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R.I.T

Guide for Sustainable Design of NEOM City

By

Khaled Fallatah

Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Architecture in the
Graduate School of Rochester Institute of Technology
Department of Architecture, Golisano Institute for Sustainability

Rochester Institute of Technology
Rochester NY
Fall 2019

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Also, special thanks for my sponsor for giving me a golden opportunity to develop and learn in such a university in order to keep abreast of Vision 2030, add to it and help achieve it.

Most importantly, a lot of thanks and appreciation to my family who encourage me to follow my dream as an architect from day one in the journey.

Finally, I would like to thank all of my colleagues who have had positive support in my educational career in the Master's period. Without those people that I mentioned above, I could not have completed this Thesis. Again, thank you all from the bottom of my heart.

ABSTRACT

Urban planners and architects have concerned about the architectural style and theme of the NEOM city, because most of the new cities in the area seemed to be a generic city, no one wants to have another Dubai, Manhattan and Singapore. So what is the best code or development guideline should a new city in the area of Saudi Arabia should follow to become the most sustainable city without losing the Saudi's identity? This thesis research will provide a form-based code guide for sustainable development of NEOM City in Saudi Arabia for architectural character based on research and analysis of some case studies that can be helpful for NEOM also the author's own experience since I am from Saudi Arabia. Also, it will develop some sustainable suggestions based on analysis case studies in terms of water treatment, energy and waste management. NEOM is a new city in the North-Western of Saudi Arabia by the Red Sea and includes territory from Jordan and Egypt as well. The government of Saudi Arabia wants to build it from scratch towards new challenge 2030 vision for new kind of tomorrow and a new blueprint for sustainable life on a scale that never been experienced before¹. This thesis will provide a guide for sustainable design of NEOM City. Also, this proposal will address the Saudi vernacular architecture, sustainable new urbanism and 21th-century technology. The reason for this proposal because residential buildings, commercial and landmarks make up most of the urban fabric of any city. NEOM city would be smart, green and sustainable city; also, with Saudi's architecture identity and old technique such as passive cooling, MEOM will have the best architecture and urban design combination ever. The research will address the smart growth code and how NEOM will add Saudi's identity to it and make the most of it for a futuristic city. New urbanism movement will impact NEOM city in positive ways such as improve environment quality, enhance walkability and provide diverts affordable housing options.

¹ "NEOM." NEOM. Accessed Nonmember 2019

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1- INTRODUCTION

The Kingdom of Saudi Arabia is one of the most countries in the Middle East which has a diversity in architecture style. The architecture in Saudi Arabia varies from one city to another depending on several factors such as climate, topography and Identity. However, most of Saudi cities in 21 century look alike because it's been affected by globalization and generic cities ideas, nowadays you can't tell the difference between Riyadh, Dubai and Singapore. Even though those three cities have different topography, climate, culture but still the architecture style very much similar to each other.



Figure 1: Rem Koolhaas generic city

generic cities by Rem Koolhaas, which is free from identity and could be built everywhere². There are many examples of abounded generic building because designer didn't concenter the social aspect and identity. people looking for design that could be beautiful, modern, meaningful, sustainable that provide their needs socially and financially at the same time.

With the growing need for a sustainable architecture suited to needs of users. The idea came to write a smart code and development guide including how to integrate the local identity with 21th century technology for NEOM city to avoid falling into Generic city trap. Saudi Arabia rich of architecture

² Rem Koolhaas "Generic City".

heritage and style. Moreover, there are many good cases that will be as inspiration for us such Masdar city in Abu Dhabi and King Abdullah University of Science and Technology (KAUST) those projects both used local material, traditional technique and they have a lot of sustainable feature that reduce energy consumption and capture daylight. Also, passive cooling technique one of the most important things that will be address in this project.



Figure 2: Masdar city.



Figure 3: KAUST

Masdar city³ and KAUST⁴ used same traditional elevation that provide privacy, ventilation and filter the air whenever there is sand storm. In term of building orientation, all buildings are built near to each other to minimize sun expose and make zig zag shape to make a cross ventilation.

³ Masdar, Mubadala Company. Masdar Clean Energy. Wind.

⁴ "King Abdullah University of Science & Technology." KAUST. Accessed August 29, 2019. <https://www.kaust.edu.sa/en>
Zig Zag: orient the buildings very close to other buildings in order to provide shade and create ventilation corridors among urban fabric
NEOM: "New Future". ... The first three letters of NEOM ("NEO") come from the Latin word for "New"; the final letter ("M") is an abbreviation of the Arabic word "Mostaqbal" which means "Future"

Facts about NEOM

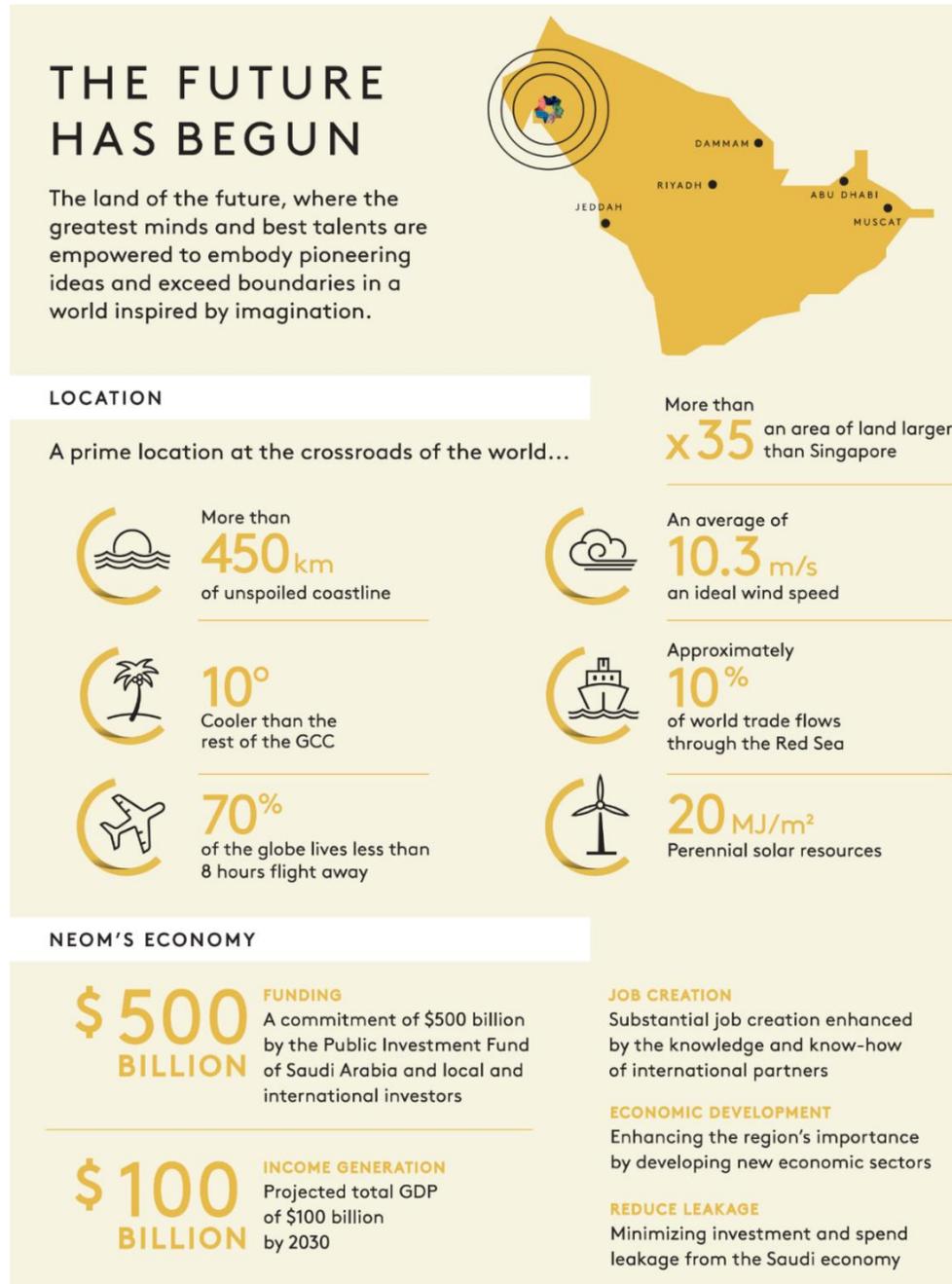


Figure 4: Facts about NEOM⁵

⁵ Accelerator of Human Progress." NEOM. Accessed August 25, 2019".

WHAT MAKES NEOM UNIQUE



ENVIRONMENT

A uniquely pristine environment



SUSTAINABILITY

Sustainability as a living principle



CONNECTIVITY

Globally connected and well located



CREATIVITY

A center for creativity and innovation



INNOVATION

Transforming the way we live and work



REGULATIONS

World-class regulation for people and business



COMMUNITY

Open, inclusive and respectful



LEADERSHIP

Visionary and committed leadership



LIVABILITY

NEOM aspires to be the best place to live and work

NEOM'S 16 ECONOMIC SECTORS ARE THE FUTURE OF



ENERGY



WATER



MOBILITY



BIOTECH



FOOD



MANUFACTURING



MEDIA



ENTERTAINMENT,
CULTURE AND FASHION



TECHNOLOGY
AND DIGITAL



TOURISM



SPORT



DESIGN AND
CONSTRUCTION



SERVICES



HEALTH AND
WELL-BEING



EDUCATION



LIVABILITY

Figure 5: Facts about NEOM⁶

⁶ Accelerator of Human Progress." NEOM. Accessed August 25, 2019".

SITE:

Located in the far northwest of Saudi Arabia, the project includes land within the Egyptian and Jordanian borders, which will provide many development opportunities with a total area of 26,500 km², and extends 460 km on the Red Sea coast. Within the framework of the ambitious aspirations of Vision 2030, the project aims to transform the Kingdom into a leading global model in various aspects of life by focusing on the acquisition of value chains in industries and technology within the project.



Figure 6: NEOM Montage by Author



Figure 7: Google Map Montage by Author.

The project was supported by a \$ 500 billion Saudi public investment fund, local and international investors. Founded in January 2019, NEOM is responsible for the development and supervision of NEOM, a joint stock company with full paid-up capital and owned by the Public Investment Fund. The company will create new cities and complete infrastructure for the region, including a port, airport network, industrial zones, creative arts support centers, innovation centers that support the business sector, as well as developing targeted economic sectors. In October 2018, the project's chief engineer, Eng. Nazmi Al Nasr, announced the operation of the first airport in NEOM before the end of 2018, and then the launch of weekly flights to the beginning of 2019, with the airport to be one of several airports to be included in the project. The airport, which bears the symbol of the International Civil Aviation Organization (ICAO) airport in Sharma, received Saudi Arabia's first flight on January 10, 2019, via two Airbus A320 commercial aircraft carrying 130 employees⁷.

⁷ Accelerator of Human Progress." NEOM. Accessed August 25, 2019".

Climate:

NEOM climate is characterized by hot summers and mild winters. Moisture levels can sometimes rise, especially in summer, and the amount of rainfall is little more than 35 mm per year. The rains are concentrated during the autumn, where the depressions accompanied by cold fronts cause the formation of heavy rain clouds and form thunderstorms due to the large difference between the temperature of the Red Sea water and cold air masses that rush at this time. The region is characterized by winds north to northwest for most of the year, and sometimes blowing strong eastern winds in the winter, which can reach speeds of up to 60 km /h. In general, the climate "NEOM" is stable for most of the year, where the number of air events are few, but they may occur, especially in the autumn, which is sometimes strong. Unlike the hot weather experienced by the Gulf states, NEOM is located in a temperate zone Weather in the northwest of the Kingdom, where the temperature in this site is about 10 degrees Celsius from the rest of the Gulf. Its proximity to mountain heights overlooking the Red Sea, which is directly affected by currents. The wind that passes through it. NEOM proceeding extends over the yard of more than 26 thousand square kilometers, and it is blessed All of this square with a charming natural beauty, and embraces the vast expanses of mountains high towers up to a length of some 2500 meters, as well as its extended beaches that will embrace all types of marine sports. This exemplary experience is further enhanced by the unique marine biodiversity that offers an experience to enjoy coral reefs, rare fish and water sports in an enchanting atmosphere⁸

⁸ "Accelerator of Human Progress." NEOM. Accessed November 2, 2019. <https://www.neom.com/en-us/sectors/>.

Organization of NEOM:

NEOM is subject to a special regulatory framework, not subject to the laws and laws of the State except the sovereign laws of the city, where it will have special laws related to legal restrictions, customs, taxes and labor laws, allowing the area to provide many services and manufacturing In addition to the creation of a special judicial body to resolve disputes in accordance with the laws of the region that follow independent legislation, on the social side, the best international standards of lifestyle will be applied in various aspects, as the project aims to provide economic opportunities. And the best ways of awareness and seeks to attract the most qualified skills from Saudi Arabia and beyond, taking into account the importance of improving the quality of life within the city and attention to various aspects; such as health, education, food, transportation, industry, entertainment, using the latest technology to implement a secure infrastructure

Energy:

The project seeks to provide the city of NEOM energy using renewable energy resources at the lowest cost. It is located within a region rich in wind and solar energy. NEOM scientists are also using water, gas, oil, and algae as new sources of energy, as well as working on energy storage networks.

Water

The city of NEOM extends 450 km on the shores of the Red Sea⁹, which will attract water research centers and startups to develop the latest technology. This gives it unlimited water resources to be exploited in renewable energy and to utilize Saudi Arabia's experience in desalination locally. This is an opportunity to become a regional source of water, and aspires to lead globally in desalination and storage technologies, which will attract research centers and startups in water development to develop the latest technologies

⁹ "Accelerator of Human Progress." NEOM. Accessed November 2, 2019. <https://www.neom.com/en-us/sectors/>.

Entertainment

The NEOM project seeks to elevate the level of entertainment; thriving the city theaters, visual arts halls, world-famous restaurants, and shopping experiences that compete with major cities and world capitals, theme parks, natural parks, in addition to the establishment of the world's largest park in the heart of the city. It seeks to attract the role of prominent fashion and brands to participate in the development of the fashion industry such as: changing rooms with virtual reality technology, changing fabrics by temperature change and others

Food

NEOM project focuses on many advanced technologies such as irrigation projects, dry farming, solar-powered greenhouses, as well as its vertically built farms to occupy less space and provide the city's residents with fresh agricultural products. Manufacturing Innovation in NEOM is thriving to encompass many technological applications, creating the right environment for these innovations to develop, such as research and development, procurement.

transportation and infrastructure.

-3D printing.

-Sensors.

-Internet of Things.

-Electric vehicles.

-robot.

-Renewable Energy Resources.

It is also important to create the conditions for testing these inventions, such as point-to-point self-propelled transport, drones, and self-learning traffic systems, in a living environment, and then develop and optimize them to the best possible form.

Methods and Theory

There is a lot of previous studies and research that covered topics like sustainable cities, sustainable neighborhood, and smart growth. The researches were followed by two different schools of thought qualitative and quantitative as a result there is so much information based on observation case studies, and theories. So, I have decided to use both ways in order to have so many information to help make the right design decisions.

First, New urbanism, Smart Code V 9.2 and Vernacular architecture in Saudi Arabia will shape NEOM urban fabric and architecture style, they will help us to give solid Guide for Sustainable Design for NEOM in several aspects such as the design of street section, open spaces, building height and more, it will be as a form based code. Second, will develop some sustainable suggestions based on analysis case studies in term of water treatment, energy and waste management.

Analysis case studies for sustainable projects such as Sustainable City in Dubai and Masdar City in Abu Dhabi¹⁰ designed by British architectural firm Foster and Partners. Its smart city and sustainable mixed-use development design that used renewable energy and a large amount of solar energy. They provide a lot of software that could help to determine how many energy consumptions, water uses and co2 emissions., along with sustainable recommendation in term how to deal with wind, thermal exchange, and building orientation.

¹⁰ Masdar.ae. Accessed October 20, 2019. <https://masdar.ae/>.

Literature review:

Utopian Design Experiments

since NEOM is a futuristic city and this thesis going to provide a guideline or code for NEOM there is some question that I should think about are we good fortune-tellers as a designer? what was the expectation for architecture and urban development thirty, forty years ago about the future that we live nowadays? did it happen or not? So, to find some answers lets analysis some of the Utopian cities that been Proposed in the past decades.

Arcosanti, Arizona



Figure 8: Arcosanti Project, Arizona¹¹

“Architect Paolo Soleri had started it up in the 1970s as an experiment in “arcology”, or a combination of architecture and ecology. Like so many before them, he thought his experiment would ultimately inspire a new dawn of human civilization. It’s poorly sited, no natural shading from landforms. It’s not an appropriate response to the climate, the buildings are facing south, with no overhangs”¹²

¹¹ Arcosanti. “World Famous Urban Laboratory and Architectural Experiment.” Arcosanti. Accessed October 28, 2019. <https://arcosanti.org/>.

¹² “Arcosanti: Why?” News and Discussion from an Architect's Viewpoint. Accessed October 24, 2019. <https://thearchitectstake.com/editorials/arcosanti-why/>.

