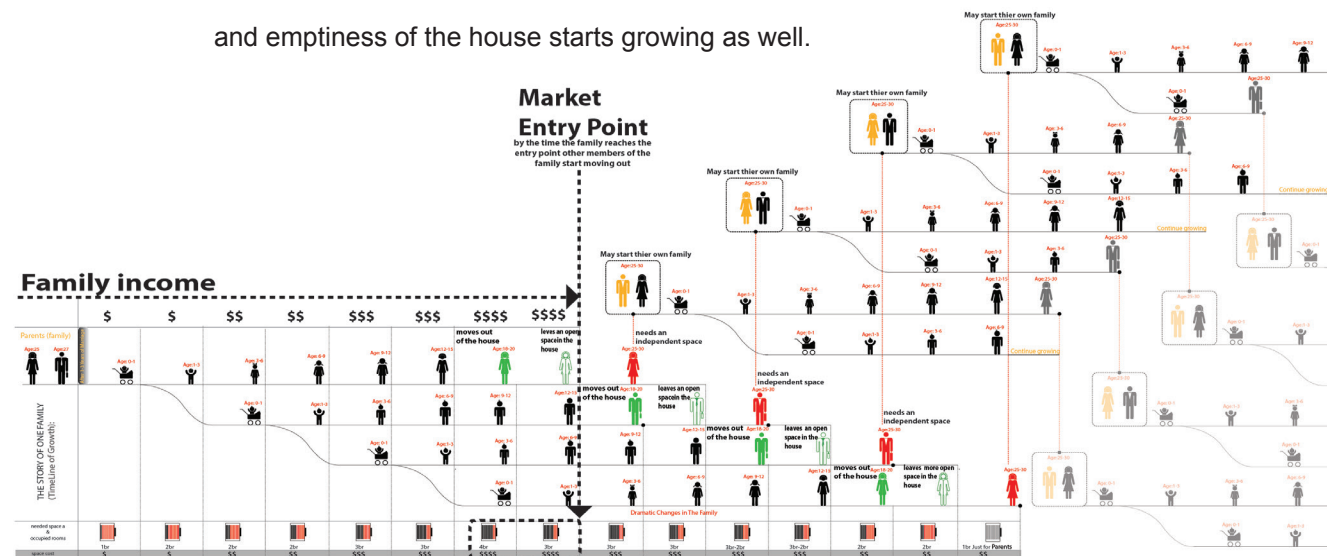
2.2.2 Saudi family life cycle and the house owning process today

In a typical Saudi family, as in other places in the world, the family starts with the couple getting married, and moving to their own place . Starting usually with two or three rooms' in the apartment. After a few years the couple start having kids and the small apartment may no longer fit their needs. The anticipated next step is to move to a private house in the single-family neighborhoods. However, this may be very hard to achieve for a number of reasons, including but not limited to, the land price compared to the average Saudi income, and the way cities expand horizontally.

CHAPTER 2| THEORETICAL FRAMEWORK

Thus many tend to rent a (half house) where they may have more rooms and an outdoor space for their kids to play. Another few years in that house, and then finally the householder-holders might be able to either buy one of the overpriced houses in the market, or they can buy a small piece of land to build the house on, if they wanted wait another few years and save some money.

That is usually done by one of two options: at this stage in the family life, the householder would be eligible for applying for a high interest Real estate lone from a bank. Simultaneously, he would be receiving a long-term interest free loan from the Saudi real estate development fund if he/they have a land and he- they plan to build a house on it. Alternatively, if he/they had already owned their house by the time, or do not own the land to build on, the lone could be redirected towards buying an existing house or paying the bank lone if there is one . In the previous structure, by the time the householder-holders move to their new and final destination, it will be a matter of few years if it did not already started and the children start moving out from the house. The void and emptiness of the house starts growing as well.



(Figure 2.5) The Saudi family structure in relation to spatial needs
Diagram by (© Alhumaid)

2.2.3 An alternative approach

There are a number of concerns in the Saudi governmental approach for housing, that are not to be discussed in this context. However, the believe that the house is a static form of architecture is what seems to be problematic. A more futuristic approach is to think of the house as a living dynamic object. Thus the house must be able to grow with the growth of the family and perhaps shrink accordingly. The need of the family starts small and ends small, however the real estate market do not a have a model that is flexible. In other word, the model available in the market is a fixed model for a fixed family, on the assumption that the family would remain the same as the time the house was first occupied. One of thinking of in such approach starts with changing the way houses are built. That means instead of delivering a complete house, the alternative would be delivering a complete infrastructural system for the house. This system would have all structural, plumbing and other requirements for future expansion. If the users want to add more rooms or elements, they can do it when they afford to do so.

2.2.4 Feasibility

In comparison to the conventional approach for owning a house, the house is a complete product and is priced accordingly. In that complete product the future owner cannot ask the seller to remove undesired spaces or rooms in order to lower the price. Additionally, the householder–holders are more likely to continue paying the high interest bank lone even after some of the children had moved out. The alternative approach would give users access to the housing product in an early stage of the construction, before the cost inflation. Thus, the householder–holders can chose to start with a smaller lone to obtain the product, and build more spaces when the family income grows with the family.

CHAPTER 2| THEORETICAL FRAMEWORK

Conventionally, on one hand, when the family needed space the most its not there, and on the other hand, when they have an excessive space, they cannot optimize the situation into their favor. Alternatively, with the proposed concept the family would be able to gain an additional income by renting the unused spaces. It can even help the family pay the lone an earlier stage, if there is one.

This also may help create a cycle of healthier relations in the small community. In the conventional model, they users are in constant movement from one place and community to the other, depending on their needs and financial states. Thus, the relationship between neighbors and children of a given neighborhood is not enduring. However, in the alternative approach people would be more invested in their communities.

CHAPTER 2 | THEORETICAL FRAMEWORK

2.3 Case Study for Flexibility : ELEMENTAL (Half-House Typology)

Quinta Monroy is a social housing project that is located in the center of Iquique, a city in the Chilean desert. The project at first aimed to house 100 families in a 5000 sqm piece of land. This was a huge challenge given the number of units that was needed to be built. Starting with a conventional design approach, the land area would only allow 30 houses for 30 families.

An alternative project approach that is more efficient with the land, was to build the project as a row house development with a zero lot line. However that would have been problematic because it would block natural ventilation and daylight if families wanted to add new rooms to the house. A high-rise approach would have not been acceptable because it would not allow any flexibility if families wanted to double the initial build space.

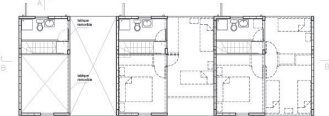
This typology that was developed by ELEMENTAL took place in sites elsewhere in Mexico and Chile. It aimed to deliver houses with minimum amount of expenses and maximum value, as the house values would increase after families invest in adding and completing those houses.

This it would allow families to enter the housing market and purchase a house at earlier stage of its life. Moreover, given that each family would probably finish the house differently, such approach would celebrate diversity and spontaneity in the housing block.

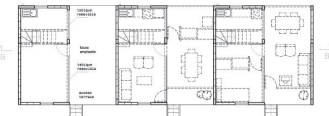


SitePlan in the Iquie project

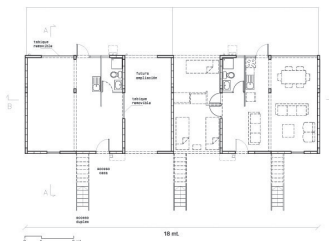
0 10 30



Third Floor Plan in the Iquie project



Second Floor Plan in the Iquie project



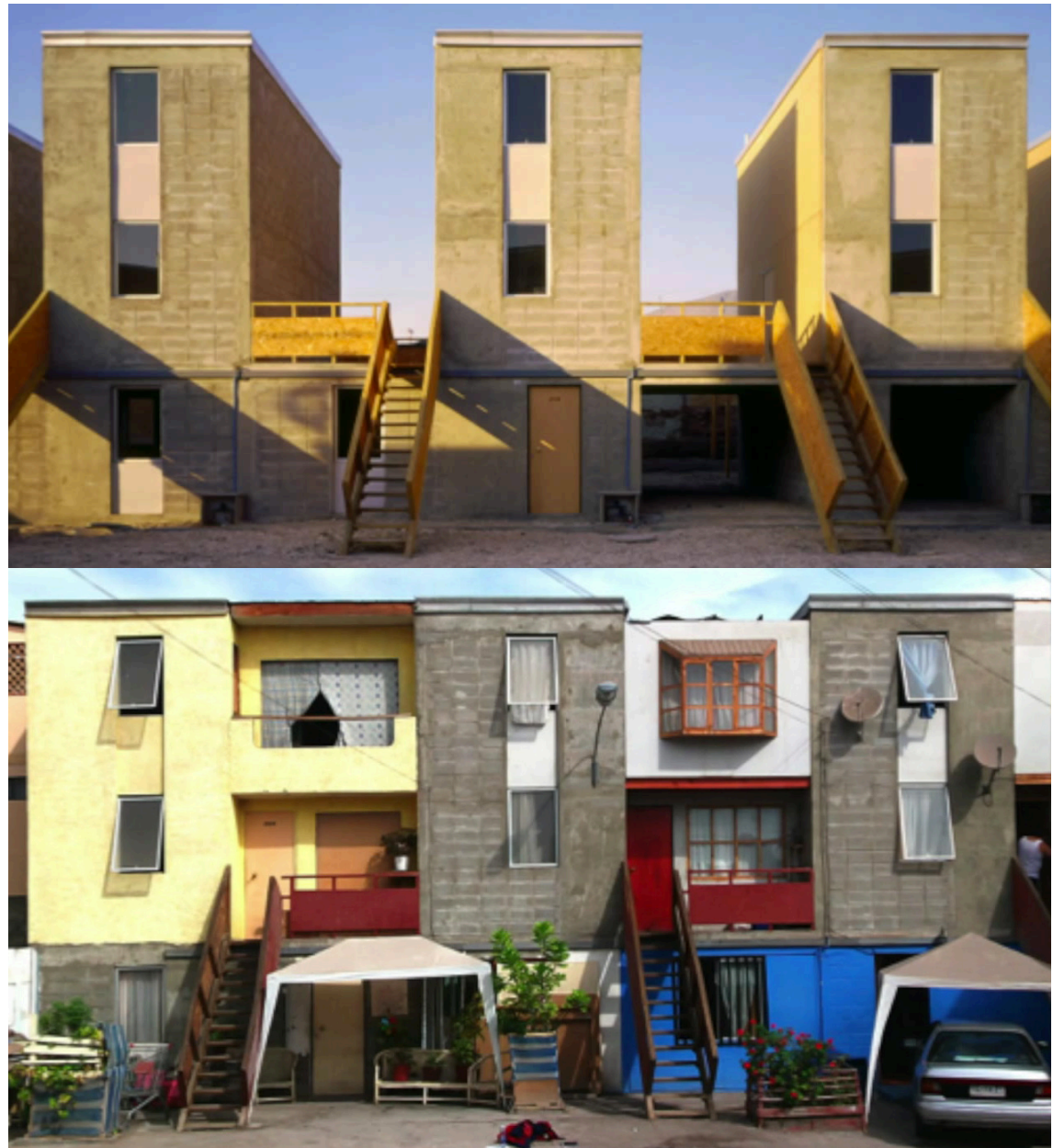
First Floor Plan in the Iquie project

(Figure 2.6) Half house Typology in
Tarapacá, Chile

(source: (ELEMENTAL))

On the top a clustered of the housing project in Iquique when they were first delivered to the clients. On the bottom the same clustered after householders take ownership of the house for future expansions

(Figure 2.7) an illustration of the Half house Typology in Tarapacá, Chile
(source: (ELEMENTAL))



**CHAPTER 3|
METHODOLOGY
&DESIGN APPROACH**

CHAPTER 3| METHODOLOGY & DESIGN APPROACH

3.1 Case Study for a High-Performance House in the Desert

Qatar is a country with a very hot and dry climate and the energy usage and consumption problems that Qatar is facing are very comparable to the ones in Saudi Arabia. As a step to a more sustainable future Qatar has built the first Passive house project in the Gulf Region in the year 2013. The Passive house standards were first introduced in Germany in the 1980's as a low-cost approach for a low-energy building consumption. The ideas that passive house standards advocate for, all depend on tightening the building envelope to achieve thermal comfort and minimize the heat exchange between the building and the outdoor environment.

According to the passive house institute, having a strong insulation with minimum thermal bridging and high performance glazing would make the building envelope airtight to achieve its zero energy goals. In some cases a heat recovery ventilator would be needed to reach the energy goals.

In Barwa City in Qatar, two side-by-side 225 square meter (2,745 square foot) single-story houses were built to explore whether if the Passive house standards would reach its goal of a zero net house. Both houses use the same geometry and layout. However, one is designed using the passive house standards and the other one uses the conventional construction standards in Qatar. The Computing simulation argued that the one built according to the passive houses standards would be able to reach its zero net goals. Results of the experiment has not been published yet.