Design Issue

We can learn from Arcosanti that building orientation and natural light should be addressed in better way for future city. Building facing south should have a special treatment such as hang over roof. Moreover, the population has been increasing since 1970s more than he was expected. Even the urban development extended to the city and covered it visually from several directions this is something was not taken in a consideration at that time. Natural sources are important aspect for any city that want to be self – sufficient. In country like Saudi Arabia water is the most important source that everyone looking for.

Case Studies:

Ordos, China Ghost City



Figure 9: Ghost City, China¹³

“Hundreds of hastily constructed yet nearly uninhabited “ghost towns” have cropped up across China in the past few decades as the country sees unprecedented economic growth and real estate development. New Ordos, located just south of Old Ordos in Inner Mongolia, is one extreme example. In the early 2000s, the Chinese government invested billions of dollars to construct the supercity on bare land in the Gobi Desert. The larger-than-life architectural projects include a huge statue of Genghis Khan overlooking its central plaza, and “Ordos 100,” a now-terminated project by Ai Weiwei and Herzog & de Meuron, featuring 100 villas designed by architects from around the world. Yet the tremendous cost of building the city resulted in some of the country’s highest property values—second only to Shanghai—so, unsurprisingly, few wanted to move in. As photographer Raphael Olivier said following his visit, “The whole place feels like a post-apocalyptic space station from a science-fiction movie.”¹⁴

¹³ Cascone, Sarah. “Stunning Photos of Chinese Ghost Town Ordos.” artnet News, December 30, 2015.

¹⁴ Kim, Demie. “7 Wild Experiments in Urban Design That Imagined a Better World.” Artsy, January 9, 2017.

What to Learn

The current state of the city is because the investments there have become intolerable as the deadlines for construction workers have not been met and loans have not been repaid by borrowers. Investors left before completing projects, leaving behind complete streets with unfinished buildings. Also, the cost of staying in the city is very expensive for the average income in China and specifically in the nearby cities that target the city's population to move to the new city. Even selling finished apartments has become a very difficult process right now.

Investors has to fulfill debt and Mortgage after selling Phase 1 to continue to Phase 2&3

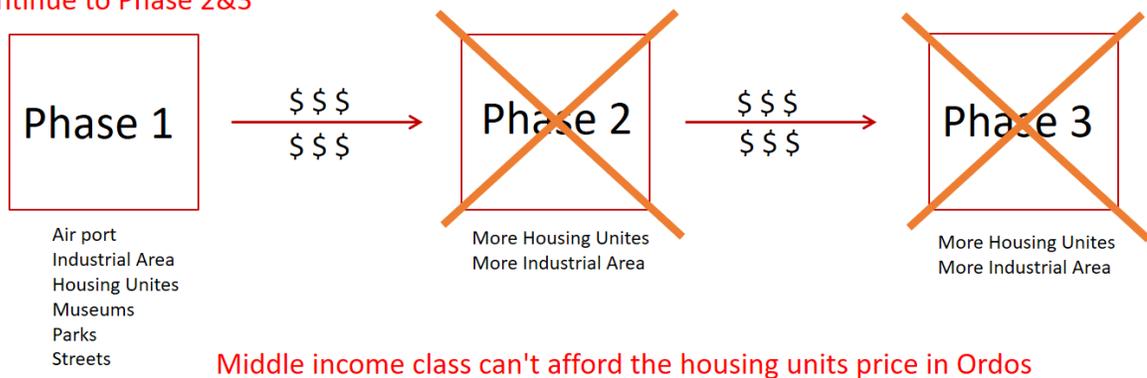


Figure 10: explanation of the economic problem in Ordos city, by Author.

Form-Based Code Case studies

Al Dhahiat Al Gharbia, Location: Makkah, Saudi Arabia



Figure 11: Al Dhahiat Master Plane, DPZ

Summary

The master plan for the 3.5 sq.km. site is to be sustainable community designed. The main goals of this development is

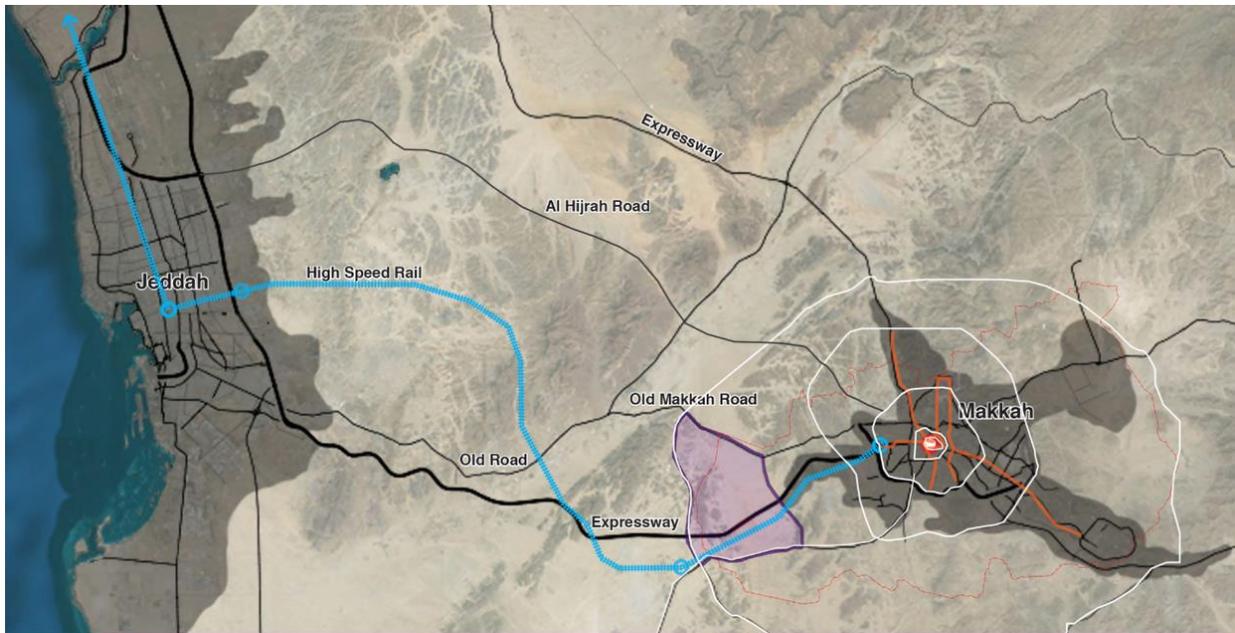
- 1 meet the goals established for the Structure Plan listed below.
- 2) to provide a predictable framework
- 3) to provide developers with the design strategies and guidelines with which to build in a walkable, livable settlement.

All new development is designed to meet the overarching goals established for the greater 87 sq.km.. western suburb. These are:

1. Establish a robust and resilient framework to guide development.
2. Create a regionally connected network of complete thoroughfares.
3. Strengthen relationships between built environment and natural systems.

The western Makkah suburb is targeted to accommodate a new population of 600,000 people over the next couple of decades¹⁵.

¹⁵ "DPZ." Al Dhahiat Al Gharbia, Makkah, Saudi Arabia. Accessed November 3, 2019.



This diagram shows the planned regional rail lines within Makkah that include a high-speed rail line and metro line. The blue line indicates the trajectory of the planned high-speed rail connecting Jeddah to Makkah. It parallels the Jeddah-Makkah Highway and bisects the Bawabat Makkah Land from west to east along the bottom south. The red /orange line indicates the planned metro line and stops, currently only to the south and east of the city center. However, plans to extend the metro to serve the western areas are also currently being investigated and developed. A minimum of two stops within the BMC lands are being explored, with one proposed along the Jeddah-Makkah Highway and another proposed along the old Jeddah-Makkah Highway. The high-speed train's final stop will be at the entrance to the city center, right after the third ring road that circles the city, and it will provide direct connections to the metro.

Figure 12: Al Dhahiat regional rail lines, DPZ¹⁶

¹⁶ "DPZ." Al Dhahiat Al Gharbiah, Makkah, Saudi Arabia. Accessed November 3, 2019.

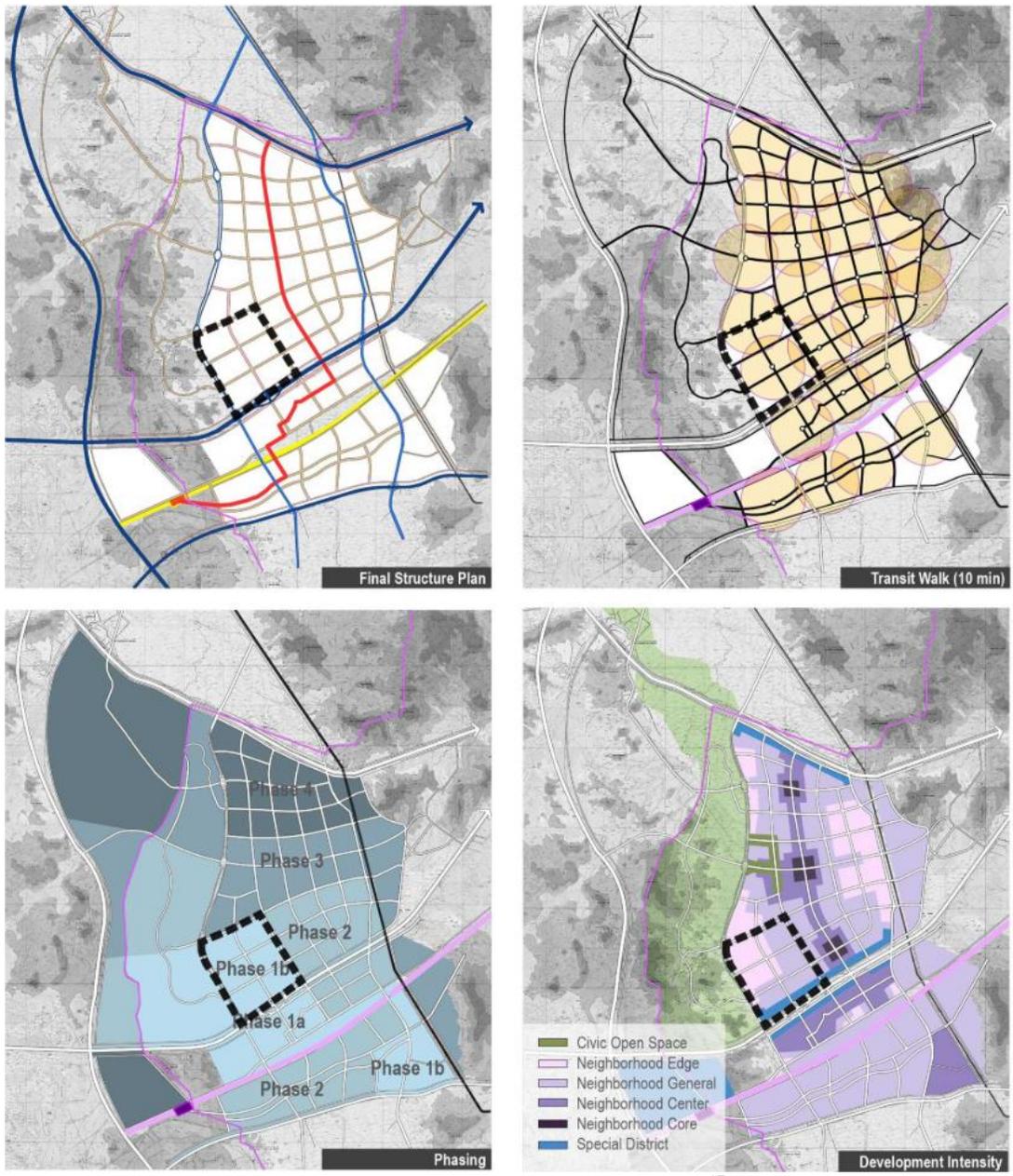
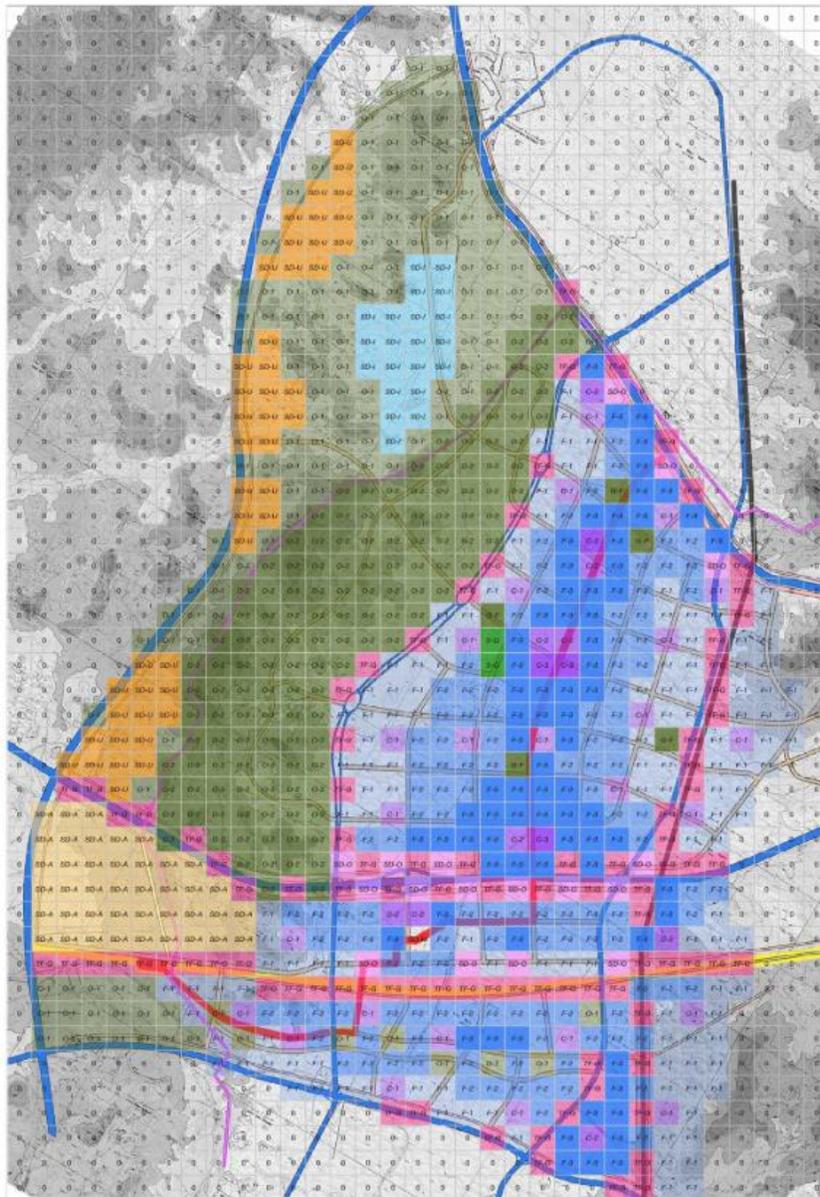


Figure 13: Al Dhahyat development Phases, DPZ¹⁷

¹⁷ "DPZ." Al Dhahyat Al Gharbiah, Makkah, Saudi Arabia. Accessed November 3, 2019



Population	
Target Population	600,000
Population in Zones 4-7	113,000
Population in Scenario	466,015
Total Population	579,015
Percentage of Target Population	95%

Land Mix: Regional	
Analyzed Land	8,360 Ha
Public Space	57%
Developable	43%

Residential Mix	
Residential Units	95,435 units
Net FAR (Zones 1-3)	1.46
Gross Net FAR (Zones 1-3)	.71
Gross FAR	.37

Unit Type	Area	Units
Villa	42%	17%
Duplex	17%	11%
Townhouse	16%	13%
Sm. Multi-Family	14%	26%
Mixed-Use Bldg	11%	33%
Single Family	75%	41%
Multi Family	25%	59%

Non-Residential Mix	
Retail Demand	559,218 m ²
Provided Retail	516,000 m ²
Provided Office	1,780,800 m ²

- O-1: Natural Open Space
- O-2: Regional Park
- GF: Green Finger
- SQ: Large Formal Open Space
- F-1: Low Intensity Fabric
- F-2: Medium Intensity Fabric
- F-3: High Intensity Fabric
- C-1: Low Intensity Center
- C-2: Medium Intensity Center
- C-3: High Intensity Center
- SD-0: Special District Office
- SD-A: University & Administration
- SD-U: Institutional
- SD-I: Existing Settlements

Interactive Regional Planning (IRP) is a system that facilitates regional scenario planning and provides real-time feedback in the analysis of various metrics influencing regional planning decisions. Initially the system was conceived as a method for analyzing regional CO2 emissions data, based upon a settlement pattern allocation analysis. Through development, calibration and use, the system proved to be equally useful in analyzing additional regional metrics such as population projections, energy loads, water usage, new infrastructure investment, housing mix and commercial capacity and so on. This inherent flexibility comes from the analytical approach of pattern-based metrics.