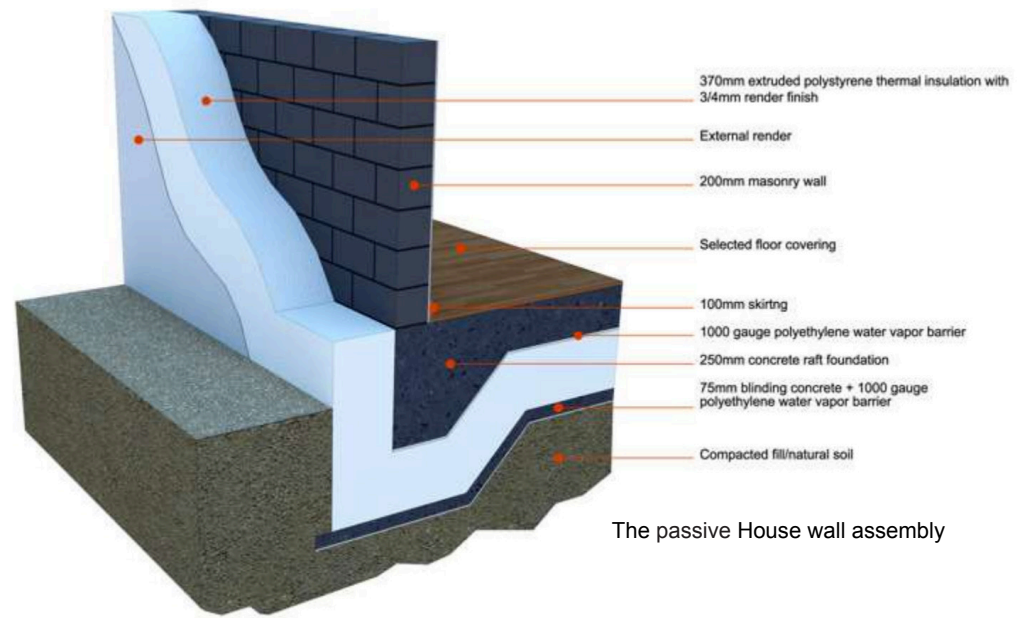
(Figure 3.1) The passive house Qatar next to the conventional house
(source: (Khalfan & Sharples 2016))

CHAPTER 3| METHODOLOGY &DESIGN APPROACH

The passive house in Qatar will have:

- A wall construction of 370 mm extruded polystyrene insulation
- 3/4 mm external render finish
- 200 mm masonry wall (compared to 150 mm external /100 mm internal concrete block with 50 mm air gap in the conventional house)
- Triple glazed windows and doors
- A skylight in atrium with louvers that open and close with sun angle
- A PV array that would produce around 58,000 kWh of electricity per year
- A black and grey water recycling system

CHAPTER 3| METHODOLOGY & DESIGN APPROACH



The passive House wall assembly



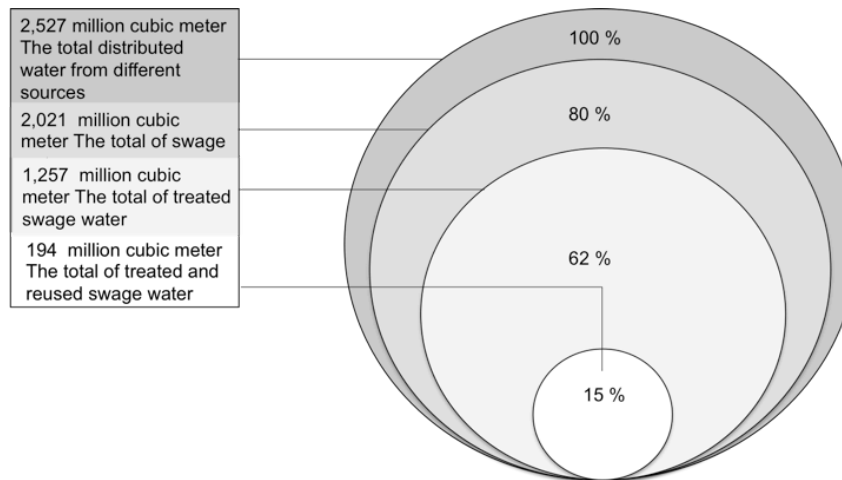
The conventional House wall assembly

(Figure 3.2) passive house Qatar the conventional house wall assembly (source: (Khalfan & Sharples 2016))

3.2 Water Management and treatment

UN reports indicate that 2.7 billion of the global population would face water shortages in the next decade. Saudi Arabia is one of the top 5 countries of the world that are facing absolute scarcity of water. The desert nature of the country necessitates dealing with water as the most critical resource of the region. Since 1980, average consumption per capita had Multiplied 7.5 times using more than 315 liters a day per capita not including industrial or agricultural applications. That is more than double the global consumption rate.

Due to these high rates of consumptions Saudi Arabia uses 20 % of its oil production for desalinating salt water and pumping its to stretching regions. However, only 15 % of the total water that goes to the sewage line is treated and reuses. This number is expected to increase noticeably in the next few years due to number of infrastructure changes in some of the Saudi major cities . However, there is limited cases were water is recycled and reused in the residential sector. That is also due to the low subsidized price that reaches the consumer.



(Figure 3.3) water usage and consumption is Saudi Arabia
Diagram by (© Alhumiaad)

3.3 The case for gray water in Saudi house

The wastewater in the residential sector is water that is polluted with organic and chemical microorganism after it has been used and it is divided into three sections:

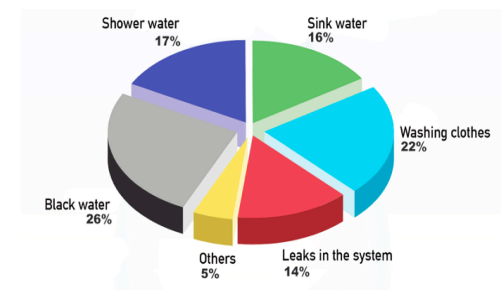
A) Gray water **B) Black water** **c) Sewage water**

A) Gray water: the definition for gray water varies from one place to the other but the Saudi building code defines it : as water that is cleanable and not used in the house toilets and kitchens. And it represents between 55% - 74% of the total usage in the residential sector.

In a “all Muslim state” such as Saudi Arabia, it is expected that the typical Muslim prays 5 times a day, but before they pray they are expected to wash parts of their bodies in practice named “Wudu”. The wastewater resulting from that practice is somewhere between 5-10 liters in each time a person practices Wudu. That alone is between 25-50 liters per day .

B) Black water : is wastewater containing bodily or other biological wastes, as from toilets, dishwashers, or kitchen drains, and kept separate from gray water in wastewater recycling systems.

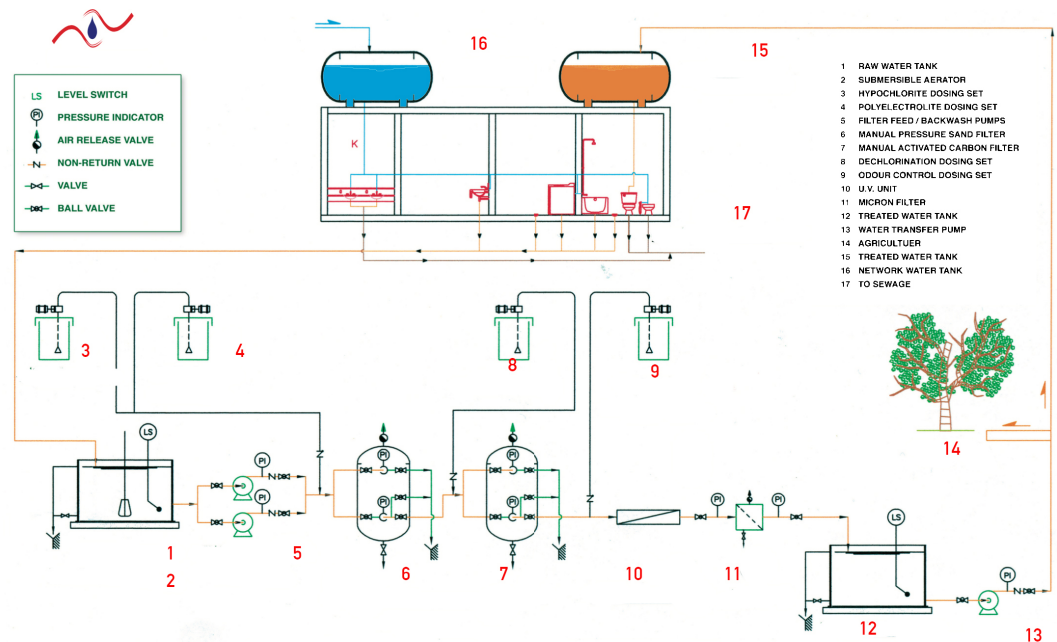
c) Sewage water is usually the combination of gray and black water that goes back the city network before.



(Figure 3.4) water usage in residential buildings Saudi Arabia
Diagram by (© Alhumaid)

3.4 Gray Water treatment

The Saudi building code do not yet allow the recycling of black water in residential buildings yet . However, it is acceptable to have gray water reused for toilets and irrigation. That is done through having two networks for drainage, one for black water and the other one for the gray one. Then gray water is collected in to a storage tank with a number of filtering layers and a feeding network to reuse that water back in the system. The next graph shows the gray water filtering requirements in the Saudi building code.



(Figure 3.5) gray water filtering requirements in the Saudi building code
(source: www.mowe.sa)

3.5 Passive Evaporative Cooling Approach

When looking at most of the energy consumption in buildings in desert climates, we will find that the biggest portion of this consumption is caused by air conditioners. One of the biggest challenges for architects or engineers is to find alternative sustainable ventilation and cooling solutions that are adaptable to hot climate conditions. The importance of natural ventilation is constantly highlighted in today's architectural conversations.

Health of the occupants and productivity often correlated with the quality of the indoor environment. The other critical issue is what is the best approach to reduce the buildings dependence on electricity and mechanics in order to reduce the consumption of energy and carbon footprint.

Historically, there was a number of ventilation and cooling methods in hot dry climates but perhaps Wind Towers, or Wind-catchers, known also as Baud-Geer in Persian, and Malqaf in the Arabic language are all names for natural ventilation models that were consistent and strongly present in the vernacular architecture of the East. Those models were crucial for softening temperature and providing thermal comfort in hot climate conditions. Since the air conditioners and mechanical cooling are accountable for more than half, and up to 80% in extreme cases of the energy use in buildings, there is a grater need for alternative and innovative cooling solutions.

CHAPTER 3| METHODOLOGY &DESIGN APPROACH

This element of vernacular architecture had proven to be an effective passive technique for cooling and ventilation within its historical context. Unfortunately, Wind Towers is disused and considered to be obsolete in today's settings before exploring the wide range of applications, and yet to be explored potentials this model may have in for future adaptations. In hot dry climates, there are a number of approaches for cooling buildings and reducing their energy consumptions.

When dealing with natural ventilation there are three elements on which the architectural design must rely on to get the best possible results. Those three elements are: Wind speed, Direction and temperature. Otherwise, when there is a shortage in air movement or when the airflow is still, pressure along with the variation between the indoor and outdoor temperature becomes the key player in the way air circulates. (Directorate General for Energy Altener Program 1998).

3.5.1 Review on wind towers in the vernacular context

Wind Tower designs varied from one place to another depending on a number of variables. However, most if not all models for Wind Towers share the same mechanism in cooling and ventilation. In most cases fresh air was led to the space below from one or a multiple openings that were placed on the highest part of the Wind Tower.

The hollow structure of the tower worked in the same way today's air conditioner would do in delivering air to the space. Wind Towers were usually the tallest parts of the building that they are attached to, and their openings were located where wind velocity greater and the air is clear from impurities. In order to get the best results the Wind-catchers should be in direct facing with the prevalent wind in the urban context. That means that if there were a number of Wind-catchers or Wind Towers at that same urban context they may have slight impact on the wind flow and velocity.

Even Though that is not likely to happen because the Wind Tower is much smaller than the structure that they are attached to, it is better to place them in a non-sequential way. In hot dry regions, air temperature was reduced by allowing the air to get in contact with a moist surface in the bottom of the tower, before reaching the space. In more humid climates, increasing the speed of the air coming to the space guaranteed better results. In both cases, other openings in the structure allowed air circulation, in order for the hot air to escape the space to be replaced with a cooler one. (Fathy1987)

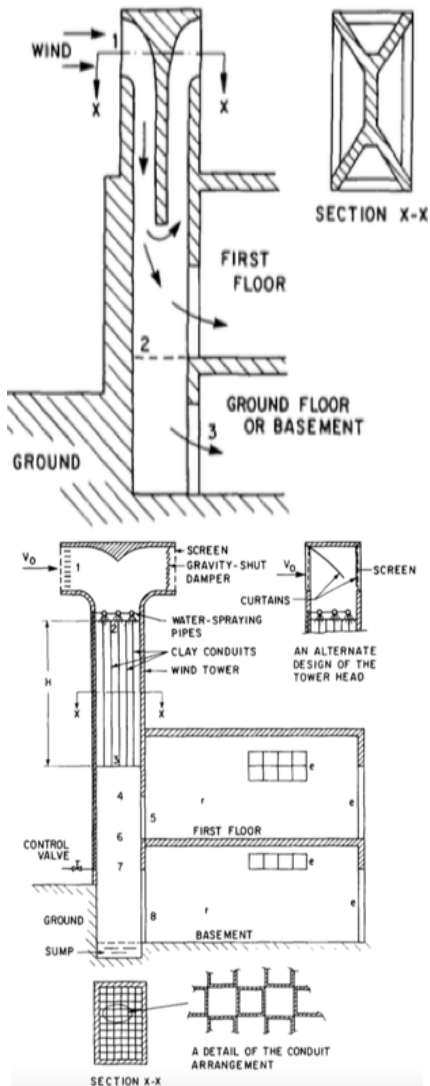
CHAPTER 3| METHODOLOGY & DESIGN APPROACH



(Figure 3.6) Example of the wind towers in the Middle East
(source: www.designmena.com)

3.5.2 Evaporative cooling and screen slides

(Bahadori 1985) introduced a new improved model for the Iranian Baud-Geer at the time, in which he presented some possible solutions to enhance the Wind Tower's performance in more than one area. In the traditional Baud-Geer the top of the structure had openings from all four directions. That meant that some of the air entering the building from one direction of the four openings might escape in the way down, through one or more of the other facing entry points. The new design suggested adding light screen slides that fully open only from the direction from which the wind is blowing while keeping the other three openings closed. By doing so, the suggested slides did not only reduce the loss in wind entering the space, but also they helped preventing smaller birds and insects from entering through the Wind Tower openings.



(Figure 3.7) to the top a traditional Baud-Geer with the four openings. on the bottom The improved model with evaporative cooling on top and clay conduits (source: Bahadori 1985)

In addition, the new design by (Bahadori 1985) showed a significant improvement in the overall coolness of the air coming through. That happened by increasing the heat transfer area that was exposed to a moist surface. In the earlier models the heat transfer area was limited on the internal walls of the Wind Tower, and cooling process, if any was applied, took place either in the bottom of the tower where a water pool is located, or at the manually moist internal surfaces of the tower. However, the proposed model had a different cross section and a different cooling mechanism than the traditional one. Long contiguous conduits with even geometrical shapes that worked as one unit, were placed in the higher parts of the Wind Tower. To optimize the use of this model, water was sprayed evenly on the conduits from above, which led to more evaporative cooling. Moreover the air entering the space was clear of large dust particles because it was filtered by the water spraying process.

CHAPTER 3| METHODOLOGY & DESIGN APPROACH

At the same means, (Bouchahm Y 2011) suggested changing a few elements within the wind tower design to reach a better result in cooling the air coming in to the space through the tower opening. The wind tower was not among the architectural elements that were used in the traditional architecture where the experiment took place. The test took place in the town of Ouargla, that is located in the southern parts of Algeria in North Africa. The town is characterized by an extremely hot dry climate during the summer with a temperature ranging between 116- 125 F. Therefore, the wind tower design was imported and tested in two existing housing units.

The first model was a conventional wind tower with an opening facing north where the prevailing wind is, and with a water pool in the bottom of the tower to cool air right before reaching the space. The results from the first model did not match the levels of expectations and was not able to provide thermal comfort, even though that other passive methods were embedded to the design. In the other model, means of evaporative cooling were implied. The external surface was wetted twice during the day in addition to the water pool in the bottom of the tower. The second model was able to deliver much better results with a suitable level of internal thermal comfort. The tests showed a strong correlation between the dryness of the internal surface of the tower and the indoor air temperature. When the internal surface starts to dry, a quick gain of heat starts to take place.

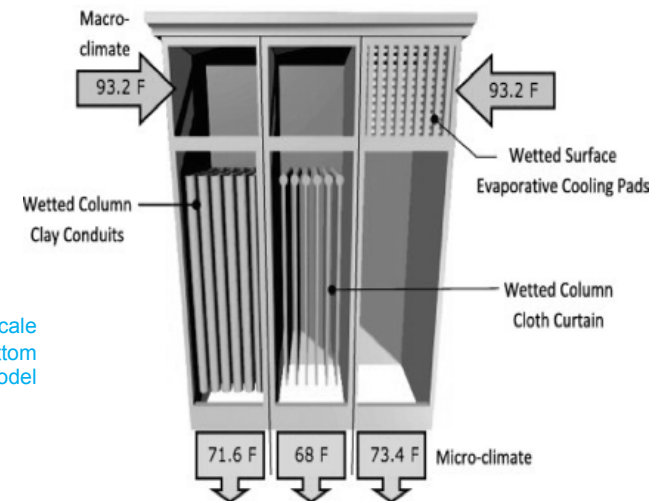
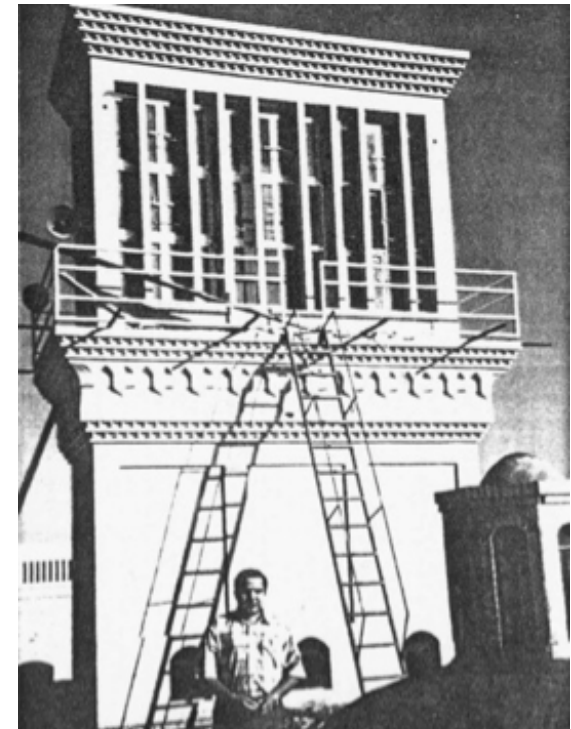
CHAPTER 3| METHODOLOGY &DESIGN APPROACH

Using the same concepts in the designs above, (A.R. Dehghani 2008) conducted an exploration comparison in the performance of the conventional wind tower with two improved ones. Both of the improved models used the means of evaporative cooling in delivering more thermal comfort in to the space. In addition they both used the same mechanism that were used in (Bahadori 1985) to reduce the air loss when entering from the head of the tower. Long hollow tubes with hanging fabric were impeded in the first improved model, and water was sprayed from above .

The second model had continuous supply of moist that extended in both the internal surface of the Wend Tower on one hand, and on the cloths that covered the opening from witch air entered the building, on the other one. Two prototypes that contained the two improved models along with the conventional, all were built side by side in one unit, and placed in two very different location. The first location was in an industrial area near Tehran, and the other one in the campus of Yazd University.

The comparison showed that the two improved designs both notably outperform the traditional one in delivering air with cooler temperatures to the space. Also they were able to bring more acceptable levels of humidity. However, the model with wet hollow tubes showed better results at the presents of higher wind velocity, and the other improved model, with wet surfaces was more efficient when wind velocity was low.

CHAPTER 3| METHODOLOGY & DESIGN APPROACH

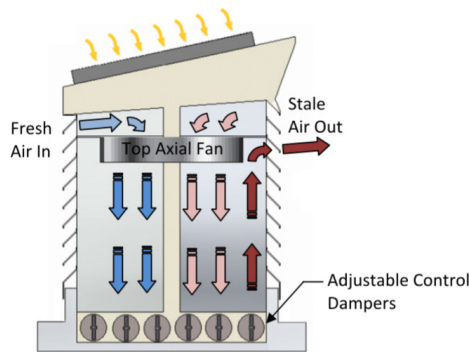
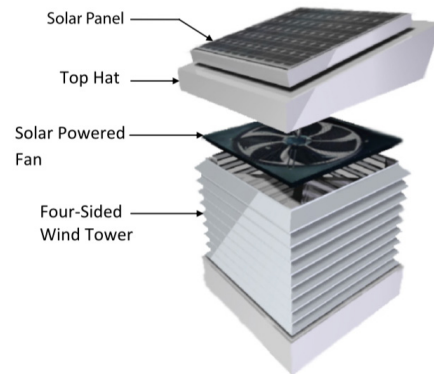


(Figure 3.8) to the top a photograph of the full scale wind tower that was built and tested . on the bottom the wind tower showing the three embedded model units showing the air temperatures in each.
(source: A.R. Dehghani 2008)

CHAPTER 3| METHODOLOGY & DESIGN APPROACH

3.5.3 Wind tower integration with the passive and active means

In the previous improved models that were shown before, evaporative cooling methods have been suggested and proven to be –up to a certain extent– applicable. The material of the wind tower that is storing and transferring heat can be replaced to achieve better outcomes. However, to get desired results with Wind Towers it was necessary to find a way to increase the airflow and velocity even if wind flows were absent in the context of an urban setting.



(Figure 3.9) the wind tower integrated with the solar fan
(source: Ghani2010)

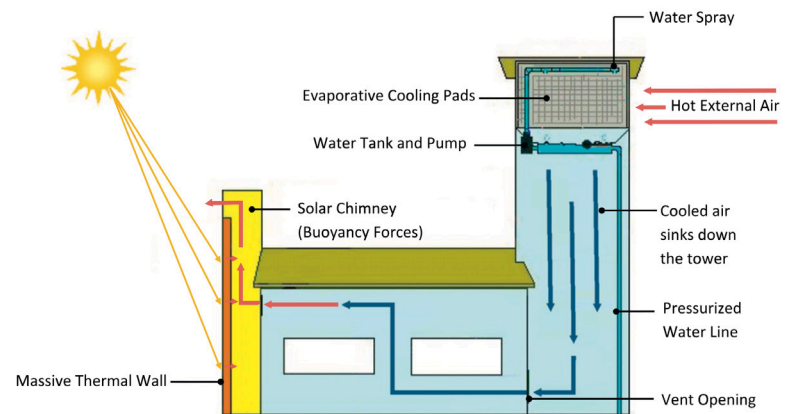
(Ghani 2010) Showed that it was possible to increase the airflow in natural ventilation applications with integration of passive mechanics to avoid high consumption of energy. In that case a stack that worked as wind a catcher was placed on the roof of the building to allow fresh cool air into the space, and simultaneously, eases the escape of hot air due to the variation between internal and external temperature. Within that wind catcher mechanical dampers were placed to control the amount of air entering the space.

Thus, it became possible to have those dampers completely opened to maximize the air flow in periods where the internal temperature of the space do match the thermal comfort levels for the occupant, and have them fully closed when the space is cooler than the occupant's needs. When there was not enough wind coming in to the space through tower openings due to macro climate reasons, a fan that worked on a solar panel was added on the top of the Wind tower. The fan worked in periods where air velocity was slow and not much air was driven to the space through the wind catcher The fan can also work as an exhaust device for pulling hot air through the wind tower.

CHAPTER 3| METHODOLOGY & DESIGN APPROACH

Comparatively, (Bansal 1994) proposed using a concept with a combination of a solar chimney and a wind tower to increase the air flow in to the space. The solar chimneys were placed on the openings where air is supposed to exit the space. Those solar chimneys worked on heating the attached wall, and therefore the air in it. Hot air surges then escapes the space allowing new air to come through the wind tower openings. The proposed concept had a significant impact on airflow patterns

In order to achieve a better result and increase the temperature drop in the air entering the space, evaporative cooling was added to the proposed model. With the present of the solar chimney the system worked more efficiently, especially in times when the wind were steady. Because air is cooler from the evaporative process, it becomes heavier and moved down through the structure in a higher velocity. In that case, increasing the height of the wind towers helped in creasing the airflow and thus, the overall coolness of the space. Another important key for the concept to function without any uncalculated overlap, the solar chimney must be thermally isolated from the cooling area. (Bahadori 1994) (Kalantar 2009)



(Figure 3.10) a passive solar chimney and evaporative cooling integrated with wind tower (source: Kalantar 2009)

3.6 Proposed Design Concept

In hot dry climates mechanical cooling techniques are embraced and as a result, air conditioners combine with other variables are adding more heat to the urban setting every day. Regions in the Middle East lived centuries using the Wind Tower in its many formations to cool their living spaces.

The claim that this element of vernacular architecture would solve all cooling and ventilation complications alone is rather naïve than noble. That being said, repetitive findings acknowledge the potential of that element. Especially, when integrated with other cooling methods. In addition, scene the Wind Tower evolved and was developed in hot climates where the presence of the sun is not a problem, it would be a lost opportunity not to embrace the advanced solar technology we have today on future integrations for the wind Tower.

The shown examples highlighted the potential of wind tower as an effective mean of cooling. Until today, it is still it difficult to fully depend on the wind tower to cool the indoor temperature and provide thermal comfort to for the occupants. However that does not mean they can not be used to help reducing the energy load for the mechanical systems.

(Taleb 2014) through computer simulations showed that a combination of eight passive strategies and the wind tower included may reach a total 23.6 in annual energy reduction in houses in Dubai. At the same means (Phillip & Lan 2013) demonstrated that that using a Passive Down-draught Evaporative Cooling system would achieve cooling more that 75 % of the cooling needed periods in Riyadh. The study looked in to both currant and future climatic conditions.

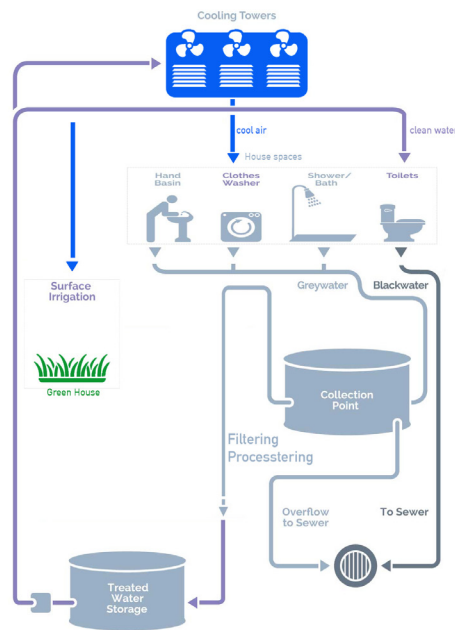
CHAPTER 3| METHODOLOGY & DESIGN APPROACH

However, most of the proposed models for hot dry climates use the methods of evaporative cooling. That may be a problem, especially, when hot dry climate usually take place in desert regions where water it self is limited. Therefore, future models or design must take that in consideration and try to reduce the use of water in the cooling cycle.

Thus, the proposed model would reintroduce the wind tower as an integral part of the cooling system for the single-family house. Within that system the cooling tower will use gray water after it is filtered as the main source for passive evaporative cooling. In periods where the passive system cannot reach needed comfort levels, a two stage evaporative cooling system will use the same tower to push the system toward reaching the required goal.

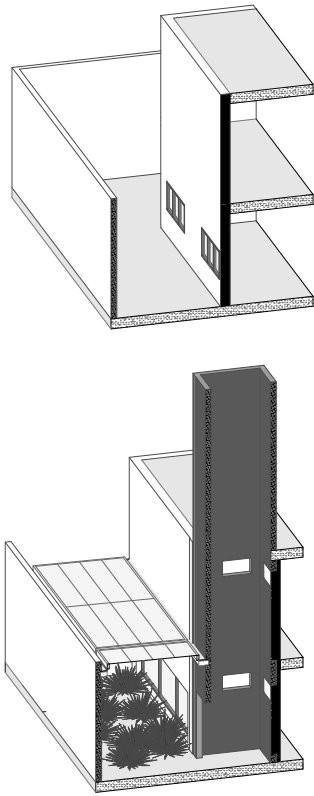
The design will then integrate green houses in the house set backs as a transition between the indoor and out door. The exhaust air from the system will be pushed to the green houses on the edges of the house. As a result, the temperature in the greenhouse itself is reduced and the air is more humid.