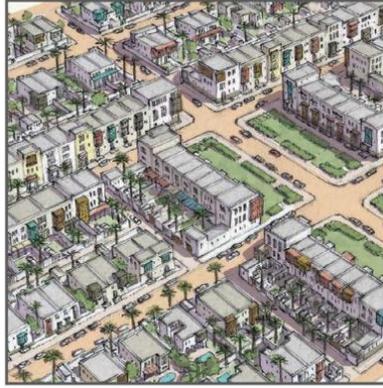
Figure 14: Al Dhahyat facts & Info, DPZ¹⁸

¹⁸ "DPZ." Al Dhahyat Al Gharbiah, Makkah, Saudi Arabia. Accessed November 3, 2019

Fabric Types for Al Dhahiyah Al Gharbiyah



F-1 Low Intensity Fabric Type: This is the lowest intensity fabric typology. It consists of low density, single-family lots, defined by side-yard houses, duplexes and villas exclusively at a gross density of 11 du/Ha.. It has the smallest variety of building types and does not include any commercial or mixed-uses.



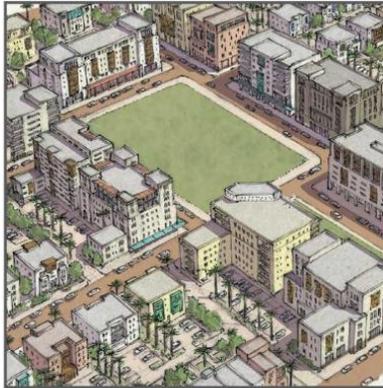
F-2 Medium Intensity Fabric Type: This is a low to medium-density residential fabric typology, consisting exclusively of low density, single-family lots, defined by villas, sideyard houses, duplexes, townhouses and a small percentage of small multi-family dwellings, at a gross density of 16 du/Ha. It includes no multi-family, commercial or mixed-uses.



F-3 High Intensity Fabric Type: This is a high-density residential fabric typology, consisting predominantly of multi-family and mixed-use buildings, with few sideyard houses, duplexes and townhouses, at a gross density of 61 du/Ha. It includes some retail uses at grade, but no fully commercial or office buildings.



C-1 Low Intensity Center Type: This is a medium-density mixed-use fabric typology, consisting of the greatest mix of building types as it include villas, sideyard houses, duplexes, townhouses, multi-family and mixed-use buildings, at a gross density of 37 du/Ha. While less dense than F-3, it includes more commercial uses (10,000 sm).



C-2 Medium Intensity Center Type: This is a high-density mixed-use fabric typology, consisting of a large mix of attached building types, ranging from townhouses, multi-family and mixed-use buildings, at a gross density of 74 du/Ha. This Fabric type excludes any single-family detached villas. It also includes a significant amount of commercial uses (20,000 sm).



C-3 High Intensity Center Type: This is the highest density mixed-use fabric typology, consisting exclusively of multi-family and mixed-use building types, at a gross density of 82 du/Ha. This Fabric type excludes any single-family detached villas, sideyard houses and duplexes. This Fabric type includes a significant amount of commercial uses and is the only type to also include office uses. (30,000 sm and 60,000 sm respectively).

Six Fabric Types were developed and then distributed by type, within Al Dhahiyah Al Gharbiyah. The higher densities were placed along major thoroughfares, while the lower densities and exclusively residential areas were placed along the western and southern edges. The most intense Fabric Types were reserved for the intersections of major thoroughfares or along planned regional transit routes.

Figure 15: Al Dhahiat Urban Fabric , DPZ¹⁹

¹⁹ "DPZ." Al Dhahiat Al Gharbiah, Makkah, Saudi Arabia. Accessed November 3, 2019

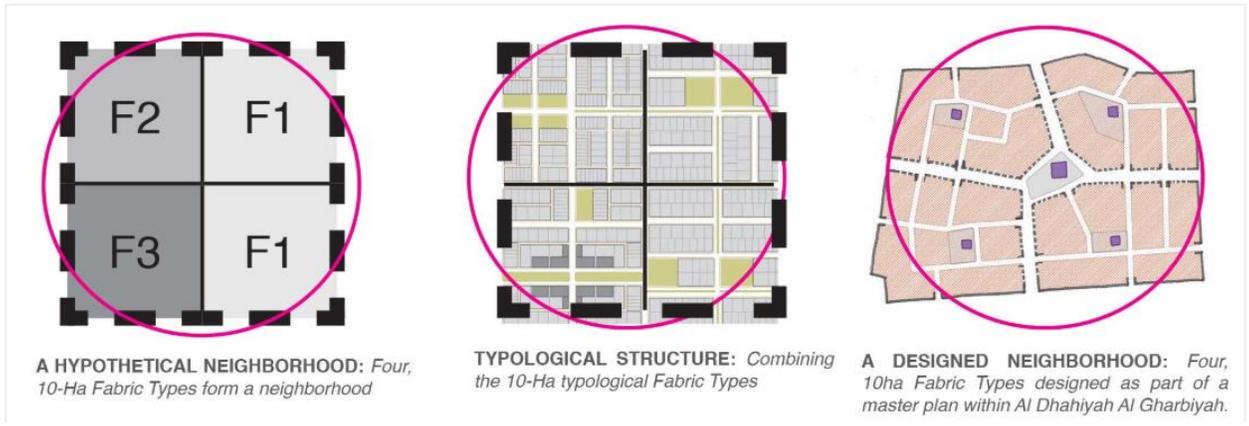


Figure 15: Al Dhahiat Urban Fabric, DPZ

The graphs above reflect the mixture of prototypical superblocks of 100,000 m² to shape a neighborhood, and they can generally be used to develop and shape a master plan. The master plan includes buildings, plots and streets of each style of fabric, with the last graphic showing how well these forms of fabric could be designed and implemented to the site.²⁰



Figure 16: Al Dhahiat Rendering, DPZ

²⁰ "DPZ." Al Dhahiat Al Gharbiyah, Makkah, Saudi Arabia. Accessed November 3, 2019

Masdar City:



Figure 17: Masdar City Master Plan

Masdar City is one of the most important clean and research cities in the UAE and the world.

Masdar City was established in 2008 to provide practical and technological solutions to protect the environment from pollution, reduce water consumption and preserve the environment. The Institute is looking at cutting-edge solutions in the areas of energy and sustainability and accelerates the spread of advanced technological innovations to the market. The city's design is a harmonious blend of traditional Arab architecture and modern technology. The city is also designed to benefit from fresh air traffic to provide natural coolness.²¹

²¹ "Masdar, Mubadala Company. Masdar Clean Energy. Wind"



Figure 17: Masdar City Solae Power, Photo by Andrew Parsons

Solar Power Generation in Masdar City, UAE

Solar energy is known to be a renewable energy source and can only be accessed until the end of the universe or life on Earth. They are also quite inexpensive energies such as coal, petroleum or natural gas. Solar energy has many uses, including heating water, heating homes, heating swimming pools and lighting. Masdar City generates clean electricity using rooftop solar panel technology. The city has one of the largest PV installations in the Middle East.²²

Living in Masdar City

Masdar City provides its residents with the opportunity to live and work at the same time because of its modern Arabic style, the city offers shaded and comfortable pedestrian facilities that reduce reliance on internal transport and air conditioning, where the project is expected to attract After its completion to nearly 40,000 inhabitants, in addition to the presence of 50,000 tourists and visitors in the city.²²

²² "Energy Services." masdar.ae. Accessed September 23, 2019.



Figure 18: Masdar City Transportation, Clean & Smart Mobility

Sustainable transport

Masdar is at the forefront of sustainable transport, in line with its strategy to reduce costs and improve the quality of life within Masdar City, Abu Dhabi. The city has clean and complete public transport options, including electric buses and self-driving vehicles. Masdar City has officially adopted the first autonomous NAVIA Autonomous Vehicle in its autonomous mobility network, a move towards the next phase of developing and expanding the city's sustainable mobility system. Masdar, Abu Dhabi Department of Transport and NAVIA, a French leader in the development of autonomous vehicles, collaborated on the design of the first and last-mile vehicle, which transports passengers to and from transport stations. It is a fully autonomous vehicle with eight seats capable of accommodating 12 passengers and a top speed of 25 km / h.²³

²³ "Clean & Smart Mobility - Transport at Masdar City."

A Sustainable City in the Desert

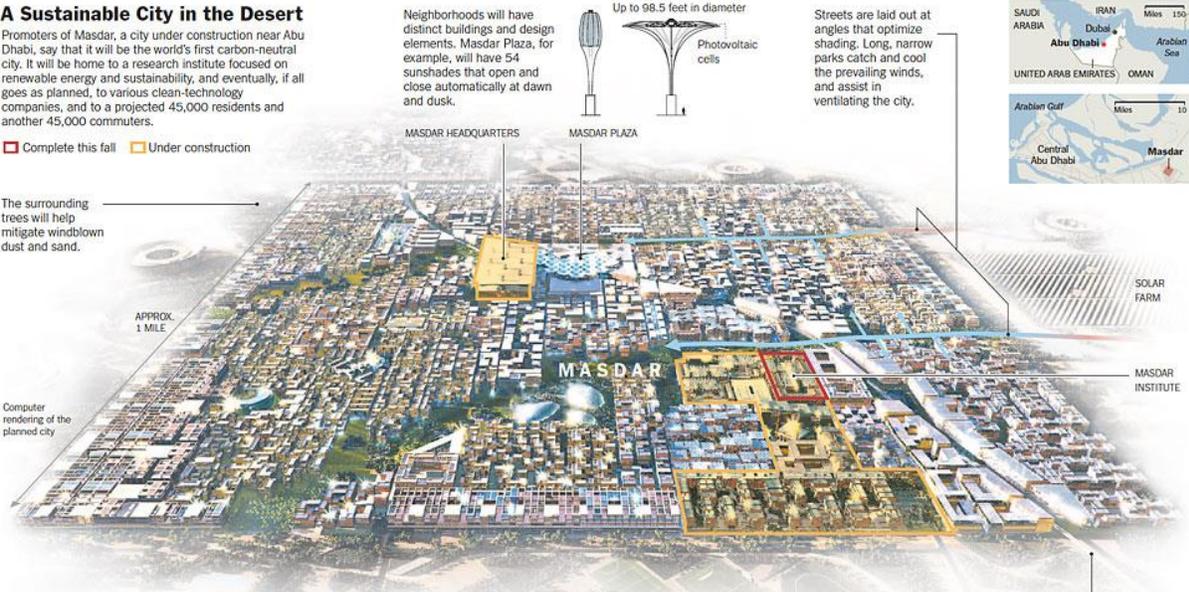
Promoters of Masdar, a city under construction near Abu Dhabi, say that it will be the world's first carbon-neutral city. It will be home to a research institute focused on renewable energy and sustainability, and eventually, if all goes as planned, to various clean-technology companies, and to a projected 45,000 residents and another 45,000 commuters.

■ Complete this fall ■ Under construction

The surrounding trees will help mitigate windblown dust and sand.

APPROX. 1 MILE

Computer rendering of the planned city



Phase 1 MASDAR INSTITUTE

The area being completed this fall has some design features common to the entire project.

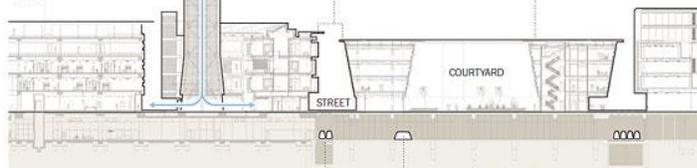
The wind tower funnels wind to ventilate a public square at its base. The air is cooled with water sprays.

Narrow streets allow for some sunlight, but overhangs create shade

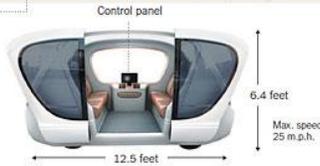
Photovoltaic panels power the buildings and provide shade to keep roofs cooler.

The city is surrounded by recreation areas, power generation facilities, parking garages and food production areas.

A light rail line will pass through the center of Masdar, linking it to downtown Abu Dhabi and providing transport within the new city.



Automated transportation
Masdar will be using an automated system of electric vehicles, including passenger cars and freight trucks. The city's ground level was elevated 23 feet, and the vehicles will operate underneath.



Masdar Headquarters
Photovoltaic panels on Masdar Headquarters, the city's biggest office building, are expected to produce more energy than the building consumes. It is scheduled to be finished in 2013.

Wind cones will provide natural ventilation and soft daylight to the building's interior.



Figure 19: Masdar City, Planning a Sustainable City in the Desert.²⁴

²⁴ "Planning a Sustainable City in the Desert." The New York Times. The New York Times, September 25, 2010.

King Abdullah University (KAUST)

King Abdullah University is an example of a great combination of a high-performance roof, solar tower, passive ventilation and integrated shading? This diagram illustrates the sustainable design feature in buildings on KAUST campus.



Figure 20: Sustainable aspects for buildings at King Abdullah (KAUST 2014).²⁵

1. high performance roof
2. solar tower
3. passive ventilation
4. high performance glazing
5. integrated shading
6. local evaporation
7. passively cooled courtyard
8. filtered daylight

²⁵ "King Abdullah University of Science & Technology." KAUST. Accessed August 29, 2019.

NEOM Characteristics:

new urbanism, Smart Code V 9.2 and Vernacular architecture in Saudi Arabia will shape NEOM urban fabric and architecture style.

Narrow Streets & Natural Shading:

Zigzagged technique and narrow street generate an amazing urban fabric for such a harsh climate in Saudi Arabia. Those techniques have been used for a long time in most of the traditional city in Saudi because it allowed buildings to shade street and protect pedestrian from direct sunlight which enhances the walkability and social activity on a neighborhood scale.

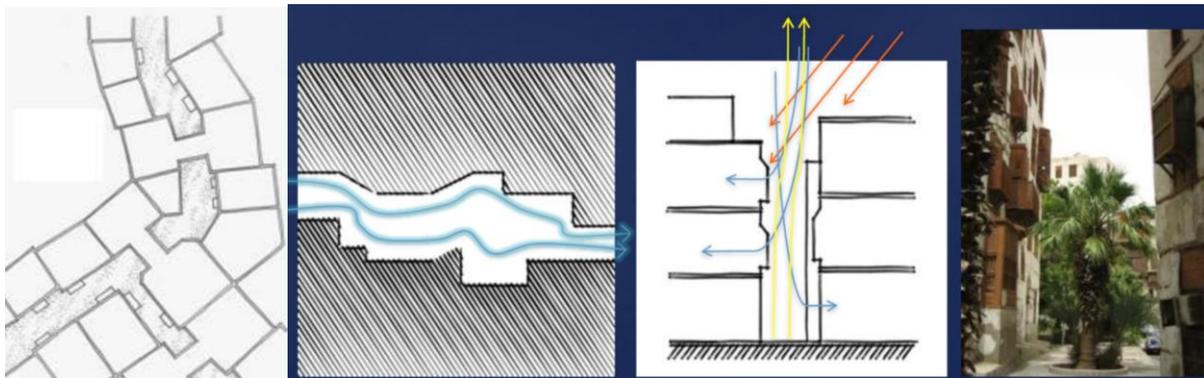


Figure 20: Street configuration: create cross ventilation, air flow and shading. {Architectural and urban distinctions 27 Sep 2014}

Airflow and providing shade contributes to reducing the air temperature and control microclimate. Also, this type of planning reduces the amount of walls exposed to solar radiation, which decreases the temperature of buildings thus reducing the energy consumed to cool buildings out.

Capturing sun light and ventilation with privacy

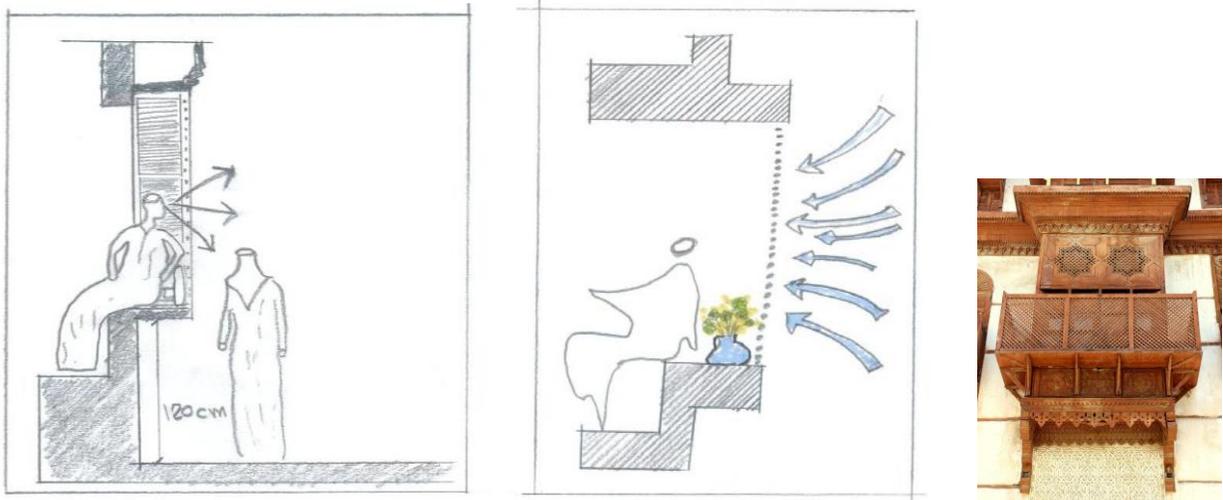


Figure 20: sketches illustrates how Mashrabiah allowed visual communication and ventilation along with maintain privacy. By Another

Typical Roshan technique that can be customize for modern design for housing buildings in NEOM city.