Thus, local vegetation can grow using less water, and plants that would never be able to grow in such heat now can. More over this transition would provide adequate daylight with less solar gain. This also will provide views and limited access to green space replacing the view to the 9-10 concrete wall in the lot parameter.



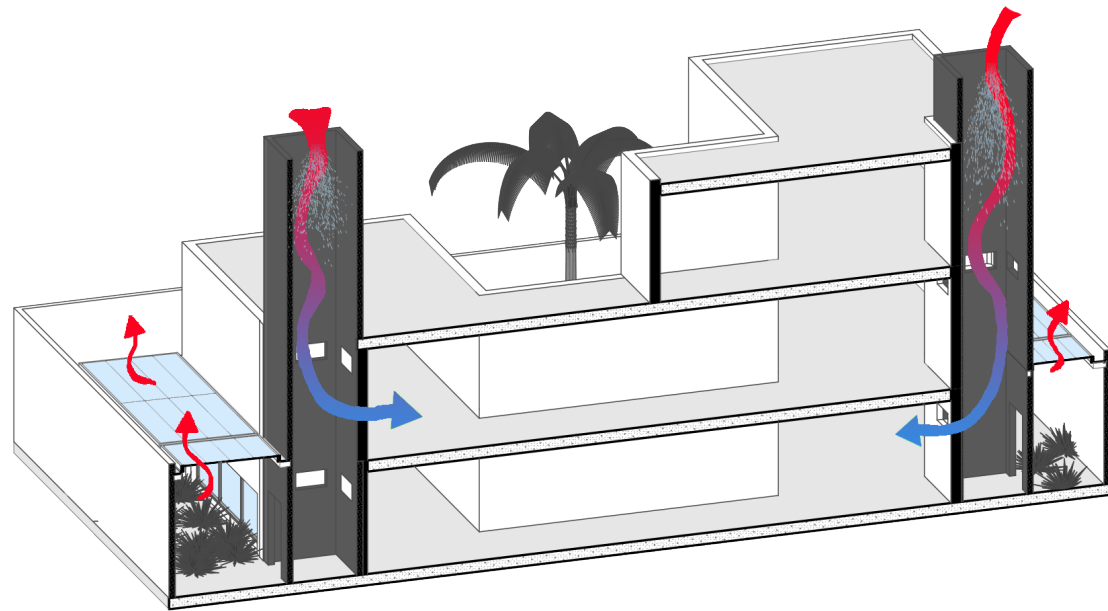
(Figure 3.11) Water circulation in relation to concept Diagram by (© Alhumid)

CHAPTER 3| METHODOLOGY & DESIGN APPROACH



(Figure 3.12) On the top a typical relation between the windows in the ground floor and the house concrete fence. On the bottom an alternative relation between the two.

Diagram by (© Alhumaid)

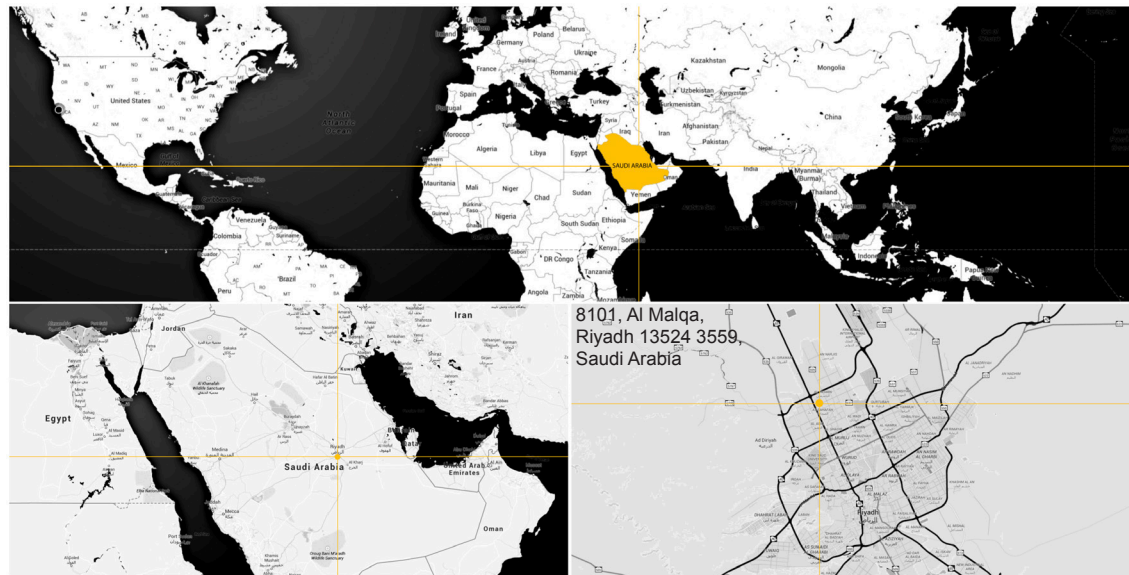


(Figure 3.13) The initial design concept with the evaporative cooling and ventilation system
Diagram by (© Alhumaid)

3.7 SITE LOCATION

3.7.1 Reasons for selecting the site

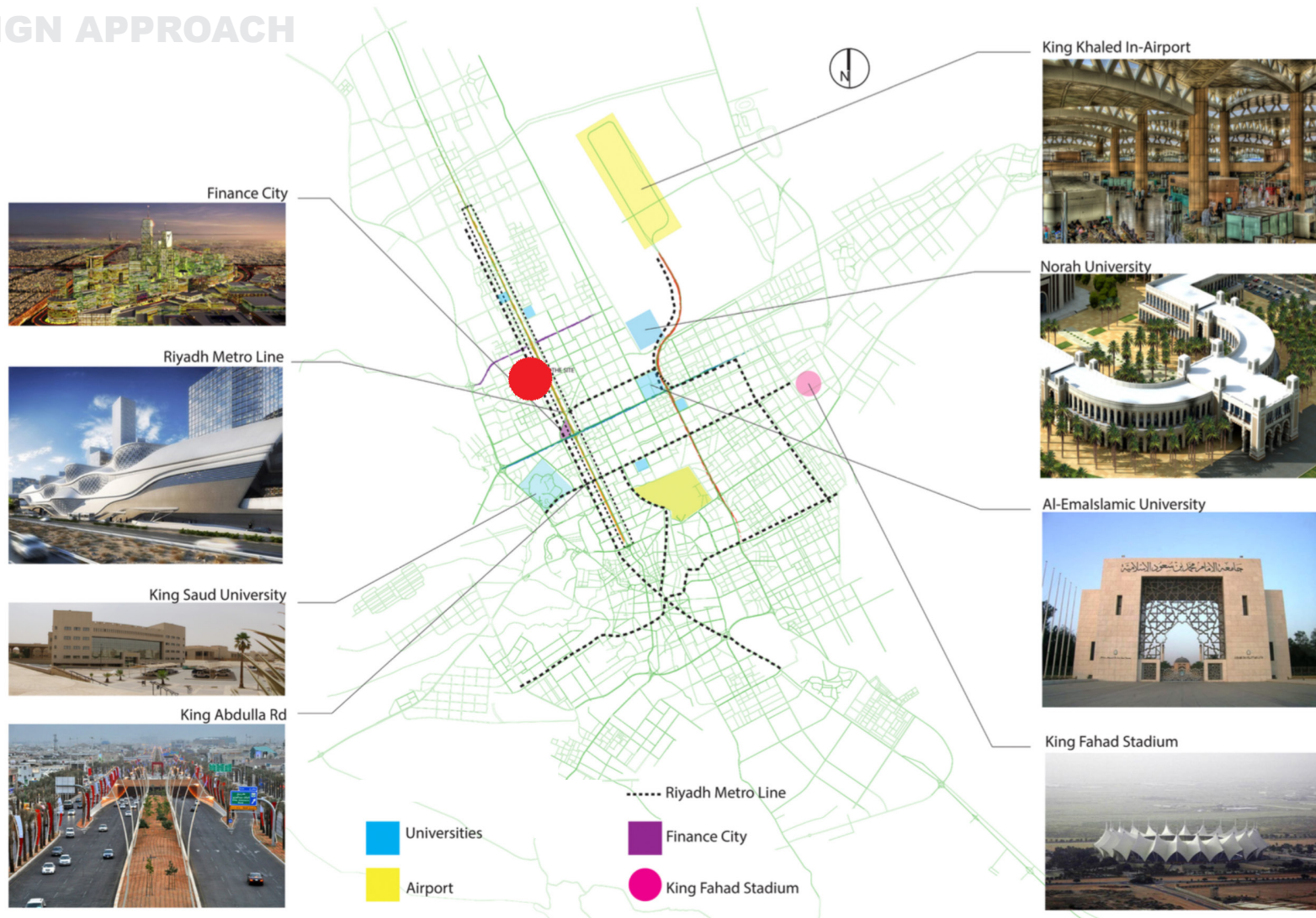
- The city of Riyadh have ben and would continue to its expansion north and the site is on the edge of the urban context now
- Close access to Riyadh's businesses districts, universities and schools
- The site is adjacent to King Fahad Road which is the most important arterial be cause it links Riyadh's south to it's north.
- Next to the site, on Al Olaya street there is the last stop station of Riyadhs new transportation system



(Figure 3.14) Site location
(source: www.google/map.com)

CHAPTER 3|
METHODOLOGY
& DESIGN APPROACH

3.7.2 Site relations to the bigger context



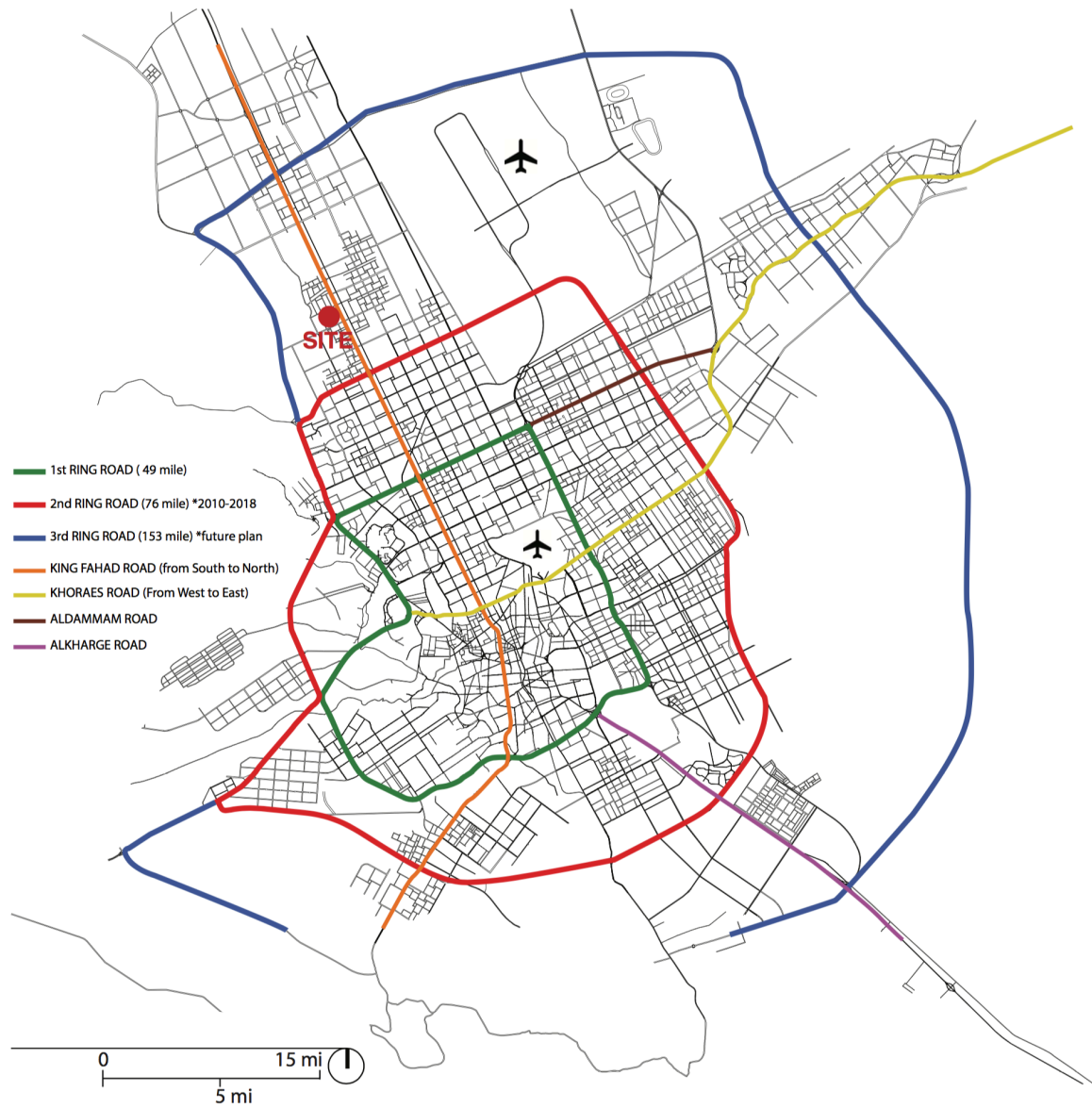
(Figure 3.15) site relation to the bigger context
Diagram by (© Alhumaid)

3.7.3 Site relations to the Historical growth of Riyadh



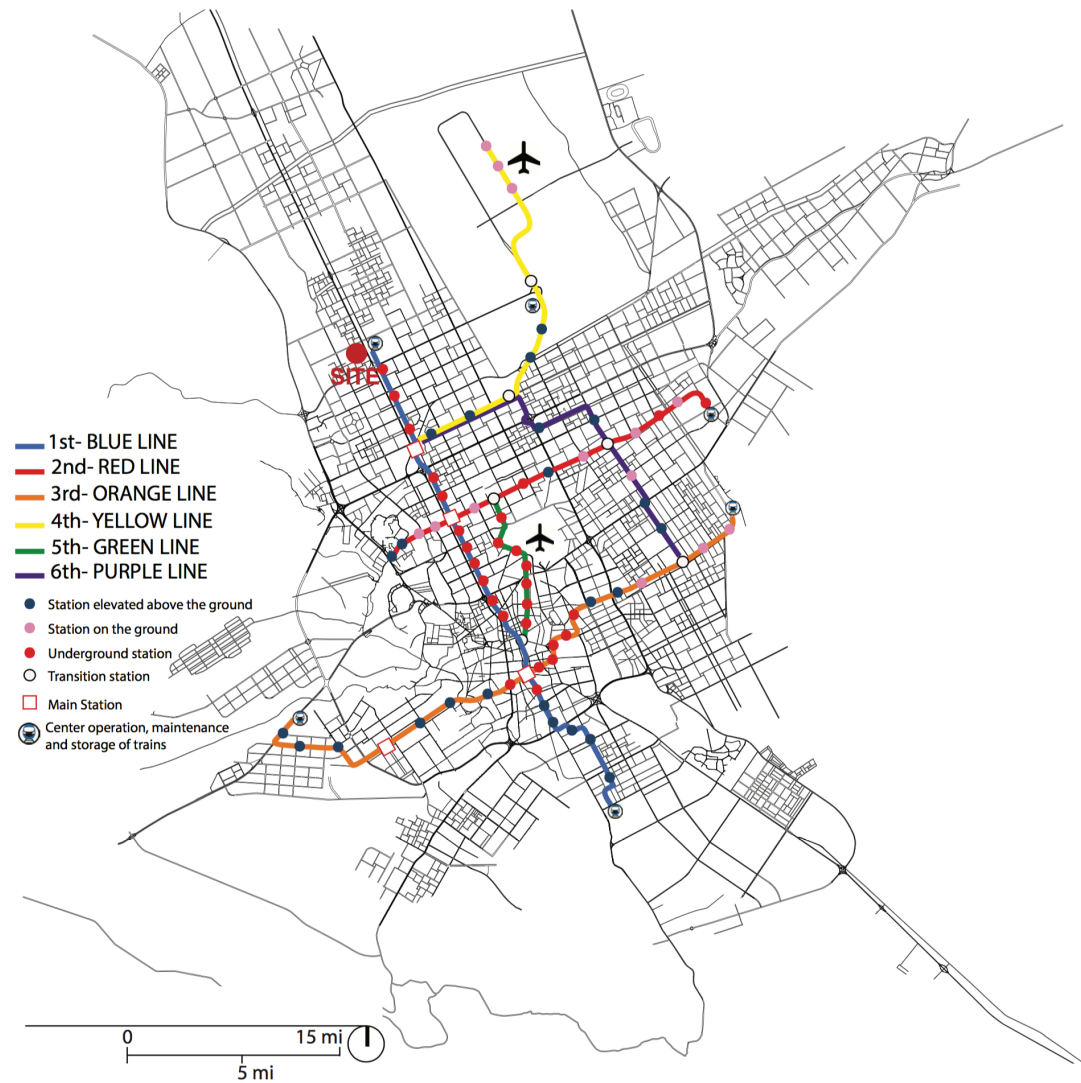
(Figure 3.16) Historical growth of Riyadh
Diagram by (© Alhumiad)

3.7.4 Site relations to Transportation in Riyadh



(Figure 3.17) Transportation in Riyadh
Diagram by (© Alhumiaid)

3.7.5 Site relations to Riyadh's train



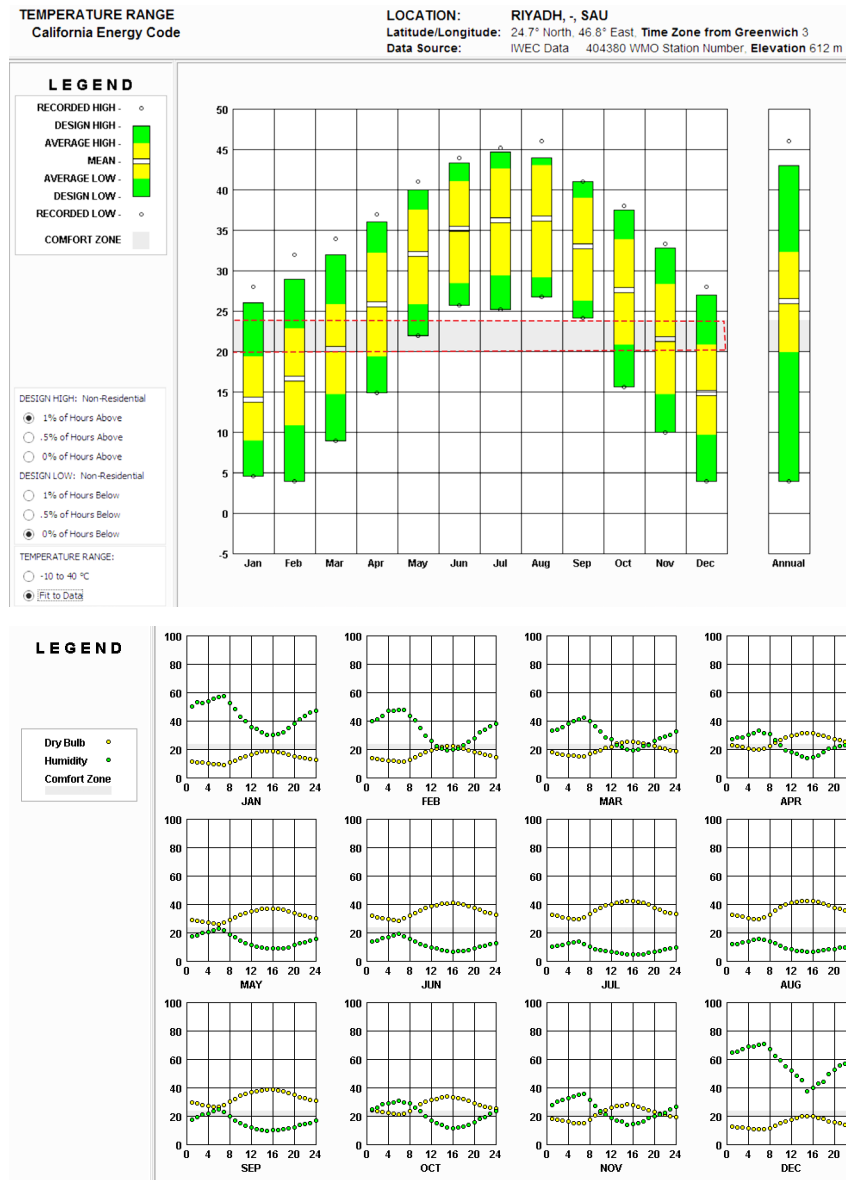
(Figure 3.18) Riyadh's train map
Diagram by (© Alhumiaid)

3.7.6 Site relations to Public plazas in Riyadh



(Figure 3.19) Public plazas in Riyadh
Diagram by (© Alhumaid)

3.8 weather Data Riyadh

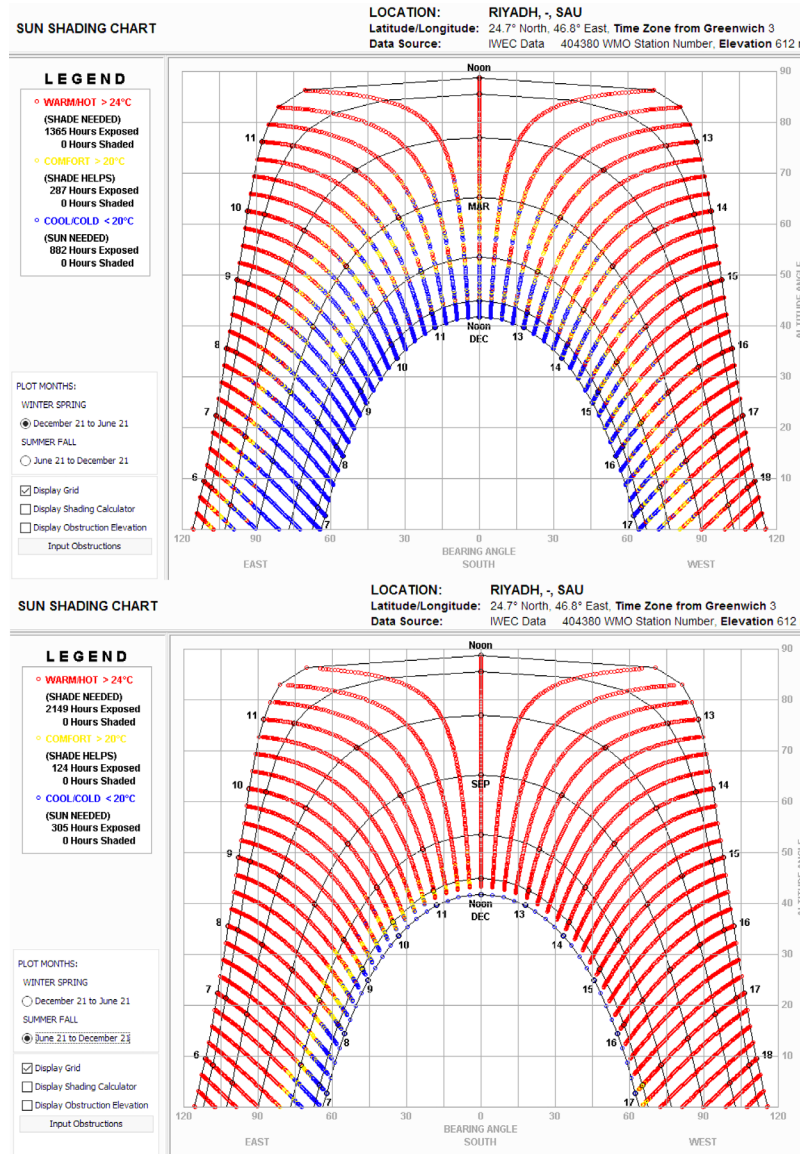


In the top chart, the average temperature ranges in relation to the comfort zone showing that the building would need cooling from Apr to Oct, and perhaps heating for other periods of the year. In the bottom one the dry bulb temperature on hourly bases and its relation to relative humidity that is much below the comfort level for the majority of the year

(Figure 3.20) Temperature range and dry bulb temperature
(source: climate consultant - software)

CHAPTER 3| METHODOLOGY & DESIGN APPROACH

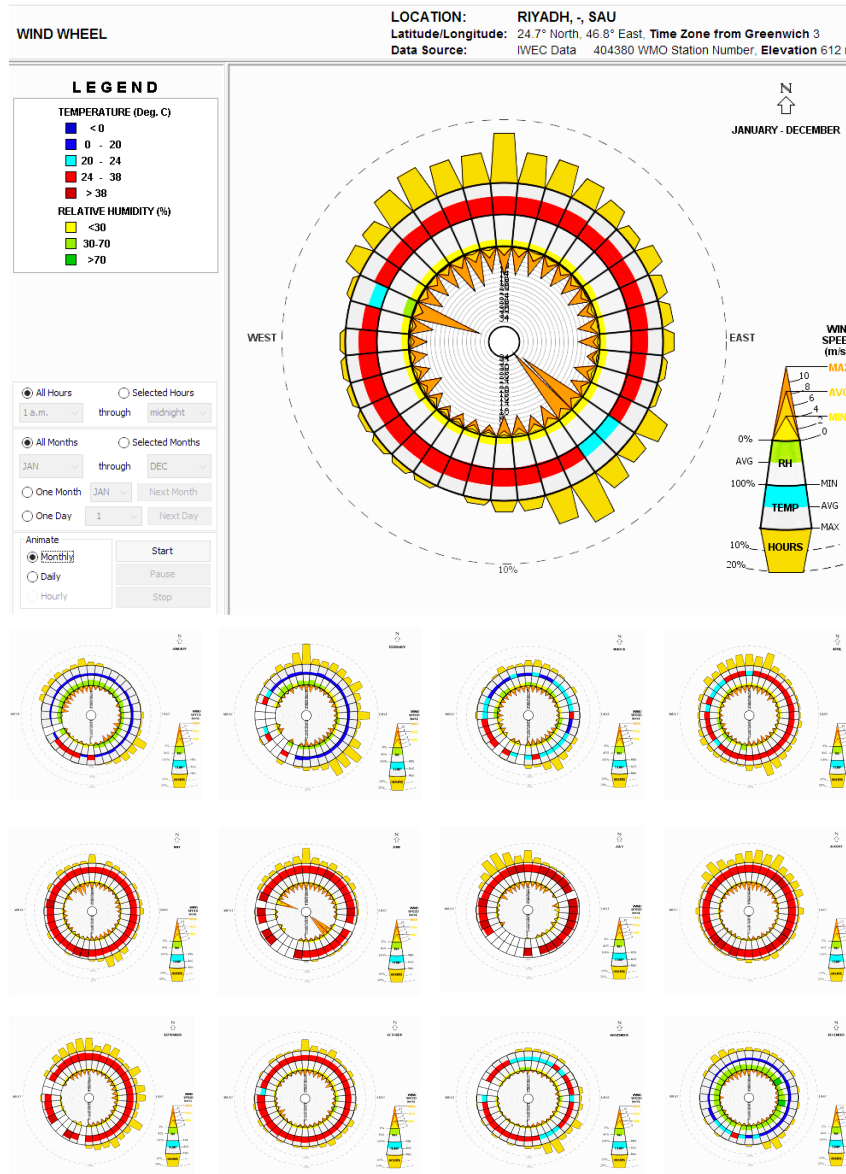
3.8 weather Data Riyadh



On the top the sun chart from Dec to Jun showing that building would need shading south, west, east facings for the majority of the day. On the bottom the sun chart from Jun to Dec showing that the building would need shadings from all four facings majority of the day

(Figure 3.21) Sun chart
 (source: climate consultant - software)