Roshan function: Maintenance of indoor space privacy Ventilation (middle panels can be slid and with louvers)

Heat insulation, reduction of solar rays and filtration of sandy air Shading of the outside surfaces (walls and streets)

conceptual design for building ventilation integrated with a green roof for housing and provides some private shaded area that allows residents to have visual communication with streets. The existence of the courtyard is important to circulate the air and achieve well ventilation in order to get into comfort zone.

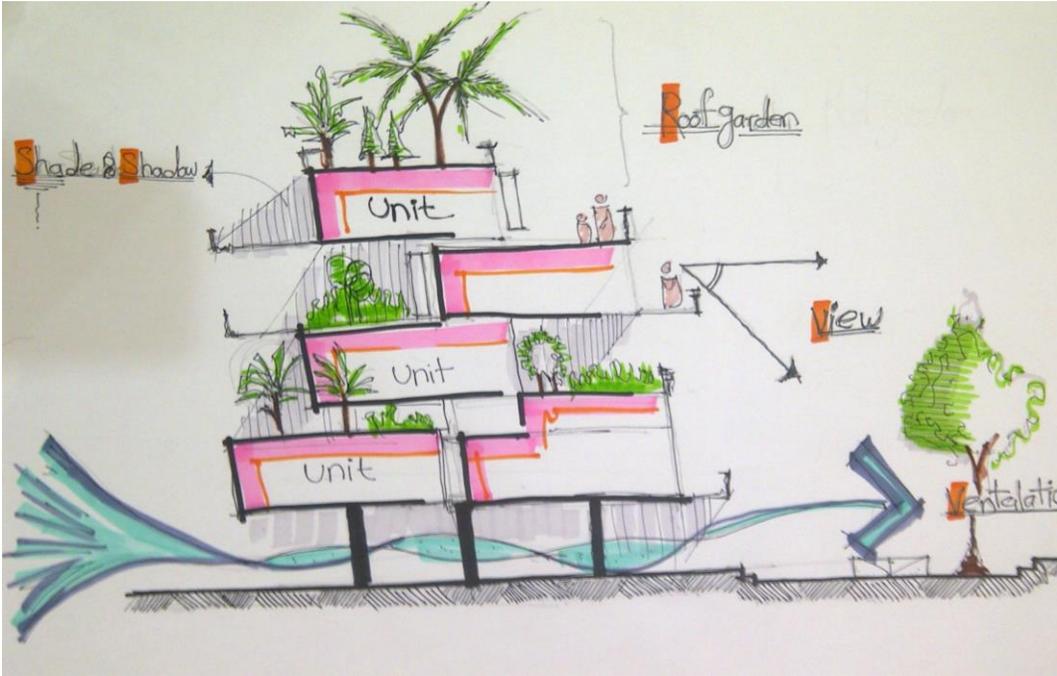


Figure 21: sketches illustrates conceptual design for building ventilation integrated with a green roof and natural ventilation. By Another

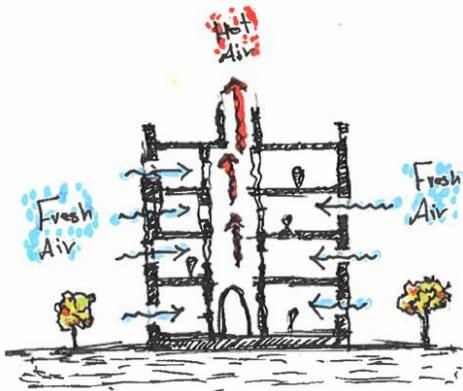


Figure 21: The existence of the courtyard is important to circulate the air and achieve well ventilation in order to get into comfort zone. By Another

Passive Cooling - Wind Catcher Technique

Wind catchers are passive ventilation systems inspired by the hundreds of years old vernacular architecture of Middle Eastern cultures. The wind catcher maintains natural air circulation and cooling via wind airflow and heat variations in towers

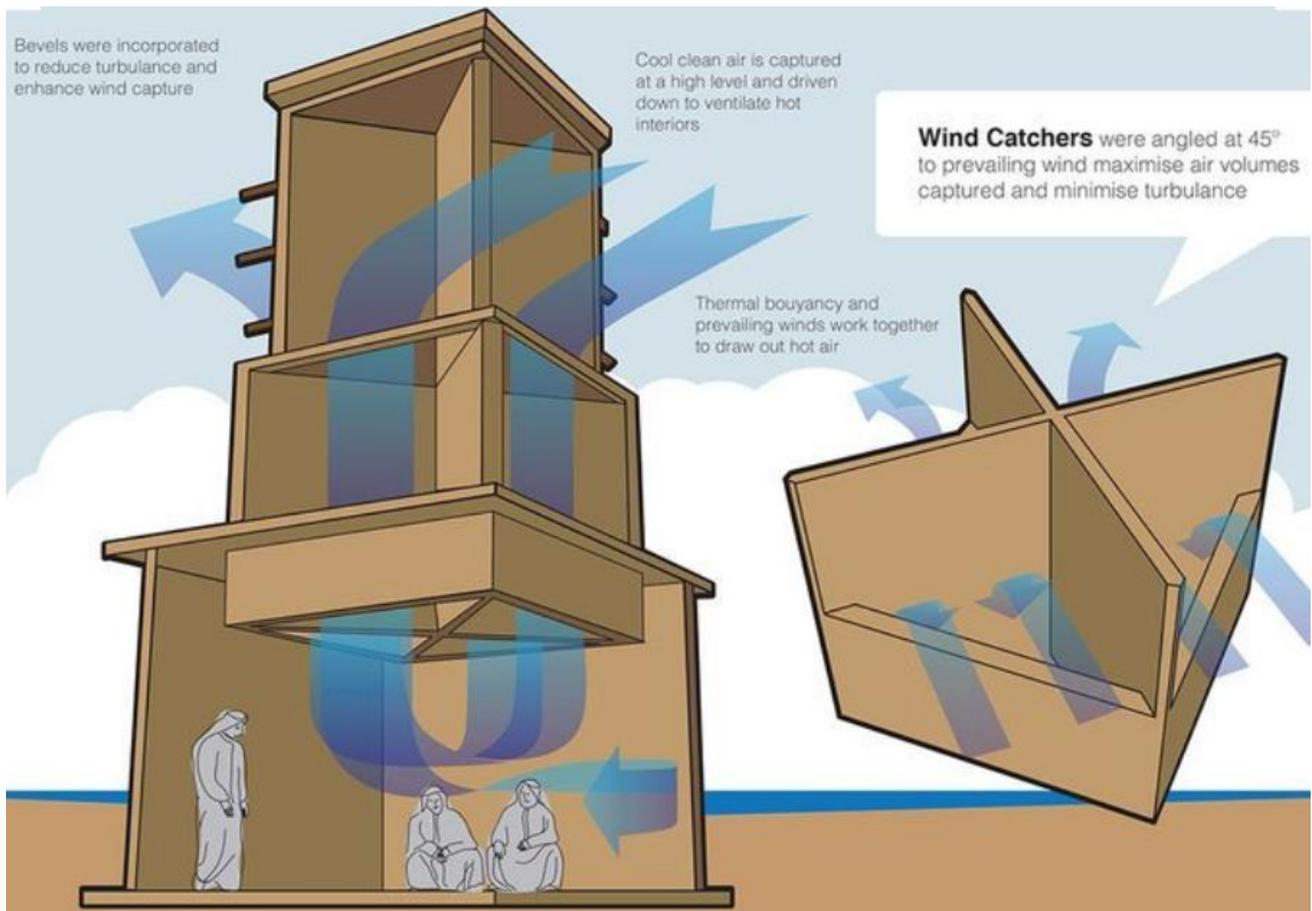


Figure 21: Image result for Hassan Fathy works

High Density:

Provide a mixture urban of commercial, retail, residential, and green open space create an amazing urban fabric for day/night activities and fulfill the need for all different age group. People would love to have social activities in their neighborhood they don't have to go far to downtown to have some food, drinks and spend some quality time which enhance the quality of life, that what high density can provide for residents.

Moreover, shorten the travel distance between daily activities such as GYM, restaurant, work, school...etc. that can encourage individuals to use green transportation and enhance walkability which reduces CO2 emission as well as energy consumption.²⁶



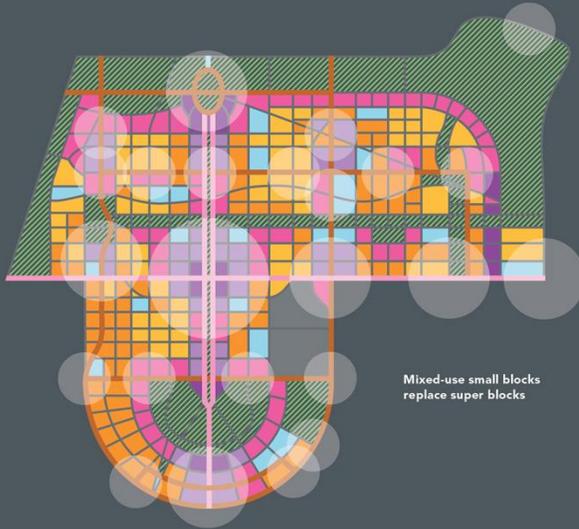
Figure 22: Variety of uses, job and walkability that mixed-use provide.²⁷

²⁶ Density. Accessed November 14, 2019. <http://www.newurbanism.org/density.html>.

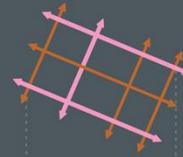
²⁷ "A Walkable Mixed-Use Neighborhood." Visual.ly. Accessed October 11, 2019.

High-density hubs of various sizes cluster mixed activities across a city

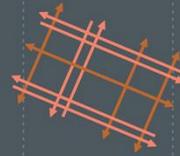
- The density and size of the center corresponds to the level of transit service.
- City, town, and village centers are located at the crossroads of transit boulevards.
- Residential neighborhoods are directly accessible to centers.



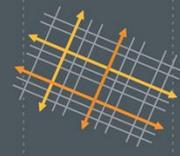
Walkable, mixed-use cities are built from a variety of street types



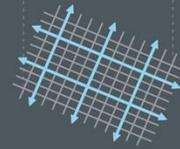
Superblocks with wide arterials before modification.



Replace major arterials with one-way street pairs and add transit to remaining arterials.



Add car free streets, some with dedicated transit lines.



Add narrow local streets with bike lanes and sidewalks.

Figure 23: Mix-used blocks.²⁸

²⁸ "A Walkable Mixed-Use Neighborhood." Visual.ly. Accessed October 11, 2019.

Public Spaces:

WHAT MAKES A GREAT PLACE?

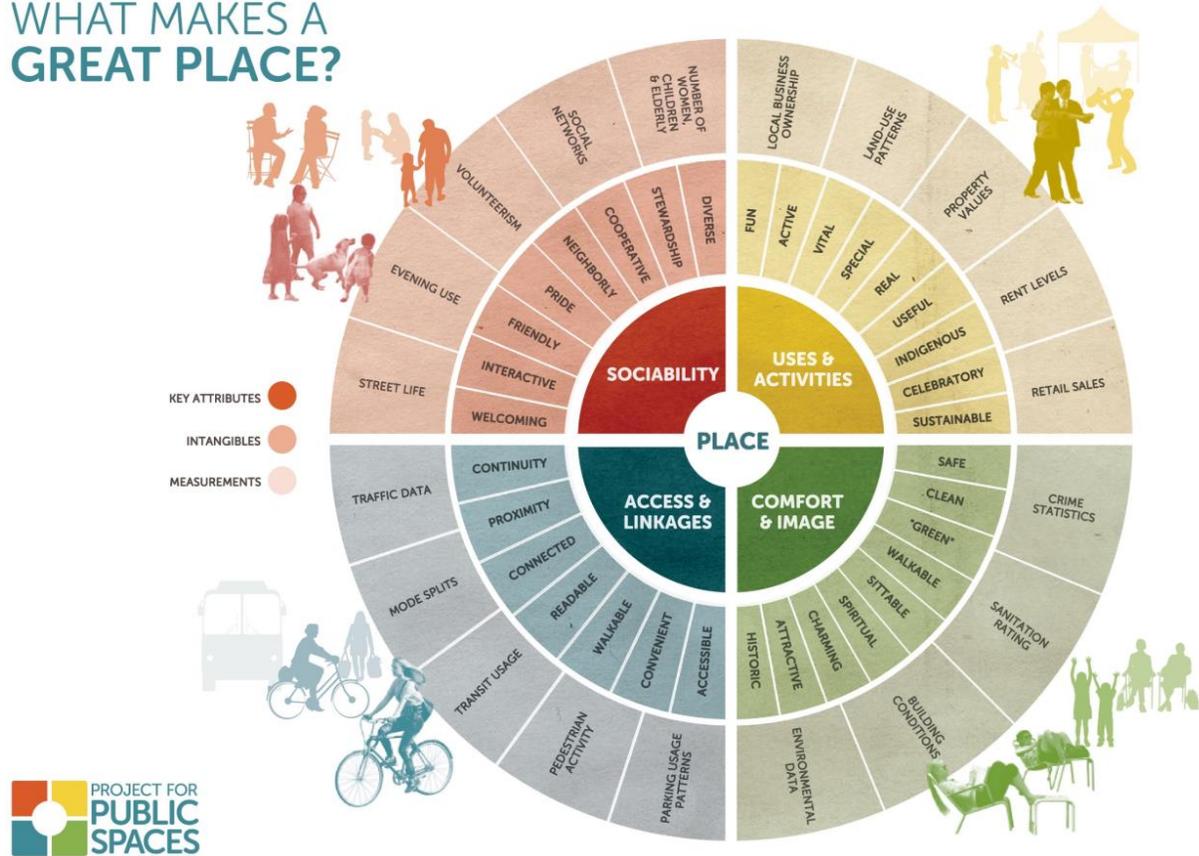


Figure 23: what make a great place.²⁹

Public spaces (including high streets, avenue markets, purchasing precincts, neighborhood centers, parks, playgrounds, and neighborhood areas in residential areas) play a fundamental role in the social lifestyles of communities. They act as a ‘self-organizing public service’, a shared useful resource in which experiences and value are created.

²⁹ “What Makes a Successful Place?” RSS. Accessed September 11, 2019.

SEVEN BASIC FACTORS OF AN EFFECTIVE PUBLIC SPACE

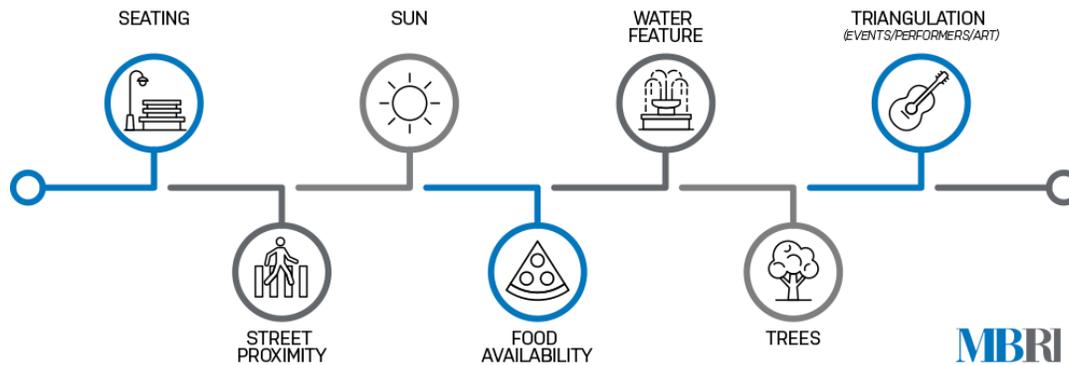


Figure 24: diagram shows factor od successful public spaces.³⁰

Green areas: In addition to contributing to air pleasant and assisting to comfort temperatures in the summer, plants has the strength to humanize cities through inviting individuals to outside activities. As cities turn out to be denser, access to green public spaces will grow to be even more essential as urban forestation can decrease people’s stress degrees and increase well-being in cities. In addition, grasses and garden plot are strategic for city drainage and upkeep of biodiversity.



Figure 24: Najran city south of Saudia Arabia, Google Map. Figure 25: Jeddah city west of Sauid Arabia, Google Map

photo of Najran city south of Saudia Arabia and Jeddah city west of Sauid Arabia iullstares the needs of planting and green spaces.

³⁰ Public Space as an Office Amenity. Accessed October 24, 2019.