3.8 weather Data Riyadh

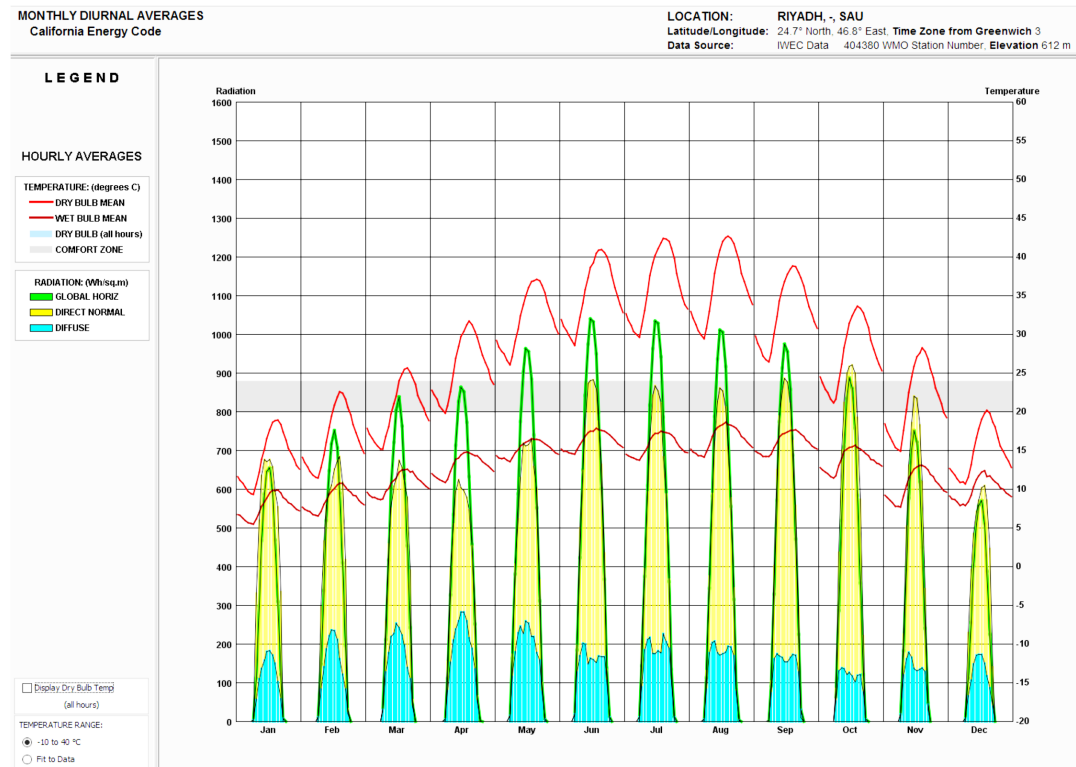


On the top the annual wind chart speeds and directions showing that the majority of the wind reaching the building would be coming from the Norton directions with an almost consist wind speed of 8-12 m/s. On the bottom an individual chart for each month of the year with the wind speed and temperatures for those months showing that from Dec to Mar are the only times where the wind temperature are cold and mild

(Figure 3.22) Wind chart
(source: climate consultant - software)

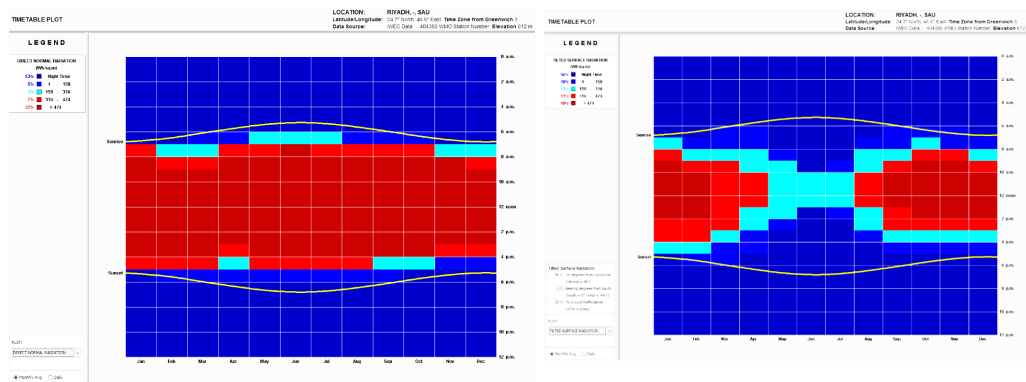
CHAPTER 3| METHODOLOGY & DESIGN APPROACH

3.8 weather Data Riyadh



On the top a graph showing the direct and diffused solar radiation and on the left bottom another illustration showing the consistentlyW (high) direct solar radiation. On the bottom right the radiation reaching south vertical surfaces.

(Figure 3.23) Direct and diffused solar radiation (source: climate consultant - software)



**CHAPTER 4|
DESIGN &
RESPONSE**

CHAPTER 4| DESIGN & RESPONSE

4 Before Designing

In Saudi Arabia in general and Riyadh in specific men and strange women do not mix together due to cultural reasons. The definition of strange men is based on complicated blood relatives' structures with in the family that is not to be elaborated here. Thus the house form and design needs to be able to accommodate both genders needs of privacy. The design needs also to be able to embrace the spatial needs of families that are less conservative, for those householders where gender segregation is not emphasized. Thus the design needs to be open to different interpretations by the users in way that allows the spaces to be completely open to on another, or completely segregated from on another.

Another key point, Most of the energy consumption in buildings in desert climates is caused by air conditioners. The biggest challenge for us architects is to find alternative sustainable ventilation solutions that are adaptable to our climate conditions. Because of aggressive dust storms that seem to intrude on our climate, until a point in which they became seasonal and inescapable, the traditional solutions for natural buildings ventilation may no longer work. Thus, the building needs to be able to adapt to different climatic conditions with a filtration mechanism that would allow the building to operate in open mode when its clear outside close mode when those dust storms are happening



(Figure 4) Example of the dust storms in Riyadh
(source: www.flickr.com - photographer : Alkassim)

CHAPTER 4| DESIGN & RESPONSE

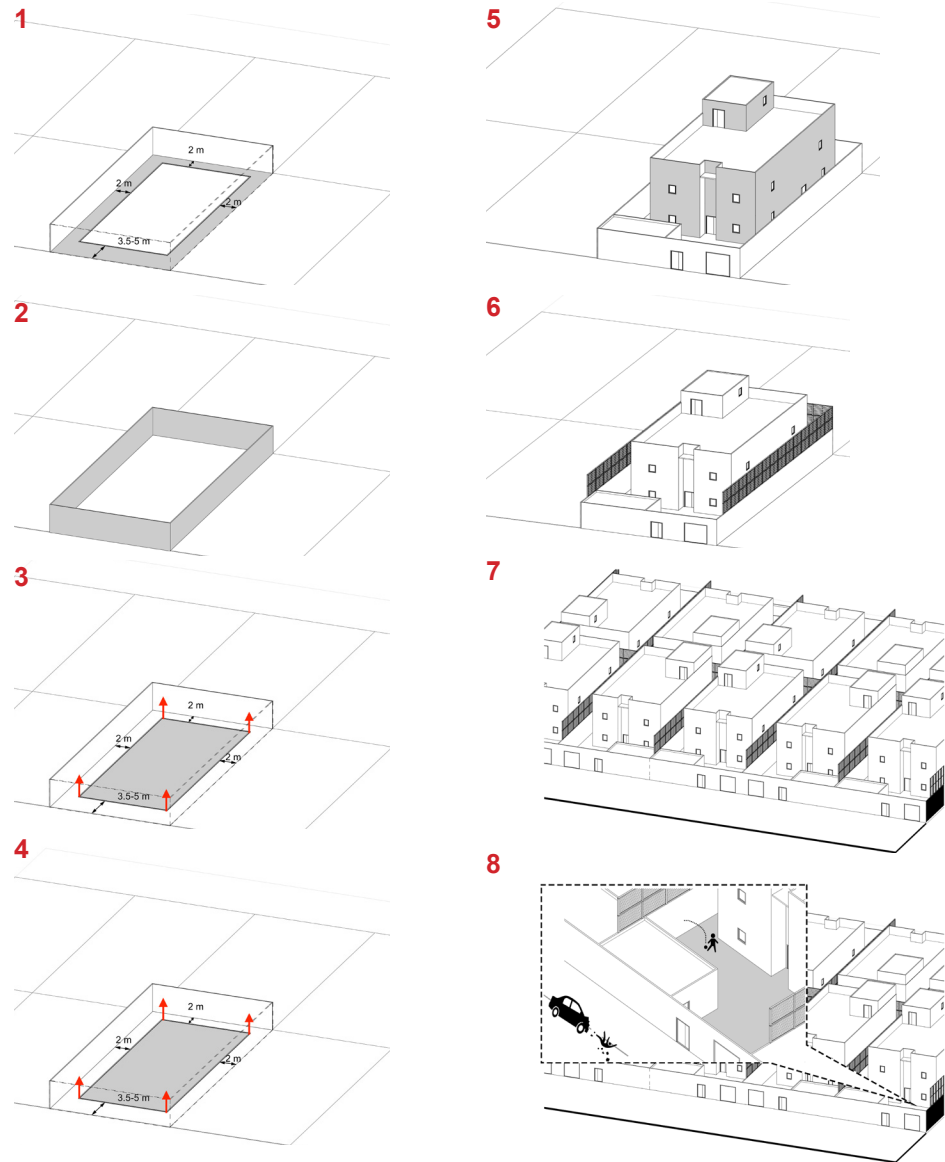
A typical house in the selected neighborhood exists in a 15 by 31 meter lot. The house built in that lot would exist in three required setbacks that are surrounded by a 4-meter fence. When maxing the building to lot ratio the result would be a house that is not respectful to the neighbors' visual privacy, and in most cases more than the family spatial needs.

Thus energy intensive with the need to cool each space individually. The end results would also force the users to add another 4-meter to the existing fence preventing light and air to be delivered with outdoor spaces that is not adequate for kids to play or socialize with their peers, forcing them to play outside the house in an unsafe environment.

(Figure 4.1) Conventional logic for housing design in the Saudi context

Diagram by (© Alhumaiad)

4.1 Conventional logic



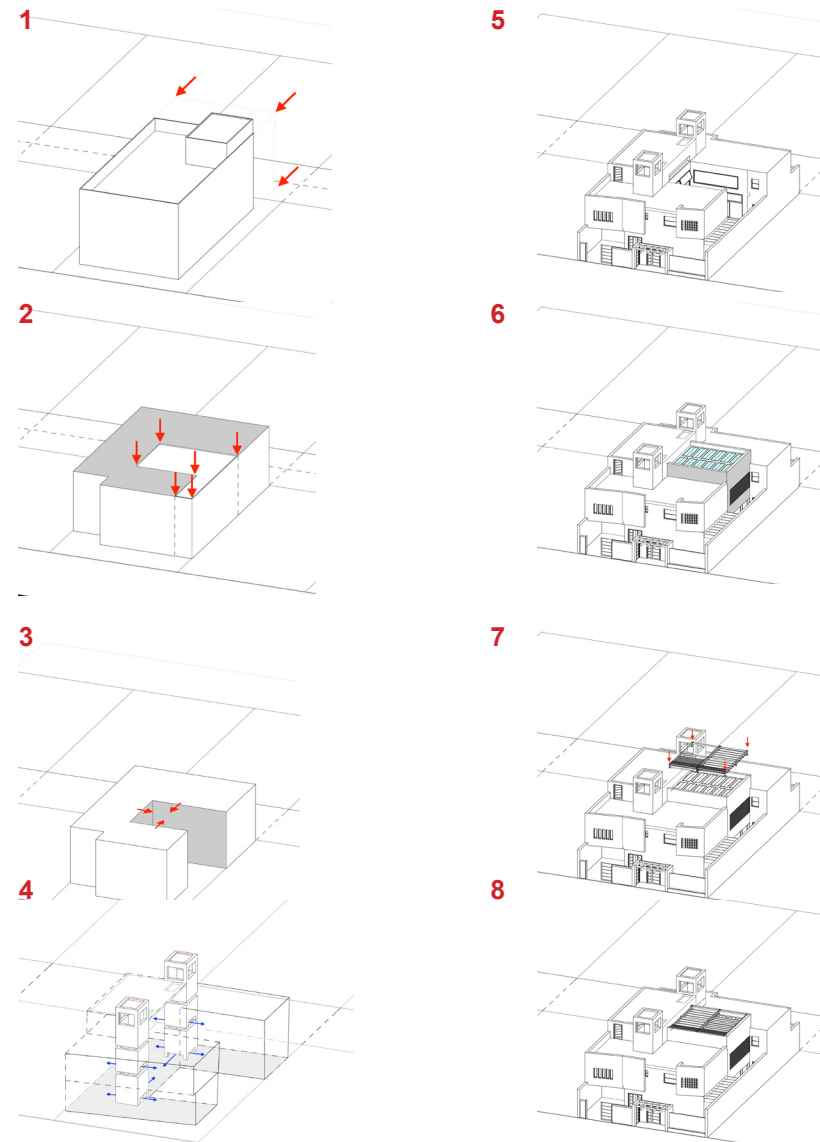
CHAPTER 4| DESIGN & RESPONSE

4.2 The Unit Design logic

The alternative approach suggests eliminating the house side and back setbacks and a portion of the front setback and start with a courtyard scheme that is open to the inside instead of the outside. Then strategically place the cooling towers that have different modes of operation in an area that would allow them to deliver cool air to the house spaces with the minimum distance for air to travel. Then envisioning the courtyard as an extension of the indoor spaces for the house. Thus having it enclosed using a skylight system and use the exhaust air from the house to make that space a tempered one.

Then adding an automated side louvers and a translucent shading system to add another layer of control and protection to the space. The proposed concept aims to decrease heat gain without impacting the daylight needs during extreme summer conditions.