Xeriscape or Zeroscape:

It is a landscaping or gardening method that decreases or avoids the need for irrigation water. in such a circumstance Saudi Arabia in need of every drop of water, the code must include Xeriscape and Xeriscape in NEOM code as required for planting. at the same time, residents cannot use fresh water to water garden and will be a serious penalty if so.³¹



Figure 25: Zero scape example.³²

³¹ Wuiw. "Xeriscape versus Zeroscape: Is There a Difference?: Water -Use It Wisely." Water Use It Wisely.

³² "Xeriscape vs. Zeroscape." Native Tree and Landscaping. Accessed December 1, 2019.

Lighting:

Efficient and person-oriented lighting encourages nighttime use of public spaces, improving safety. Public lighting provides the conditions for traveling safer if there is no natural light when placed on the pedestrian and cyclist level.

Local Identity:

Community identity: for the small businesses that define the area, public spaces should be built. Large businesses (such as supermarkets or other chain businesses) may contribute to the economy in general, but they have little involvement in the community level. Small companies and corporations have important long-term effects, contributing to the reputation and local identity.

Smart Code V 9.2

Rural to Urban Transect

NEOM has many natural areas which are considered the most important attractions in the city such as beaches, plains and high mountains. If we can plan the city of NEOM to be an integrated mixture of the natural environment and built environment and take advantage of both sides that can improve the city quality in term of well-being, public health, energy consumption, walkability and more. S, I decide to choose Rural to Urban Transect among the other urban theory.

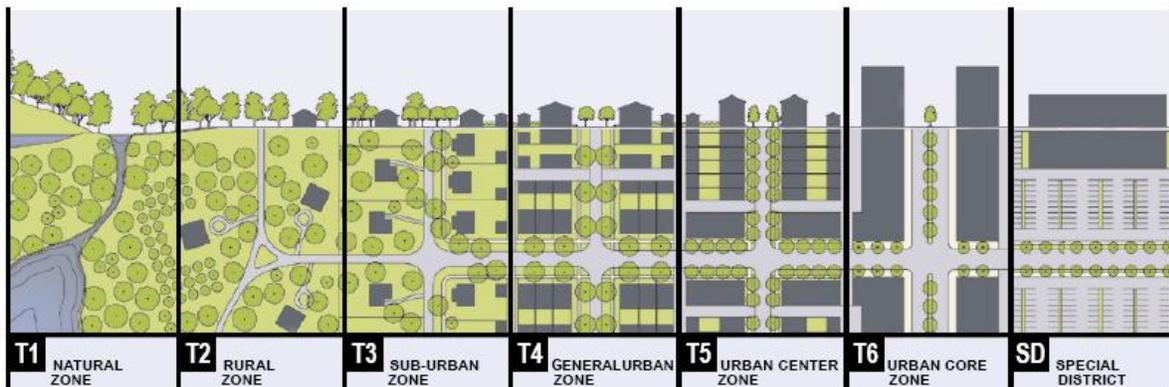


Figure 26: A Typical Rural-Urban Transect, with Transect Zones.³³

³³“SmartCode Central.” SmartCode Central. Accessed August 26, 2019.

the six normative Transect Zones.

SMARTCODE

Municipality

TABLE 1. TRANSECT ZONE DESCRIPTIONS

TABLE 1: Transect Zone Descriptions. This table provides descriptions of the character of each T-zone.

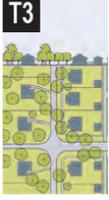
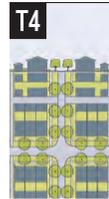
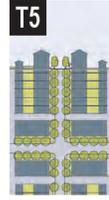
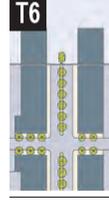
 <p>T1</p>	<p>T-1 NATURAL T-1 Natural Zone consists of lands approximating or reverting to a wilderness condition, including lands unsuitable for settlement due to topography, hydrology or vegetation.</p>	<p>General Character: Natural landscape with some agricultural use Building Placement: Not applicable Frontage Types: Not applicable Typical Building Height: Not applicable Type of Civic Space: Parks, Greenways</p>
 <p>T2</p>	<p>T-2 RURAL T-2 Rural Zone consists of sparsely settled lands in open or cultivated states. These include woodland, agricultural land, grassland, and irrigable desert. Typical buildings are farmhouses, agricultural buildings, cabins, and villas.</p>	<p>General Character: Primarily agricultural with woodland & wetland and scattered buildings Building Placement: Variable Setbacks Frontage Types: Not applicable Typical Building Height: 1- to 2-Story Type of Civic Space: Parks, Greenways</p>
 <p>T3</p>	<p>T-3 SUB-URBAN T-3 Sub-Urban Zone consists of low density residential areas, adjacent to higher zones that some mixed use. Home occupations and outbuildings are allowed. Planting is naturalistic and setbacks are relatively deep. Blocks may be large and the roads irregular to accommodate natural conditions.</p>	<p>General Character: Lawns, and landscaped yards surrounding detached single-family houses; pedestrians occasionally Building Placement: Large and variable front and side yard Setbacks Frontage Types: Porches, fences, naturalistic tree planting Typical Building Height: 1- to 2-Story with some 3-Story Type of Civic Space: Parks, Greenways</p>
 <p>T4</p>	<p>T-4 GENERAL URBAN T-4 General Urban Zone consists of a mixed use but primarily residential urban fabric. It may have a wide range of building types: single, sideyard, and rowhouses. Setbacks and landscaping are variable. Streets with curbs and sidewalks define medium-sized blocks.</p>	<p>General Character: Mix of Houses, Townhouses & small Apartment buildings, with scattered Commercial activity; balance between landscape and buildings; presence of pedestrians Building Placement: Shallow to medium front and side yard Setbacks Frontage Types: Porches, fences, Dooryards Typical Building Height: 2- to 3-Story with a few taller Mixed Use buildings Type of Civic Space: Squares, Greens</p>
 <p>T5</p>	<p>T-5 URBAN CENTER T-5 Urban Center Zone consists of higher density mixed use building that accommodate retail, offices, rowhouses and apartments. It has a tight network of streets, with wide sidewalks, steady street tree planting and buildings set close to the sidewalks.</p>	<p>General Character: Shops mixed with Townhouses, larger Apartment houses, Offices, workplace, and Civic buildings; predominantly attached buildings; trees within the public right-of-way; substantial pedestrian activity Building Placement: Shallow Setbacks or none; buildings oriented to street defining a street wall Frontage Types: Stoops, Shopfronts, Galleries Typical Building Height: 3- to 5-Story with some variation Type of Civic Space: Parks, Plazas and Squares, median landscaping</p>
 <p>T6</p>	<p>T-6 URBAN CORE T-6 Urban Core Zone consists of the highest density and height, with the greatest variety of uses, and civic buildings of regional importance. It may have larger blocks; streets have steady street tree planting and buildings are set close to wide sidewalks. Typically only large towns and cities have an Urban Core Zone.</p>	<p>General Character: Medium to high-Density Mixed Use buildings, entertainment, Civic and cultural uses. Attached buildings forming a continuous street wall; trees within the public right-of-way; highest pedestrian and transit activity Building Placement: Shallow Setbacks or none; buildings oriented to street, defining a street wall Frontage Types: Stoops, Dooryards, Forecourts, Shopfronts, Galleries, and Arcades Typical Building Height: 4-plus Story with a few shorter buildings Type of Civic Space: Parks, Plazas and Squares; median landscaping</p>

Figure 27: TABLE 3B: Vehicular Lane/Parking Assemblies. The projected design speeds determine the dimensions of the vehicular lanes and Turning Radii assembled for Thoroughfares.³⁴

³⁴“SmartCode Central.” SmartCode Central. Accessed August 26, 2019.

	ONE WAY MOVEMENT			TWO WAY MOVEMENT		
a. NO PARKING	T1 T2 T3 Design ADT: 300 VPD Pedestrian Crossing: 3 Seconds Design Speed: 20-30 MPH	T1 T2 T3 Design ADT: 600 VPD Pedestrian Crossing: 5 Seconds Design Speed: Below 20 MPH	T1 T2 T3 Design ADT: 2,500 VPD Pedestrian Crossing: 5 Seconds Design Speed: 20-25 MPH	T1 T2 Design ADT: 22,000 VPD Pedestrian Crossing: 9 Seconds Design Speed: 35 MPH and above	T1 T2 Design ADT: 36,000 VPD Pedestrian Crossing: 13 Seconds Design Speed: 35 MPH and above	
b. YIELD PARKING	T3 T4 Design ADT: 1,000 VPD Pedestrian Crossing: 5 Seconds Design Speed: Below 20 MPH		T3 T4 Design ADT: 1,000 VPD Pedestrian Crossing: 7 Seconds Design Speed: Below 20 MPH			
c. PARKING ONE SIDE PARALLEL	T3 T4 Design ADT: 5,000 VPD Pedestrian Crossing: 5 Seconds Design Speed: 20-30 MPH	T3 T4 T5 Design ADT: 16,000 VPD Pedestrian Crossing: 8 Seconds Design Speed: 25-30 MPH	T4 T5 Design ADT: 16,000 VPD Pedestrian Crossing: 8 Seconds Design Speed: 25-30 MPH	T4 T5 T6 Design ADT: 15,000 VPD Pedestrian Crossing: 11 Seconds Design Speed: 25-30 MPH	T5 T6 Design ADT: 32,000 VPD Pedestrian Crossing: 13 Seconds Design Speed: 35 MPH and above	
d. PARKING BOTH SIDES PARALLEL	T4 Design ADT: 8,000 VPD Pedestrian Crossing: 7 Seconds Design Speed: Below 20 MPH	T4 T5 T6 Design ADT: 20,000 VPD Pedestrian Crossing: 10 Seconds Design Speed: 25-30 MPH	T4 T5 T6 Design ADT: 15,000 VPD Pedestrian Crossing: 10 Seconds Design Speed: 25-30 MPH	T5 T6 Design ADT: 22,000 VPD Pedestrian Crossing: 13 Seconds Design Speed: 25-30 MPH	T5 T6 Design ADT: 32,000 VPD Pedestrian Crossing: 15 Seconds Design Speed: 35 MPH and above	
e. PARKING BOTH SIDES DIAGONAL	T5 T6 Design ADT: 16,000 VPD Pedestrian Crossing: 15 Seconds Design Speed: Below 20 MPH	T5 T6 Design ADT: 20,000 VPD Pedestrian Crossing: 17 Seconds Design Speed: 20-25 MPH	T5 T6 Design ADT: 15,000 VPD Pedestrian Crossing: 17 Seconds Design Speed: 20-25 MPH	T5 T6 Design ADT: 22,000 VPD Pedestrian Crossing: 20 Seconds Design Speed: 25-30 MPH	T5 T6 Design ADT: 31,000 VPD Pedestrian Crossing: 23 Seconds Design Speed: 25-30 MPH	
f. PARKING ACCESS			T3 T4 Design ADT: 1,000 VPD Pedestrian Crossing: 3 Seconds Design Speed: Below 20 MPH	T5 T6 Design ADT: 1,000 VPD Pedestrian Crossing: 6 Seconds Design Speed: Below 20 MPH		

Figure 28: table 3B. VEHICULAR LANE & PARKING assemblies.³⁵

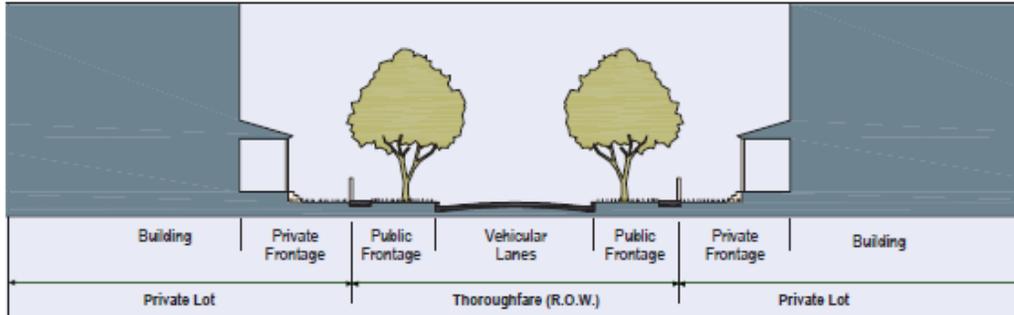
³⁵ "SmartCode Central." SmartCode Central. Accessed August 26, 2019.

TABLE 17. DEFINITIONS ILLUSTRATED

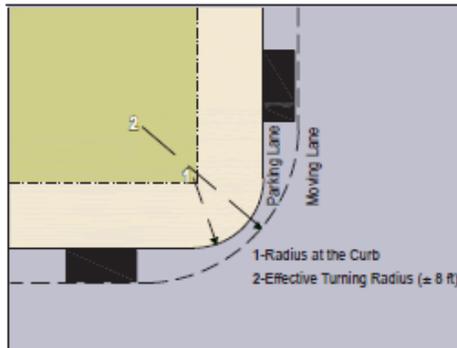
SMARTCODE

Municipality

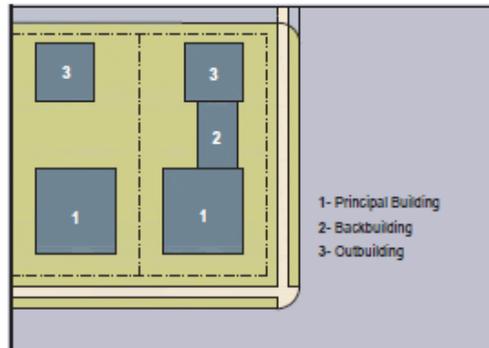
a. THOROUGHFARE & FRONTAGES



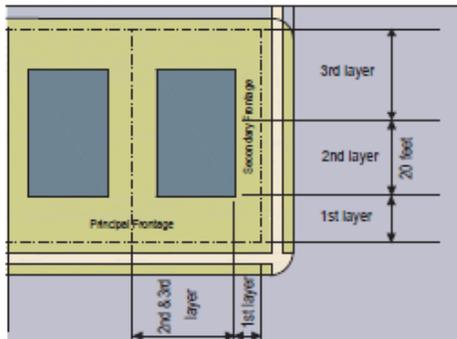
b. TURNING RADIUS



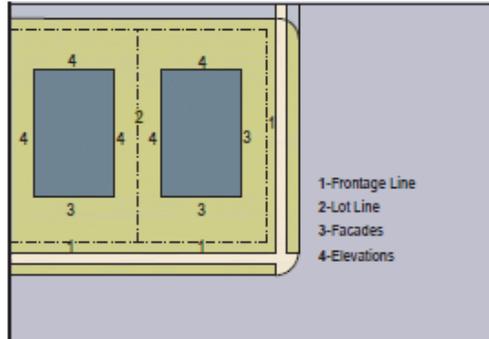
c. BUILDING DISPOSITION



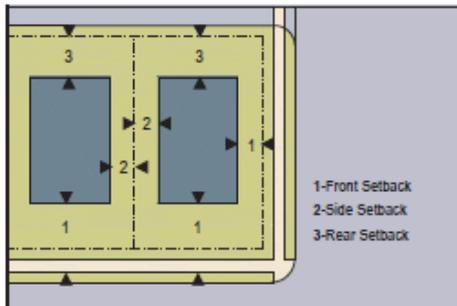
d. LOT LAYERS



e. FRONTAGE & LOT LINES



f. SETBACK DESIGNATIONS



g. NETWORK-BASED PEDESTRIAN SHED



Figure 30: Table 4B THOROUGHFARE & FRONTAGES.³⁷

³⁷ "SmartCode Central." SmartCode Central. Accessed August 26, 2019.

By following the Smart Code V 9.2 will be able to avoid weird relationship between pedestrian area and street traffics like this examples

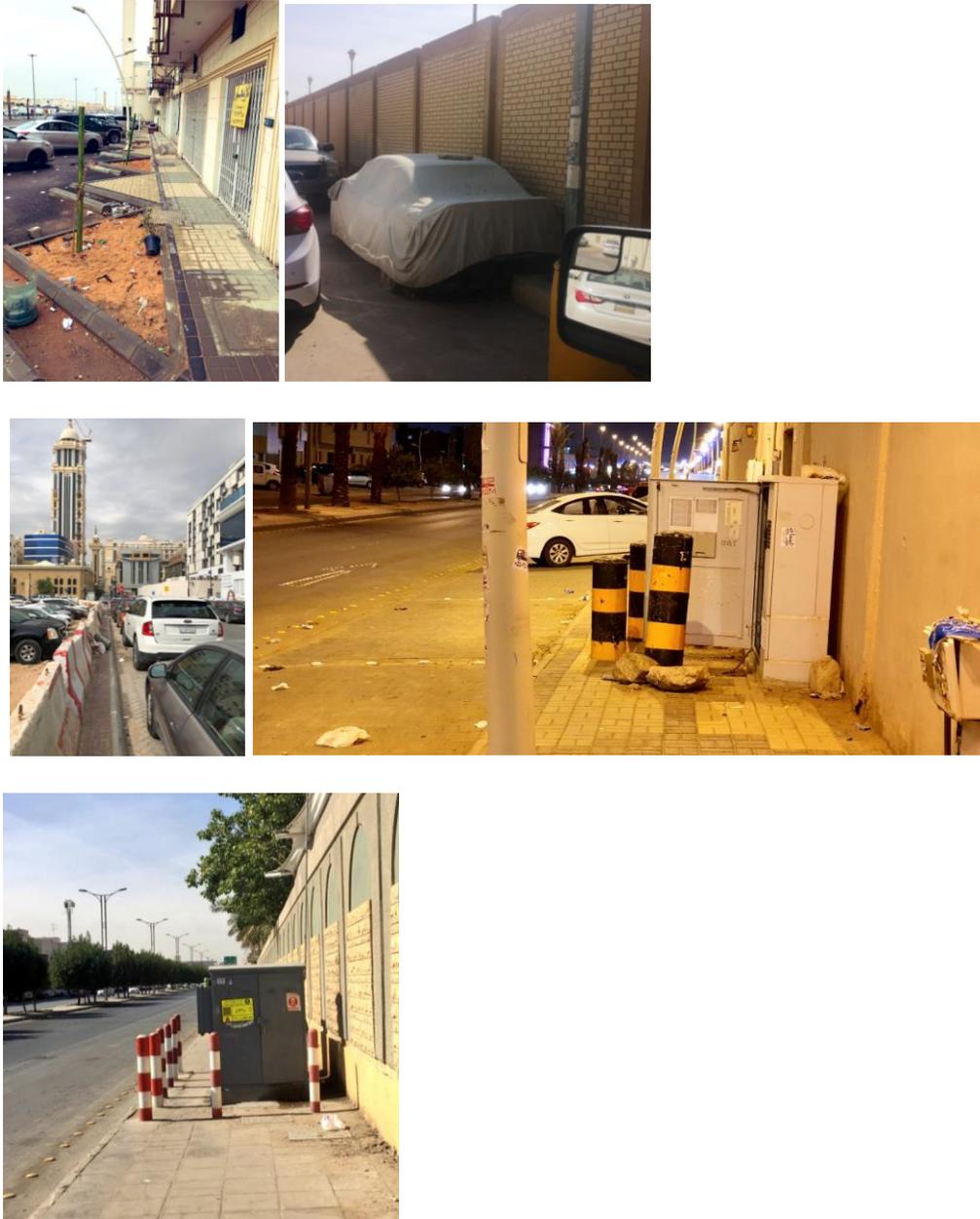


Figure 31: Photo shows some unpleasant situations in multiple cities in KSA .³⁸

³⁸ "حقوق المشاة حقوق." (@QQQO2012). Twitter. Twitter, July 9, 2017.

TABLE 11: EXPLANATORY DIAGRAMS

a. THOROUGHFARE & FRONTAGES

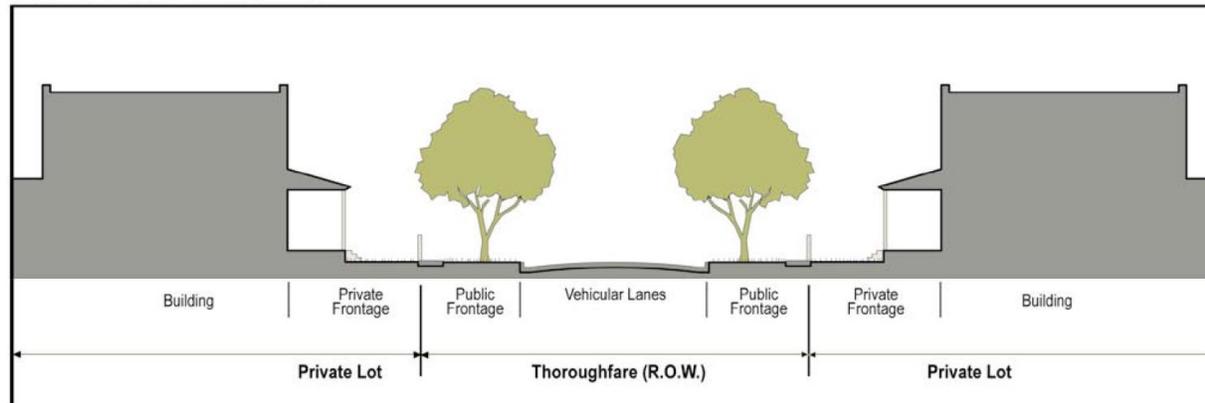


Figure 32: Street Section from Smart Code.³⁹

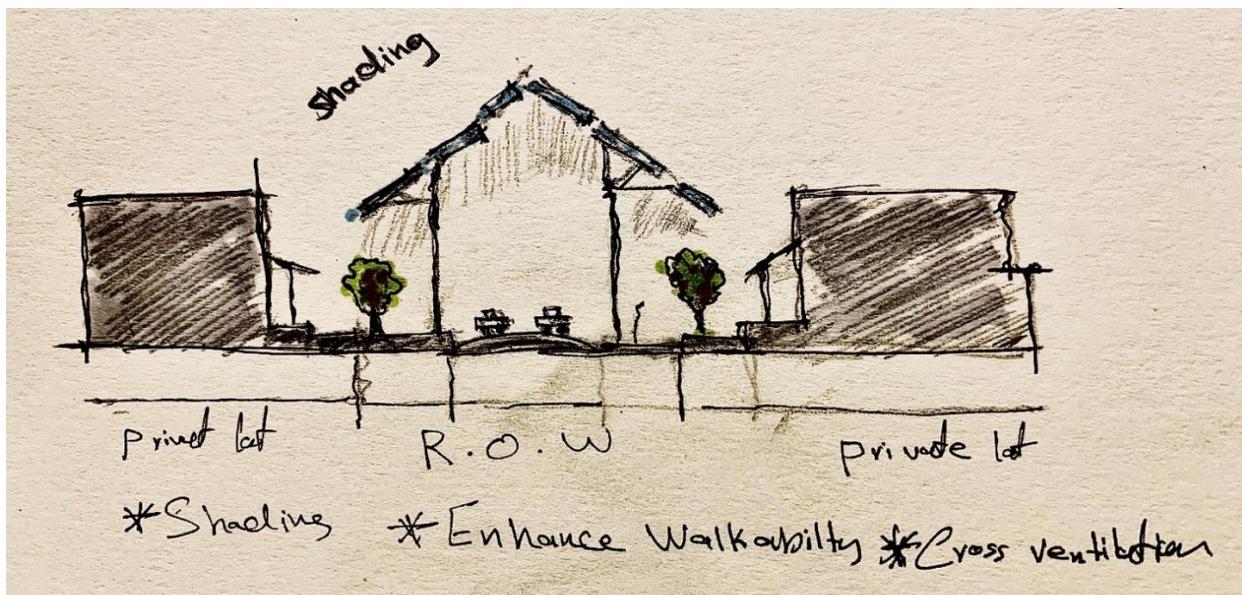
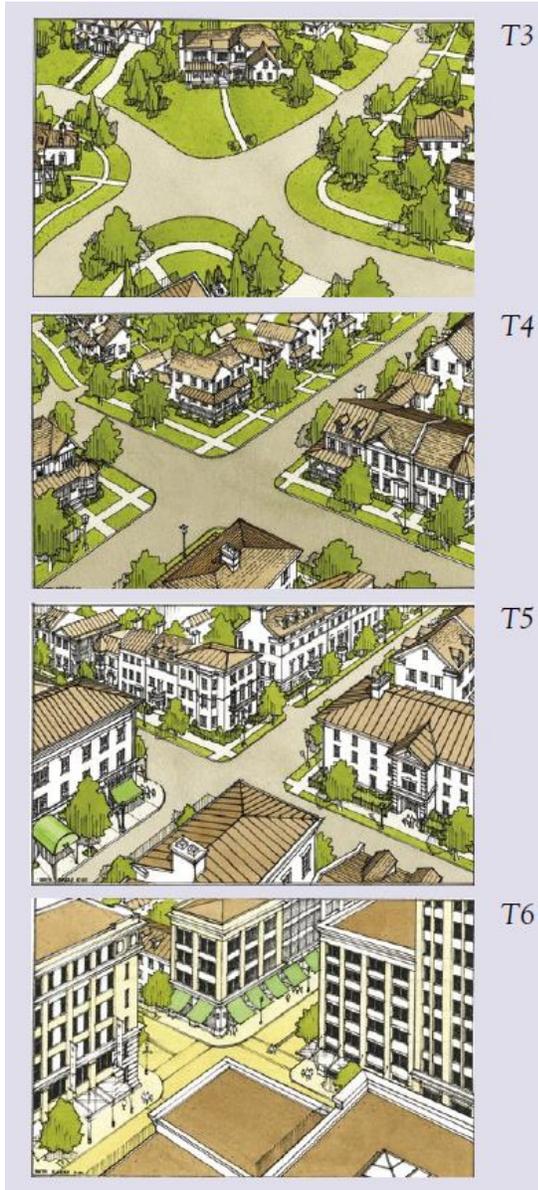


Figure 32: quick sketch how to customize Smart Code Street Section to Saudi Arabia Climate. By author.

³⁹ "SmartCode Central." SmartCode Central. Accessed August 26, 2019.

Urban Fabric:



the communities want to enjoy the city lifestyle (T6) and be able to enjoy some of the regulation freedom of (T3&T2).

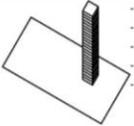
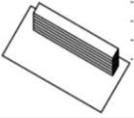
Trying to provide many different types of fabrics and choices to accommodate different needs for all generations. Make sure there is a room for everyone to have a diverse community with a different group of ages

Figure 33: different type of urban fabric, Smart Code.⁴⁰

⁴⁰ "SmartCode Central." SmartCode Central. Accessed August 26, 2019

Urban Fabric:

BUILDING TYPES AND PLANNED URBAN FABRIC'S ANALYSIS

COMMON HOUSING TIPOLOGIES: THE BLOCK			COMMON HOUSING TIPOLOGIES: THE GENERATED URBAN FABRIC		
	<ul style="list-style-type: none"> - MINIMUM DISPERSING AREA - WIDE GREEN SPACES - RESOURCE OPTIMIZATION - STRONG IDENTITY - EXCELLENT PERMEABILITY 	<ul style="list-style-type: none"> - NO BUILT - EMPTY RELATIONSHIP - NO CONTROL OF PUBLIC SPACES 		<ul style="list-style-type: none"> - WIDE GREEN PUBLIC SPACES - EXCELLENT PERMEABILITY - HIGH POPULATION DENSITY - RECONFIGURABILITY OF PUBLIC SPACES 	<ul style="list-style-type: none"> - NEED OF WIDE LAND AREA - LOSS OF IDENTITY - STIMULATION OF CAR UTILIZATION - NO CONTROL OF PUBLIC SPACES
	<ul style="list-style-type: none"> - MINIMUM DISPERSING AREA - WIDE GREEN SPACES - RESOURCE OPTIMIZATION - STRONG IDENTITY 	<ul style="list-style-type: none"> - MINIMUM BUILT - EMPTY RELATIONSHIP - NO CONTROL OF PUBLIC SPACES - ONE-SIDED PERMEABILITY 		<ul style="list-style-type: none"> - WIDE GREEN PUBLIC SPACES - HIGH POPULATION DENSITY 	<ul style="list-style-type: none"> - BAD BUILT - EMPTY RELATIONSHIP - DISORIENTATION - LOSS OF IDENTITY - LIMITED PERMEABILITY
	<ul style="list-style-type: none"> - GOOD BUILT - EMPTY RELATIONSHIP - HUMAN SCALE - CONTROL OF PUBLIC SPACES - PERMEABILITY 	<ul style="list-style-type: none"> - BIG DISPERSING AREA - WASTE OF RESOURCES - NO/FEW GREEN PUBLIC SPACES 		<ul style="list-style-type: none"> - GOOD BUILT - EMPTY RELATIONSHIP - HUMAN SCALE - COMPACT URBAN FABRIC - CONTROL OF PUBLIC SPACES - STRONG IDENTITY 	<ul style="list-style-type: none"> - NO/TOO FEW GREEN PUBLIC SPACES - NO/TOO FEW PARKING AREAS

BUILDING TYPES AND PLANNED URBAN FABRIC'S ANALYSIS

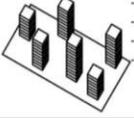
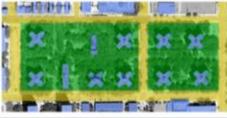
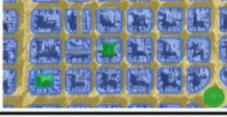
COMMON HOUSING TIPOLOGIES: THE BLOCK			COMMON HOUSING TIPOLOGIES: THE GENERATED URBAN FABRIC		
	<ul style="list-style-type: none"> - RESOURCES OPTIMIZATION - WIDE GREEN SPACES - PERMEABILITY - SUFFICIENT CONTROL OF PUBLIC SPACES 	<ul style="list-style-type: none"> - NO BUILT - EMPTY RELATIONSHIP - LOSS OF IDENTITY - TOUGH ORIENTATION 		<ul style="list-style-type: none"> - WIDE GREEN PUBLIC SPACES - GOOD PERMEABILITY - GOOD CONTROL OF PUBLIC SPACES - RECONFIGURABILITY OF PUBLIC SPACES 	<ul style="list-style-type: none"> - NO STREET FRONTAGE - DISORIENTATION - LOSS OF IDENTITY - STIMULATION OF CAR UTILIZATION
	<ul style="list-style-type: none"> - GOOD BUILT - EMPTY RELATIONSHIP - PRIVATE GREEN SPACES - CONTROL OF PUBLIC SPACES - RESOURCES OPTIMIZATION 	<ul style="list-style-type: none"> - NO/FEW GREEN PUBLIC SPACES - NO PERMEABILITY - LOSS OF IDENTITY 		<ul style="list-style-type: none"> - GOOD BUILT - EMPTY RELATIONSHIP - GOOD SPACE ARTICULATION AND CONTROL OF PUBLIC SPACES - COMPACT URBAN FABRIC 	<ul style="list-style-type: none"> - NO/TOO FEW GREEN PUBLIC SPACES - DISORIENTATION
	<ul style="list-style-type: none"> - RESOURCES OPTIMIZATION - WIDE GREEN PUBLIC SPACES - PERMEABILITY - SUFFICIENT CONTROL OF PUBLIC SPACES 	<ul style="list-style-type: none"> - POOR BUILT - EMPTY RELATIONSHIP - LOSS OF IDENTITY 		<ul style="list-style-type: none"> - RESOURCES OPTIMIZATION - WIDE GREEN PUBLIC SPACES - GOOD BUILT - EMPTY RELATIONSHIP - PERMEABILITY - GOOD CONTROL OF PUBLIC SPACES 	<ul style="list-style-type: none"> - NEED OF WIDE LAND AREA - DISORIENTATION

Figure 34: Building types and planning urban fabric analysis.⁴¹

⁴¹ Codini, Matteo. "BUILDING TYPES AND PLANNED URBAN FABRIC'S ANALYSIS." BUILDING TYPES AND PLANNED URBAN FABRIC'S ANALYSIS, January 1, 1970.

Affordable Sustainable Housing:

Providing affordable housing is such a big deal for any new city, It can help low-income residents saving money, gain access to better jobs, improving health and for mid-income as well. As has been noticed, Ordos city in China turned into ghost town mainly because the city did not provide a housing units that low-mid income can afforded. Building sustainable housing is great but expensive sustainable housing that is another story. Government and investors should not build the most sustainable along with high tech building for housing projects because that's will increase the unite price compare to other cities such as Jeddah and Riyadh. I believe that real state is the mirror for economy, NEOM planning to build a 1 million in five years that will cost over a 100\$ billion. There are some American, Chinses and Korean developers and firms have shown interest in this project. So, a question that should ask, how much it cost to buy a 3-bedroom apartment or a house in NEOM city?

NEOM Challenges: Water, Energy and Waste Management

Water Treatment:

Because of continued government support, the Kingdom of Saudi Arabia has seen tremendous success in its economic, water and agricultural sectors. In this regard, considerable progress has been made by the Ministry of Environment, Water and Agriculture (MEWA), as can be seen in the progress made in these sectors. While shaping Vision 2030 particular examples of this development include increased water and food security Increased efficiency of various services, protection of the environment and innovative ideas implemented to improve the sustainability of these industries.

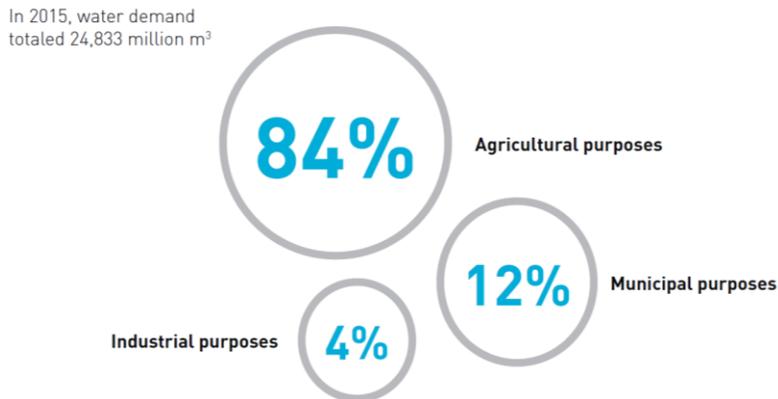


Figure 35: In 2015 Water demand totaled 24,833 million³ m.⁴²

According to United Nations Development Programme the water demand for Saudi Arabia in 2015 was 24,833 million m³. Saudi Arabia is the world's leading producer of desalinated water, with a share of 16.5 percent of total supply worldwide. The Saline Water Conversion Corporation (SWCC) operates the 3 largest water desalination plants in the country, including Ras Al Khair desalination plant and 1.1 million m³ of water per day.