(Figure 4.2) The housing unit design logic
Diagram by (© Alhumaid)



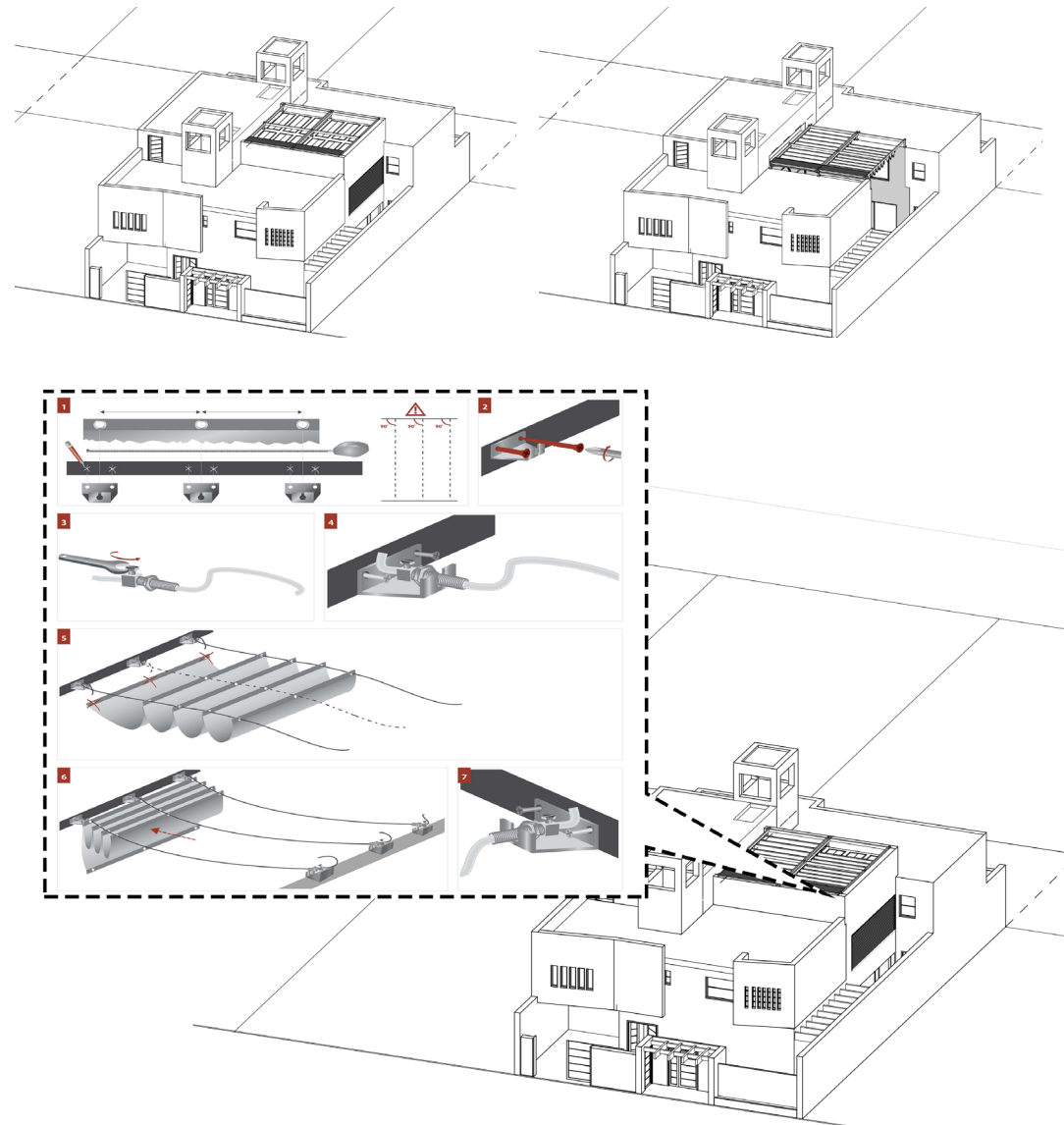
CHAPTER 4| DESIGN & RESPONSE

4.3 Value Engineering Thinking

During the design process it was important to design the system with a value engineering approach. Meaning that it is possible to eliminate parts of the system without impacting the whole. Such decisions usually take place during the construction phase of any project. In this case it is possible that the house cooling system may be adequate without the need to enclose the courtyard completely.

In another scenario it may be more feasible to have the courtyard open to the sky only with the automated shading system, and if the automated shading system was too expensive to install, it is also possible to replace it with a manual one that could be affordable and possible to self-install without the need for hiring trained labor. The final conclusion can only take place after accurately modeling the building for the multiple scenarios and analyzing which one would be cost effective the most.

(Figure 4.3) Value Engineering Thinking
Diagram by (© Alhumiaad)



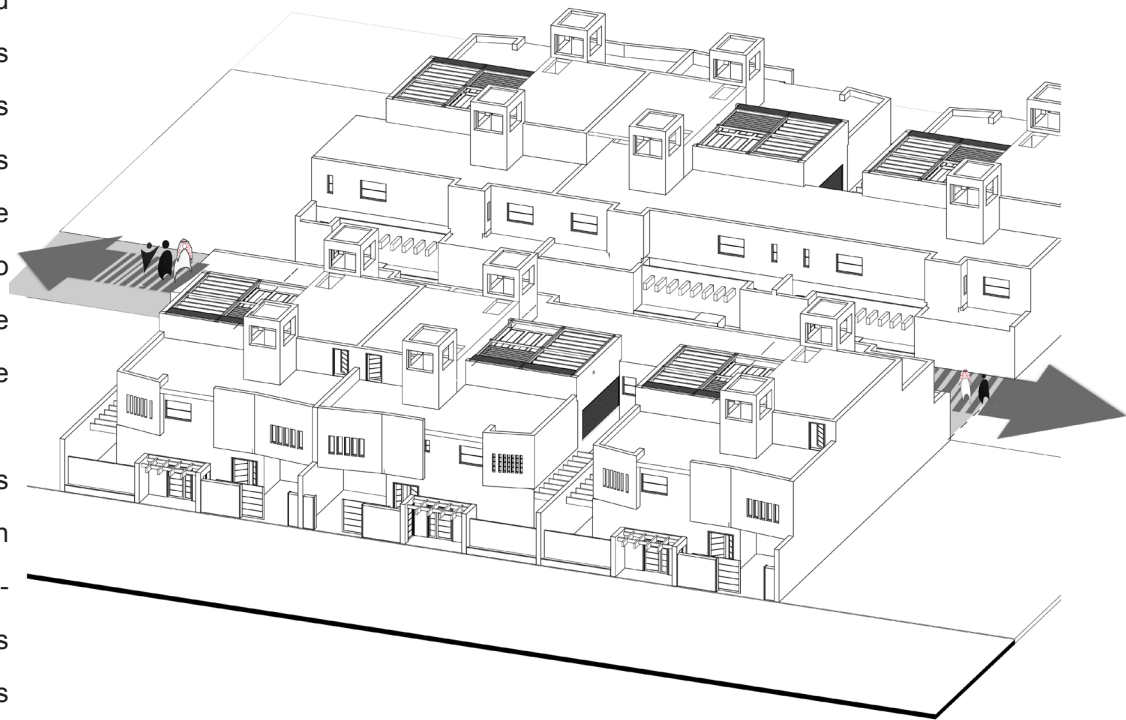
CHAPTER 4| DESIGN & RESPONSE

4.4 Pedestrian Shared Alley

After eliminating the rear and front setbacks and decreasing the area of units (unutilized) outdoors spaces, the collective portion of those spaces was used to create a pedestrian alley that penetrates each single block of houses. Each unit would have a direct access to that alley that would allow kids to play in a semiprivate and safe environment where families can supervise their kids and facilitate the scene for socializing.

Another key point the design aims to address is providing equal access to green public space. On average the distance between any park and any single-family house within the same neighborhood is 10-15 km (6-10 miles). With Riyadh neighborhoods design and climate, walking one hour in a place

that is not design for such activity is not an option. Thus, Individuals who lack access to a car or a driver would also lack access to those green spaces. In this specific case, women and teenagers who cannot afford to spend time or money commuting are given direct access to green space. Thus, the design creates a network of pedestrian walking and biking paths within the blocks.



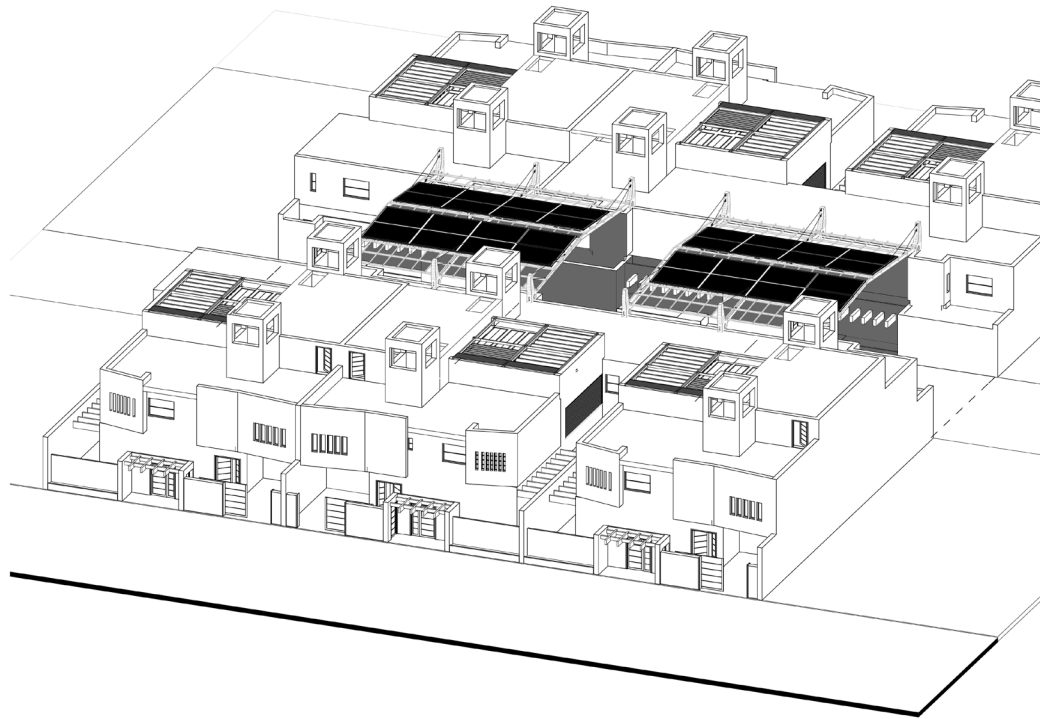
(Figure 4.4) pedestrian shared alley
Diagram by (© Alhumriad)

CHAPTER 4| DESIGN & RESPONSE

4.5 Shades and Future Photovoltaic

In order to activate the pedestrian alley and increase the periods in which the alley can be used, a shading system that will not block daylight from reaching the houses was installed using the same structural grid of those houses. At the time, the electricity price in Saudi Arabia is 13 us dollars for (1-2000)kwh for the residential use. Thus, the return on investment for installing a photovoltaic system is extremely low and not encouraging.

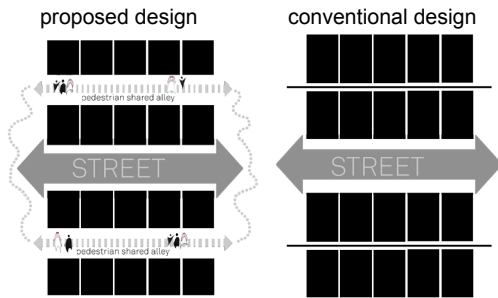
However, were the price for electricity to change in the future, or the price to install the photovoltaic becomes more effective; the same pitched shading system is ready to install photovoltaic with a mild energy loss between the shades oriented south and tilted 6 degree from the top to the one facing north tilted also 6 from the top.



(Figure 4.5) shading system for pedestrian shared alley
Diagram by (© Alhumriad)

CHAPTER 4 | DESIGN & RESPONSE

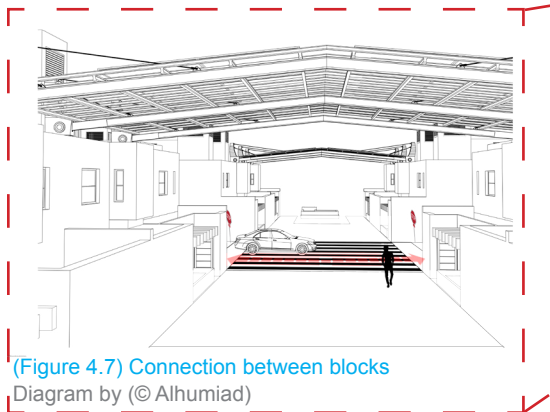
4.6 Site Plan



(Figure 4.6) Comparison between the conventional and proposed design structure of relationships between the neighbors
Diagram by (© Alhumiad)



(Figure 4.8) site plan
Diagram by (© Alhumiad)



(Figure 4.7) Connection between blocks
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CHAPTER 4| DESIGN & RESPONSE

4.6 Urban Form



(Figure 4.10) On the top a sample south elevation of the project and on the bottom an urban section perspective
Diagram by (© Alhumid)



(Figure 4.11) pedestrian shared alley
Diagram by (© Alhumaid)



(Figure 4.12) pedestrian shared alley
Diagram by (© Alhumad)

4.8 Unit Layout



(Figure 4.13) ground floor axonometric
Diagram by (© Alhumid)

4.8 Unit Layout



(Figure 4.14) Second floor axonometric
Diagram by (© Alhumid)