⁴² Ministry of Environment, Water and Agriculture (MEWA)

Figures

and Statistics

61%

Share of desalinated water in total distributed water 2015

39%

Share of water produced from wells and dams in total distributed water 2015

1335 million m³

Volume of desalinated water actually produced in 2016

29

Water desalination plants in the Kingdom

During 2015, the quantity of distributed water totaled 3,025 million m³, with an increase of 5% over 2014 level. The water, mainly produced from sea water desalination and groundwater wells and dams, was distributed to various provinces of the Kingdom, based on relevant needs, through the public water system.

Developments of distributed water quantities by main source

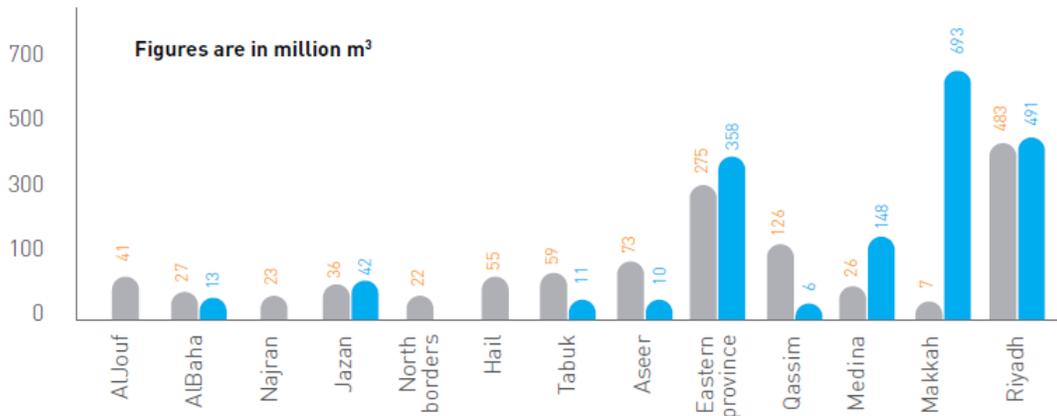
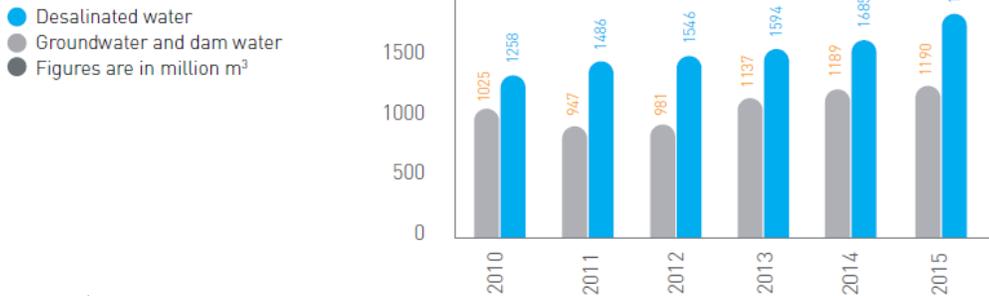
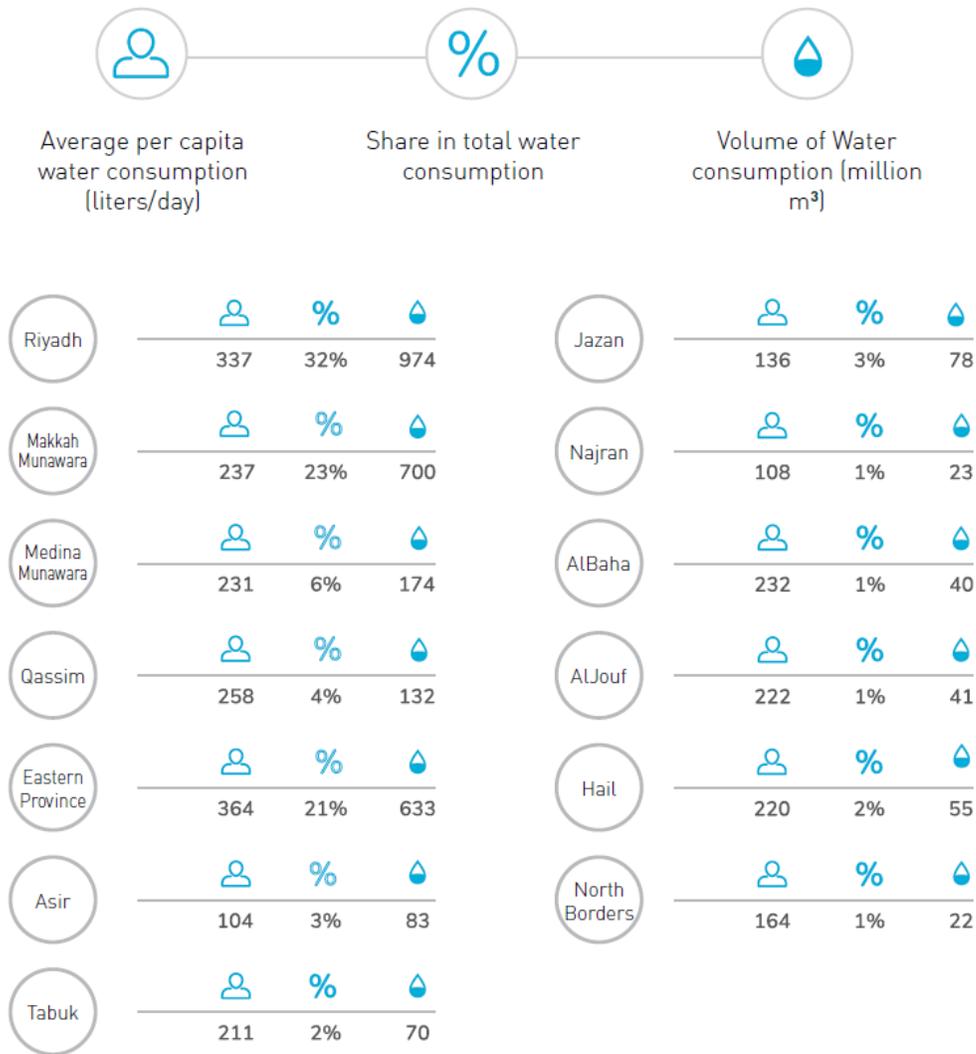


Figure 36: Ministry of Environment, Water and Agriculture (MEWA), KSA.⁴³

⁴³ "Saudi Arabia ... Sustainable Development Knowledge Platform." United Nations. United Nations. Accessed November 15, 2019.



Out of its firm belief in scientific research and technology development, the Saline Water Conversion Corp (SWCC) has established a specialized research institute to conduct research studies in the field of water desalination. The institute is located next to one of the biggest desalination and power generation plants in the Jubail province, on the eastern coast of the Kingdom of Saudi Arabia. The Research & Development Center was established as part of the Saudi American Cooperation Agreement. It was inaugurated in 1987, SWCC established its Research Institute at Al-Jubail, KSA, as part of the Saudi American Cooperation Agreement. It was inaugurated in 1987 under the name of Research & Development Center. The institute made big strides in the field of research and development, contributing to improvements in desalination technology, water treatment techniques, increasing efficiency in operations and maintenance and reducing production cost in the operating stations.

Figure 37: Ministry of Environment, Water and Agriculture (MEWA), KSA.⁴⁴

⁴⁴ "Saudi Arabia ... Sustainable Development Knowledge Platform." United Nations. United Nations. Accessed November 15, 2019.

Codes and Regulations for Graywater Usage:

Case of Arizona

“Greywater activist Val Little, founder of the Southern Arizona Water Conservation Alliance (Water CASA), did a survey in southern Arizona in 1998 and found that 13 percent of people used greywater illegally. The excessively restrictive code prohibited her from educating residents on how to properly treat greywater, so she was working to change the rules. The outcome was a quality-based code detailing criteria for safety and health. Residential greywater systems following the standards are legal — without permits, penalties or audits — provided the system produces fewer than 400 gallons daily.⁴⁵

Summary Characteristics of Optimal Greywater-Friendly Regulations

- Easy to follow
- Performance-based. Guidelines outline health and safety requirements
- Do not require a permit or fee for the safest situations.
- Permit required only for more risky or complicated situations.
- Code is statewide with a mechanism in place to educate local regulators

As we can see the community in Arizona have the tendency and willing to use gray water due to the lack of fresh water in their state. in the same fashion, Saudi Arabia considered a dry land and water treatment is one of the biggest challenges over there, people would love to find a sustainable way to reduce their water bill and insure fresh water availability. The community need to be educated about gray water treatment and the regulation must include gray water management as a requirement not as an option.

⁴⁵ “Desert City Uses Water, Then Uses It Again.” MPR News. Accessed November 12, 2019.

Water Resources Development:

The production of water resources in the desert is a challenging and relatively limited, taking into consideration the need for continuous monitoring. This is in addition to some of the limited resources that can be created, such as rainwater harvesting and flooding to restore groundwater. Working with Nile Basin country like Egypt is one of the important steps that will contribute to water production in positive ways.

Improving the efficient use of existing water resources:

Agricultural quality can be enhanced by various measures such as irrigation growth. Review the existing agricultural wastewater reuse strategy by introducing intermediate agricultural wastewater reuse and cultivating some highly tolerant crops. It is possible to improve the efficiency of water use in the drinking water and industry sectors by improving and expanding the infrastructure as well as some financial steps that will rationalize water consumption with priority being given to research and studies that may help to find some other solutions to improve the efficiency of use.

Protection of public health and the environment:

That can be achieved by two steps, step 1: It involves preventing the entry of industrial contaminants into the network by promoting environmentally friendly goods and moving polluting industries away from residential areas and facilitating the use of environmentally friendly fertilizers in agriculture. step 2: If these contaminants cannot be avoided, it is recommended that contaminated water should be treated before it reenters the system and that sewage treatment should be included with substitution.

Energy:

The energy industry has played a major role in enforcing the SDGs of Saudi Arabia and has made a significant contribution to increasing the volume of GDP. The oil sector, for example, reported a 43% share of GDP in 2017.⁴⁶ Huge profits in the growth of electricity networks have effectively led to rising living standards and the supply of electricity to all areas of the Kingdom of Saudi Arabia, like towns and villages, with a 99% residential supply rate. In an effort to support the continued development of the energy industry, the Kingdom aims to enhance economic stability through coordination, studies, local and international relationships, national networking, infrastructure development, knowledge, national professional development and technology advancement. Certain key factors in ensuring stability include looking forward to open, secure, well-functioning, sustainable and reliable energy markets and creating an energy supply with reasonable costs, efficiency, sustainability and the use of all sources of energy and technology.⁴⁷ Saudi Arabia has devoted close attention to renewable energy production, especially wind, solar and nuclear energy. In this context, it has initiated many services, ventures and initiatives, as follows:

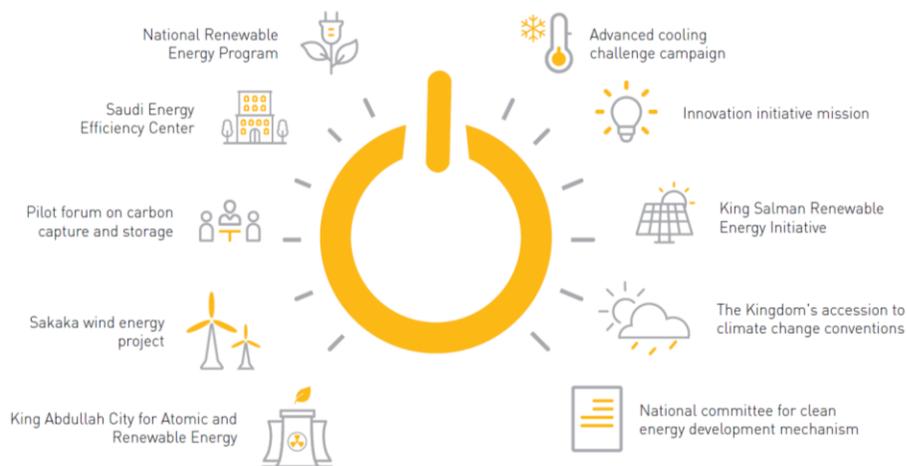


Figure 38: Ministry of Energy, Industry and Mineral Resources, KSA

⁴⁶ Program, YESSER E-Government. تقارير وإحصاءات سعودية. Accessed October 18, 2019.

⁴⁷ Program, YESSER E-Government. تقارير وإحصاءات سعودية. Accessed October 18, 2019.

Saudi Arabia's Energy Consumption:

Three primary industries responsible for more than 90% of local energy usage

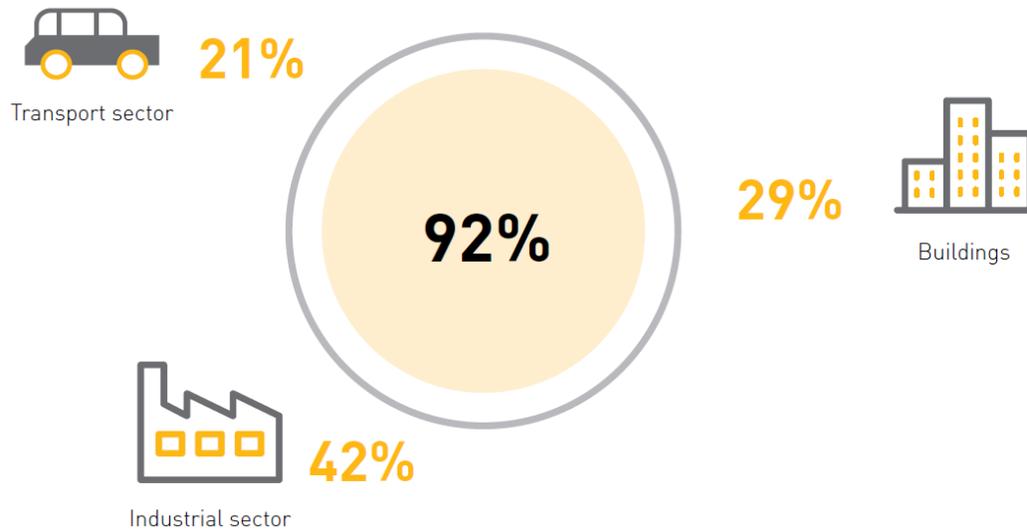


Figure 39: Ministry of Energy, Industry and Mineral Resources, KSA

“Buildings use 29% of total domestic consumption of primary energy and about 75% of total electricity produced. Air-conditioning units’ account for about 65% of this consumption. As thermal insulation can help reduce energy consumption of air-conditioning units by as much as 30%, a high priority has been given to improving the energy efficiency of air conditioners and enforcing thermal insulation of buildings.”⁴⁸

Sustainable recommendation for energy efficiency

- 1- make a quality thermal insulation part of the building code as a required condition.
- 2- Educate communities about energy efficiency usage and sustainable life style.
- 3- develop a new standers and requirement for dryer washing machines and dryer.
- 4- develop a new standers and requirement for all sizes of air-condition system.

⁴⁸ “Saudi Arabia .:. Sustainable Development Knowledge Platform.” United Nations. United Nations. Accessed November 15, 2019.

Sustainable alternative source for energy:

Offshore Wind Farms:

NEOM has more than 279 miles of unspoiled coastline with speed wind between 15-23 mph, it's such an opportunity for offshore wind farm because this speed falls in the above average wind speed for turbine.⁴⁹

The block Island farm off the cost of Rhode Island has a 5 turbines total 30 MW of capacity and it power 17,000 homes in New England. The block Island farm not only a sources of renewable energy it contributes the local economy as well. The expert predict that this farm will created about 160,000 jobs and will cut greenhouse emissions by 1.8%.⁵⁰

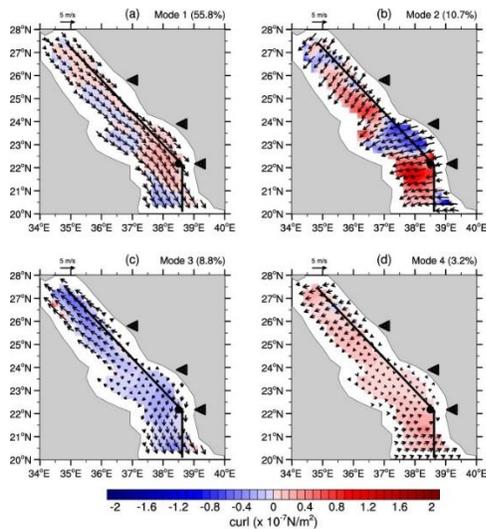


Figure 39: Speed and direction of wind in Red Sea.⁵¹



Figure 40: Offshore Turbine by Lisa Prevost.⁵²

⁴⁹ Accelerator of Human Progress." NEOM. Accessed August 25, 2019".

⁵⁰ Prevost, Lisa. "Connecticut, Rhode Island Vie for Roles in Emerging Offshore Wind Industry." Energy News Network, September 11, 2019.

⁵¹ Menezes, Viviane V., J. Thomas Farrar, and Amy S. Bower. "Westward Mountain-Gap Wind Jets of the Northern Red Sea as Seen by QuikSCAT." Remote Sensing of Environment. Elsevier, March 19, 2018.

⁵² Prevost, Lisa. "Connecticut, Rhode Island Vie for Roles in Emerging Offshore Wind Industry." Energy News Network, September 11, 2019.

Offshore wind supplies are plentiful: the offshore wind has the ability to provide large quantities of clean, sustainable energy to meet regional energy needs.



Illustration by Josh Bauer, NREL 49054

Figure 41: different technique of offshore turbine.⁵³

Offshore wind turbines may float: Innovative offshore wind platforms for use in deep waters are being built by several companies. The spar-buoy, tension leg deck, and semi-submersible are three types of floating platforms.

⁵³ "Top 10 Things You Didn't Know About Offshore Wind Energy." Energy.gov. Accessed November 7, 2019.

Solar Energy:

the climate in Saudi Arabia overall is a harsh climate with sunshine almost through the hall year. that can be opportunity for solar as a renewable source of energy.



Figure 42: Abu Dhabi, Noon Project.⁵⁴

Grate example in Abu Dhabi called Noon Project for solar panel,

Abu Dhabi has rolled on the world's largest single solar power plant that could provide green energy to 90,000 people. Once the Noor Abu Dhabi with 3.2 million solar panels is fully functional, it will cut emissions by about one million metric tons of CO₂-the equivalent of 200,000 cars off the road. NEOM has the ability to make the most of the sun shine through the year and start similar project in different scale according to electricity needs.⁵⁵

⁵⁴ Report, Staff. "World's Largest Solar Project, with Power Enough for 90,000 People, Switched on in Abu Dhabi." Uae – Gulf News. Gulf News, June 29, 2019

⁵⁵ Report, Staff. "World's Largest Solar Project, with Power Enough for 90,000 People, Switched on in Abu Dhabi." Uae – Gulf News. Gulf News, June 29, 2019

Waste Management:

Waste management is a process of treating solid waste. It offers a variety of non-trash items recycling solutions. It's about using garbage as a precious resource. Of the materials you used safely and effectively. There are 8 main waste management methods sets, each of which is split into many types, such as source reduction, reuse, feeding of animals, recycling, fertilization, fermentation, landfills, incineration and land use. At home, for example, reduction and recycling, which helps to reduce the amount of materials that cannot be recycle. NEOM city should have a plan for waste management, we can use Jubail Industrial City in Saudi Arabia as a case study to create a bassline for waste management in NEOM.

Jubail Industrial City:

In the industrial city of Jubail, the Royal Commission for Jubail and Yanbu (RCJY) has initiated an integrated environmental services program to handle cleaning operations. The project aims to make the city waste free by smartly converting waste disposal in a clean and sustainable way. It also aims to increase the level of protection of the environment, prolong the life of landfills and enable recycling and converting waste into power programs.



Figure 43: Sustainable Waste Management -RCJY- operation & maintenance sector- cleaning department.⁵⁶

⁵⁶ "Saudi Arabia... Sustainable Development Knowledge Platform." United Nations. United Nations. Accessed November 15, 2019.

Figures & Statistics

New Technologies	The engineering design of Jubail Industrial City environmental landfill allows for environmentally safe disposal of waste through sample analysis of groundwater resulting from decomposition of waste. The process involves examination and disposal of decomposed waste as well as control and measurement of gases resulting from landfilling operations.	91 Equipment with state-of-the-art technology, in operation on a daily basis 7800 waste bins are emptied every day 300 waste bins are washed and sterilized every day Several other modern technologies are used, such as underground pneumatic waste conveying and suction systems, as well as road sweeper trucks.												
Waste disposal methods	<table border="1"> <thead> <tr> <th></th> <th>Incineration method</th> <th>Landfill method</th> <th>Recycle method</th> </tr> </thead> <tbody> <tr> <td>2010</td> <td>25%</td> <td>41%</td> <td>34%</td> </tr> <tr> <td>2017</td> <td>11%</td> <td>38%</td> <td>51%</td> </tr> </tbody> </table>		Incineration method	Landfill method	Recycle method	2010	25%	41%	34%	2017	11%	38%	51%	Over 200 types of waste are generated in Jubail Industrial City
	Incineration method	Landfill method	Recycle method											
2010	25%	41%	34%											
2017	11%	38%	51%											
Daily operations in figures	<p>Cleaning of residential districts and commercial areas Waste management services are provided to:</p> <p>40,000 residential houses 103 commercial centers 281 tons of waste</p> <p>Cleaning of main roads and internal streets Cleaning and sweeping services are provided to:</p> <p>75 km of internal streets 65 km of main roads</p>	<p>Waste treatment and environmental sustainability</p> <p>23 tons are sorted every day for treatment</p> <p>226 paper collection bins posted at all government buildings</p>												
General figures	About 51% of industrial waste have been recycled. In 2018, municipal waste recycling grew by 2.87% , compared to some 0.35% in 2015.	By 2020, RCJY looks forward to recycle 61% of all waste generated in Jubail Industrial City, through use of state-of-the-art technology.												

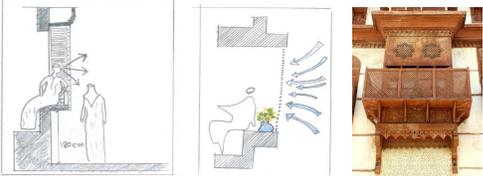
Figure 44: Statistics by RCJY- operation & maintenance sector- cleaning department.⁵⁷

⁵⁷ "Saudi Arabia:.. Sustainable Development Knowledge Platform." United Nations. United Nations. Accessed November 15, 2019.

Conclusion

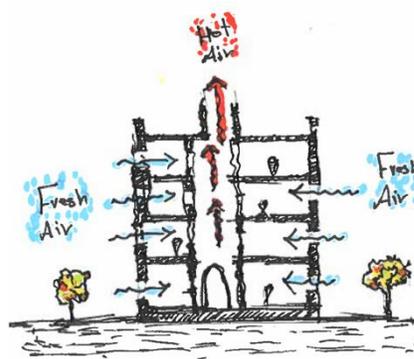
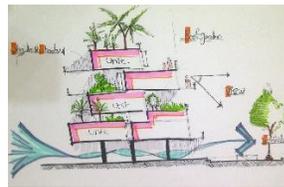
To sum up, this section will summarize the solution that been addressed as a form based code for preserving architectural character in NEOM city and some suggestions for sustainable techniques to address water, energy and waste management in NEOM city.

First: Architectural Character

Category	Details & Benefits
<p>Narrow Streets & Natural Shading.</p>	<ul style="list-style-type: none"> - Zigzagged technique and narrow street to shade street and protect pedestrian from direct sunlight which enhances the walkability and social activity on a neighborhood scale. - this type of planning reduces the amount of walls exposed to solar radiation, which decreases the temperature of buildings thus reducing the energy consumed to cool buildings out.
<ul style="list-style-type: none"> - Capturing sun light - Ventilation with privacy - Green Roof - Courtyard 	<div style="display: flex; justify-content: space-around; align-items: center;">  </div> <ul style="list-style-type: none"> - Typical Roshan technique that can be customize for modern design. <p>Roshan function: Maintenance of indoor space privacy Ventilation, reduction of solar rays and</p>

filtration of sandy air Shading of the outside surfaces (walls and streets)

- provides some private shaded area that allows residents to have visual communication with streets. The existence of the courtyard is important to circulate the air and achieve well ventilation in order to get into comfort zone

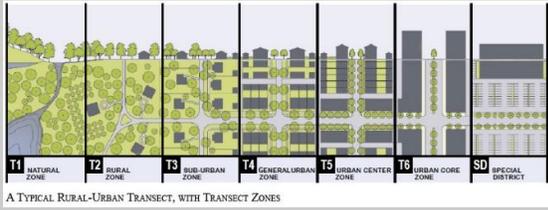


Passive Cooling - Wind Catcher Technique.

- inspired by the hundreds of years old vernacular architecture of Middle Eastern cultures. The wind catcher maintains natural air circulation and cooling via wind airflow and heat variations in towers

<p>High Density Design.</p>	<ul style="list-style-type: none"> - Provide a mixture urban of commercial, retail, residential, and green open space create an amazing urban fabric for day/night activities and fulfill the need for all different age group. - Shorten the travel distance between daily activities such as GYM, restaurant, work, school...etc. that can encourage individuals to use green transportation and enhance walkability which reduces CO2 emission as well as energy consumption.
<p>Zero Scape.</p>	<ul style="list-style-type: none"> - It is a landscaping or gardening method that decreases or avoids the need for irrigation water. in such a circumstance Saudi Arabia in need of every drop of water, the code must include Xeriscape and Xeriscape in NEOM code as required for planting.
<p>Green Area.</p>	<ul style="list-style-type: none"> - In addition to contributing to air pleasant and assisting to comfort temperatures in the summer, plants has the strength to humanize cities through inviting individuals to outside activities

Rural to Urban Transect.



A TYPICAL RURAL-URBAN TRANSECT, WITH TRANSECT ZONES

- NEOM has many natural areas which are considered the most important attractions in the city such as beaches, plains and high mountains. If we can plan the city of NEOM to be an integrated mixture of the natural environment and built environment and take advantage of both sides that can improve the city quality in term of well-being, public health, energy consumption, walkability and more. So, I decide to choose Rural to Urban Transect among the other urban theory.

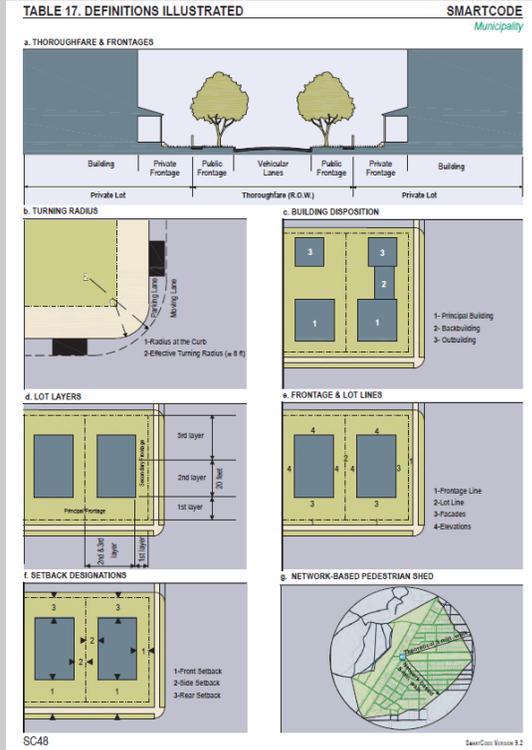
Vehicular Lane/Parking Assemblies Smart Code 9.2 TABLE 3B.

- . The projected design speeds determine the dimensions of the vehicular lanes and Turning Radii assembled for Thoroughfares

	ONE WAY THOROUGHFARE			TWO WAY THOROUGHFARE		
A. PARKING	T1 T2 T3	T1 T2 T3	T1 T2 T3	T1 T2	T1 T2	T1 T2
B. PARKING	T3 T4	T3 T4	T3 T4	T3 T4	T3 T4	T3 T4
C. PARKING ONE SIDE PARALLEL	T3 T4 T5	T3 T4 T5	T4 T5 T6	T4 T5 T6	T5 T6	T5 T6
D. PARKING BOTH SIDES PARALLEL	T4	T4 T5 T6	T4 T5 T6	T5 T6	T5 T6	T5 T6
E. PARKING BOTH SIDES DIAGONAL	T5 T6	T5 T6	T5 T6	T5 T6	T5 T6	T5 T6
F. PARKING ACCESS	T3 T4	T3 T4	T5 T6	T3 T4	T5 T6	T5 T6

Thoroughfare, Frontages and Street Section

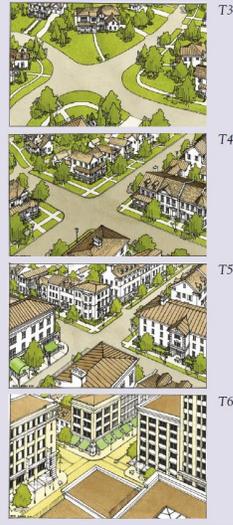
Smart Code 9.2 Table 17



Provide a Multiple Urban Fabric Types

- The communities want to enjoy the city lifestyle (T6) and be able to enjoy some of the regulation freedom of (T3&T2).Trying to provide many different types of fabrics and choices to accommodate different needs for all generations. Make sure there is a room for everyone to have a diverse community with a different group of ages

Provide a Multiple Urban Fabric Types



Second:

Sustainable Techniques to address water, energy and waste management in NEOM city.

Category	Suggestions
Water Treatment	<ul style="list-style-type: none">- Greywater-Friendly Regulations- Water Resources Development- Improving the efficient use of existing water resources- Protection of public health and the environment
Energy	<ul style="list-style-type: none">- Offshore Wind Farms- Solar Energy- Sustainable recommendation for energy efficiency
Waste management NEOM city should have a plan for waste management, we can use Jubail Industrial City in Saudi Arabia as a case study to create a baseline for waste management in NEOM.	<ul style="list-style-type: none">- Safe and environmental sanitary landfills- Recycling- Maintenance of Assets- Develop a method to ensure and improve quality of process and sustainability

Skyline of NEOM Vision 2030

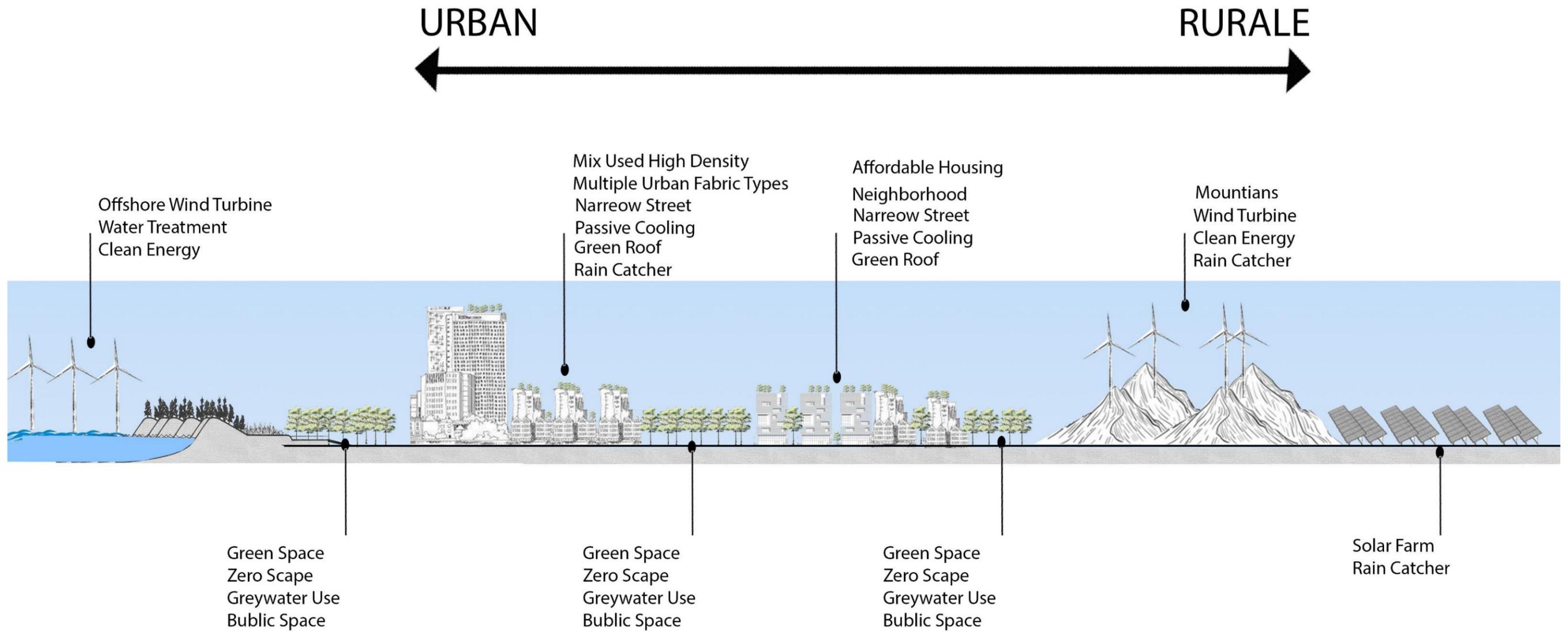


Figure 44: Skyline Sketch of NEOM Vision 2030, By Author.

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