4.8 Unit Layout



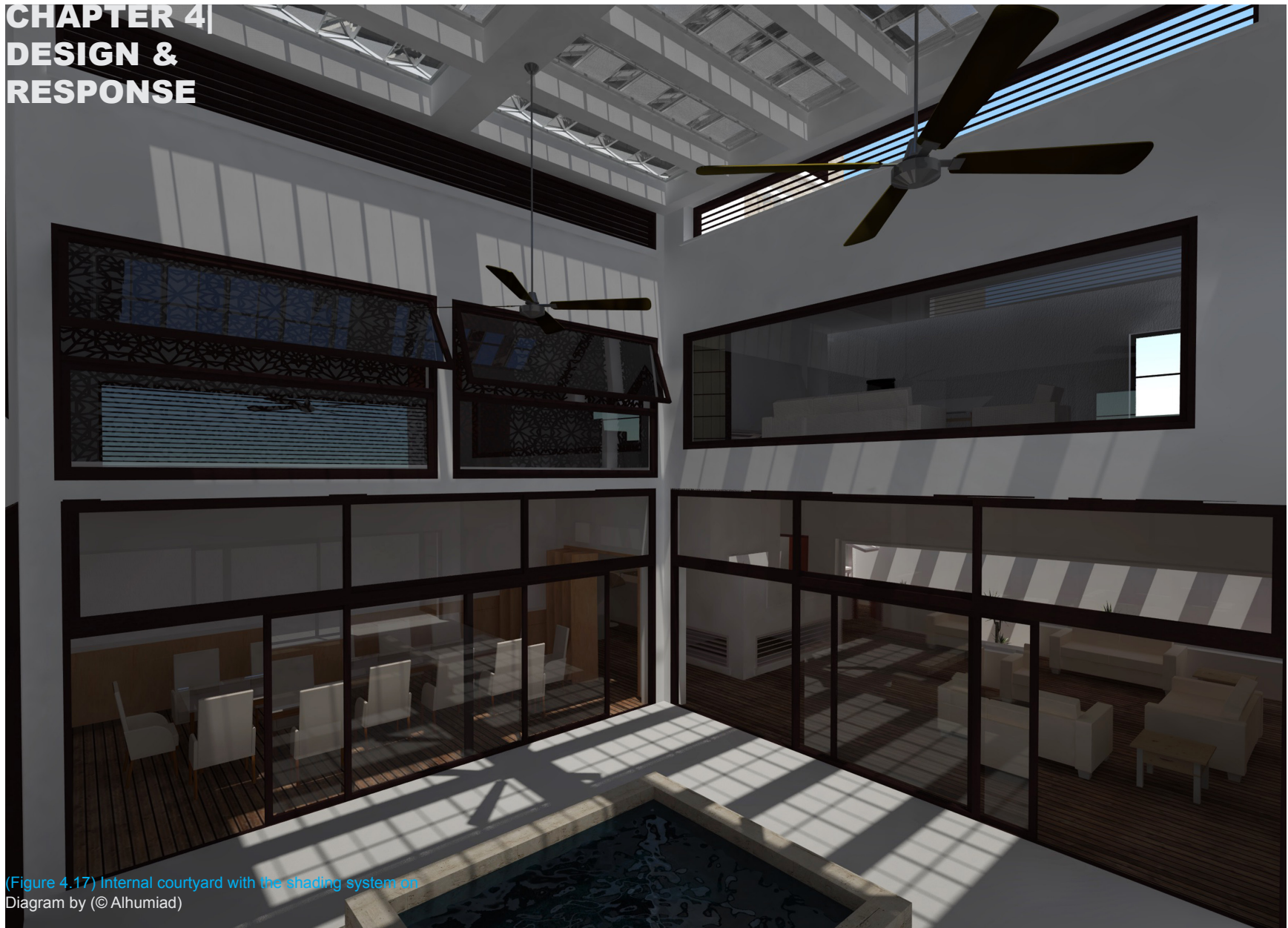
(Figure 4.15) complete house axonometric
Diagram by (© Alhumid)

4.9 System Integration



(Figure 4.16) System Integration and components
Diagram by (© Alhumid)

CHAPTER 4 | DESIGN & RESPONSE



(Figure 4.17) Internal courtyard with the shading system on
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**CHAPTER 4
DESIGN &
RESPONSE**



(Figure 4.18) Internal courtyard with the shading system of
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**CHAPTER 4|
DESIGN &
RESPONSE**



(Figure 4.19) Internal perspective from the dining room
Diagram by (© Alhumaid)

CHAPTER 4 | DESIGN & RESPONSE

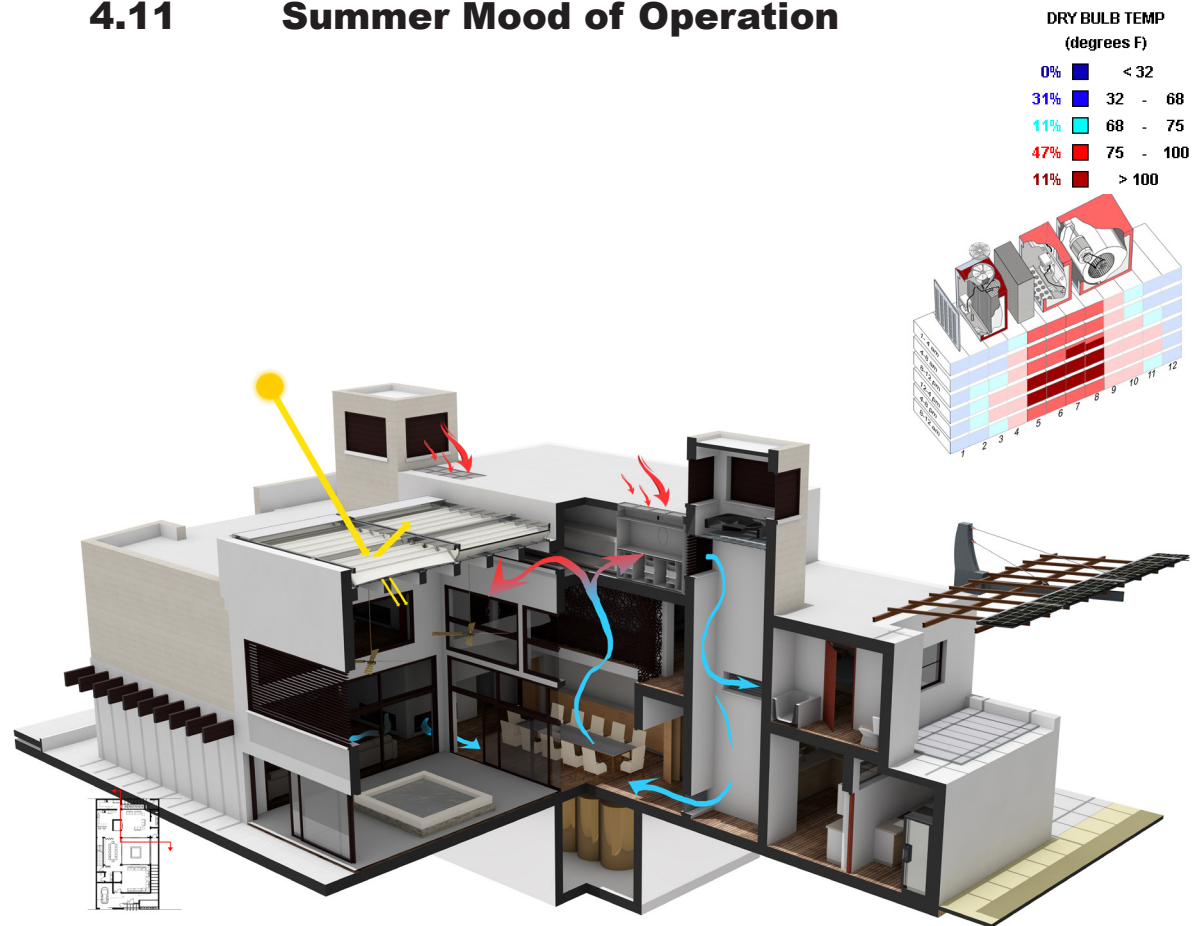
During extreme hot season the automated shading system covers the court yard skylight in order to decrease heat gain. The two stage evaporative cooling system that is attached to the cooling towers goes into a full mechanical mode and the compressor takes place to be able to deliver needed thermal comfort levels for the house occupant.

In periods of the day or the season where the outdoor temperature is hot but lower than the extreme the system decides if it would shift to the evaporative cooling mode that is more energy efficient but uses a lot of water for the cooling process. Thus a grey water system is integrated with the evaporative cooler to close the loop operate more efficiently.

When the cooling towers are in the compressor mode a portion of the exhaust air is pushed to the courtyard to mitigate the temperature in the space, and the other portion goes back to the

(Figure 4.19) Section axonometric that explains the Summer mood of operation
Diagram by (© Alhumiaad)

4.11 Summer Mood of Operation



system, and the system decides whether it will reuse the pre chilled air or if it will be pushed to the courtyard.

When the evaporative cooling mode is in place, the system relies on constant air supply to move the humid air. In this case the exhaust air is also pushed to the courtyard to prevent space from being too humid and to lower the temperature in the courtyard. In both cases low energy fans can assist air exchange between the indoor and the outdoor.

CHAPTER 4 | DESIGN & RESPONSE

During spring or times where the outdoor temperature is adequate to cool the building, outdoor air is either directly brought to the space or filtered depending on the climatic condition. When airflow levels do not match the desired ones, fans that are built in the cooling towers assist air moving through the structure of the tower. As air temperature increase it rises by a stack effect in the dining area, and escapes the house from an opening that is located on a higher place in the structure.

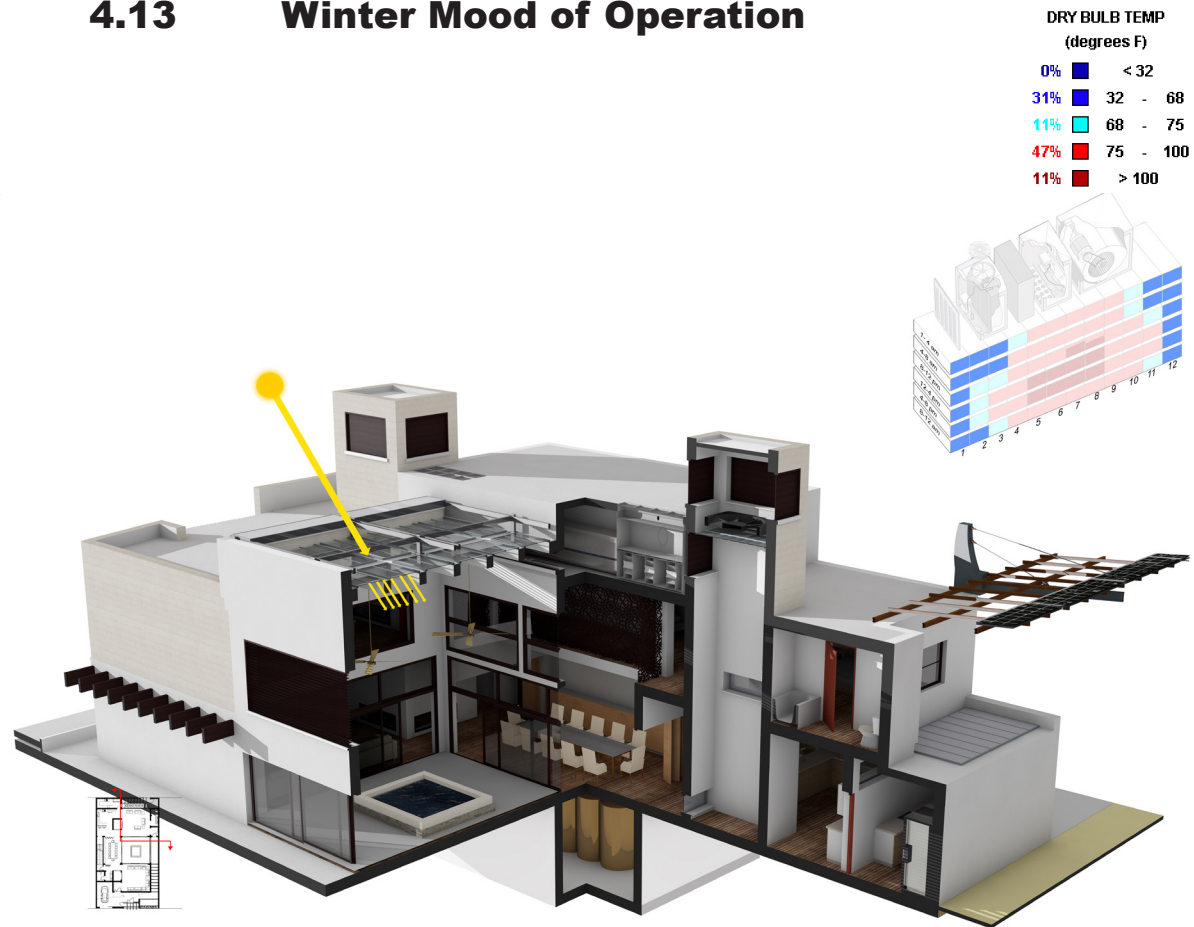


(Figure 4.20) Section axonometric that explains the Spring mood of operation
Diagram by (© Alhumiaad)

CHAPTER 4 | DESIGN & RESPONSE

During winter, the shading system is off to encourage heat gain and the house opening and louvers are completely in an enclosed mode minimizing air leaks. In this case the courtyard becomes a sunny warm space that is an extension to the indoor spaces.

4.13 Winter Mood of Operation



(Figure 4.21) Section axonometric that explains the Winter mood of operation
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**CHAPTER 5|
CONCLUSION**

5 Conclusion

This project aim was to design a built environment that is resourceful and respectful to both the natural and social landscape of the setting in which this design takes place. Resourceful with integrating waister water to optimize the cooling cycle and reduce the energy usage in a place where water is the most valuable resource and energy production is often taken for granted.

Resourceful also with integrating the parks systems with the housing fabric and set the scene for those parks to be more activated than a typical park. In general, all public parks in the city of Riyadh are open green spaces that were parachute on the city landscape without any reference to both the culture and the climate. Nevertheless, open green spaces in Riyadh are not the answer because first of all, they require enormous amount of water to maintain, but most importantly, the way people conceive open space in Saudi Arabia is very different than many other places when it comes to privacy. Thus, this project attempted to rethink the definition of public space by using the traditional hierarchy of private and semi-private on one hand, and of public and semi-public from the other hand. The aim was not only to insure activating each of those spaces but also to add both a communal and social value along with enhancing the experience of that space.

Finally, for the purpose of this thesis and its time frame all houses were designed using the same logic. However, a more interesting approach is to give users some sort of control on the end result to emphasize diversity and allow users to express their local identities that enhances the sense of belonging to the place. The house design is a semi-modular in a way that would allow the householder to be able to divide the unit in to two units instead of one after renovating the

CHAPTER 5| CONCLUSION

house and the stairs without impacting how the system would work. That is because each unit can relay on one of the cooling towers to cool that zone. Yet, with the courtyard scheme and privacy issues the unit division is more suitable to fit the needs of an extended family than it to fit two unrelated ones.

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