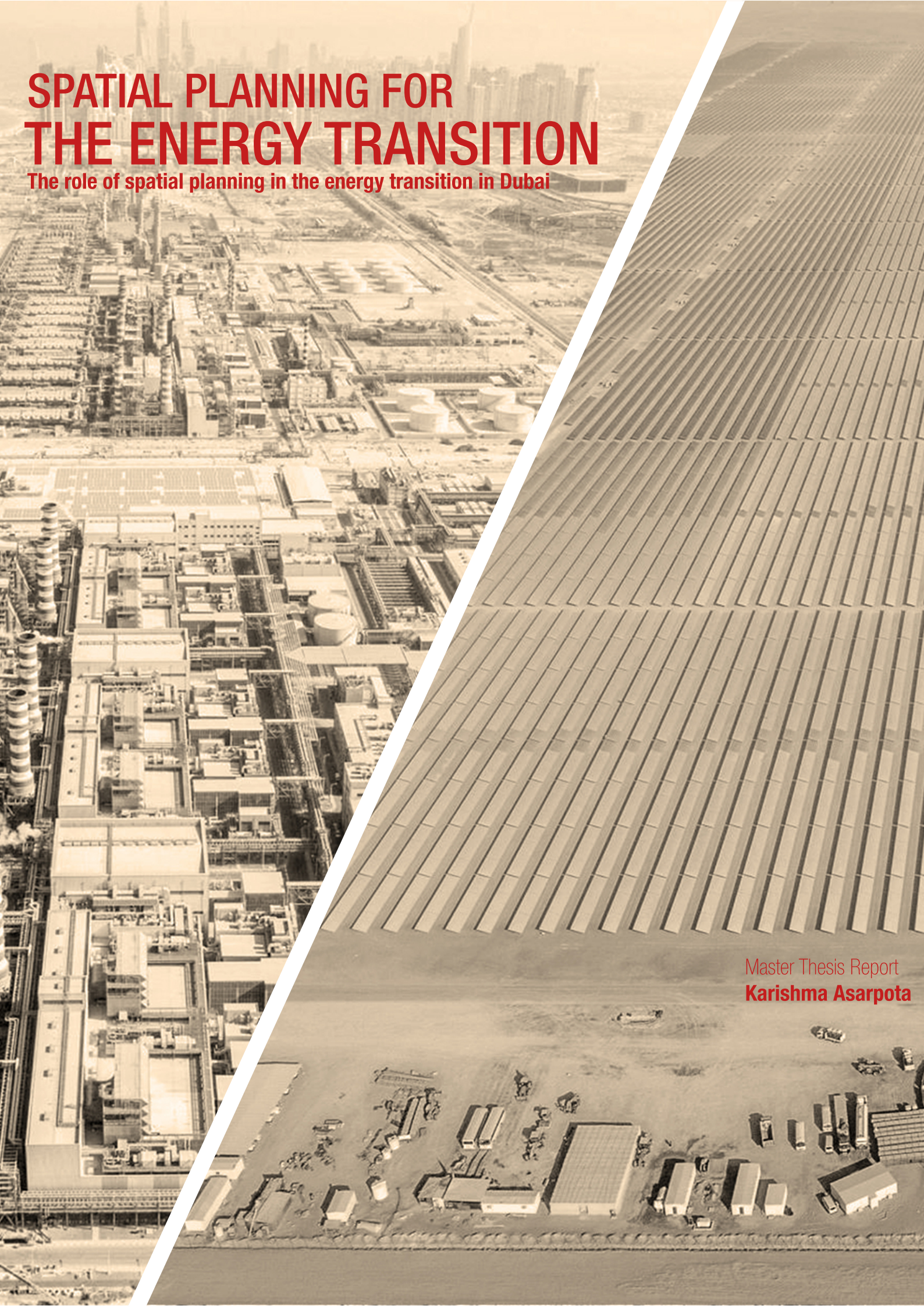
SPATIAL PLANNING FOR THE ENERGY TRANSITION

The role of spatial planning in the energy transition in Dubai



Master Thesis Report

Karishma Asarpota

Cover illustration

DEWA Electricty and Water Plant, Jabel Ali (left)
Mohammed Bin Rashid Solar Park, Dubai (right)

Source: Luca Locatelli, Institute for the National Geographic

P5 Report
June 2018
Spatial Planning for the Energy Transition

Keywords: Spatial planning, comparative analysis, governance, urban energy transition

Author

Name: Karishma Asarpota
Student number: 4619625
Email: karishma108@gmail.com
Phone: +31 6 39690383

Mentors

Prof. Vincent Nadin
Professor and Chair of Spatial Planning and Strategy, Chairman of Department of Urbanism

Prof. dr. ing. Carola Hein
Professor and Chair of History of Architecture and Urban Planning

Special Advisor

Daniela Maiullari
PhD Candidate

Complex Cities

Delft University of Technology
Faculty of Architecture and the Built Environment
Department of Urbanism
MSc 3 Urbanism, Academic year 2017/2018

'We do not wait for events but we make them happen.'
Sheikh Mohammed bin Rashid Al Maktoum
Vice President and Prime Minister of the United Arab Emirates and the Ruler of Dubai

A billboard placed near the World Trade Centre in February 2009
Source: Elsheshtawy, 2010

Contents

Acknowledgements

This thesis is a result of a year-long research undertaken with the Complex Cities research group at the Faculty of Architecture and Built Environment at TU Delft. Studying about spatial planning from an energy lens, learning about other cities and presenting a critical perspective on Dubai's energy system has been a thoroughly challenging and enriching process. This research would not have come together without the large amount of help I have been fortunate to receive from many.

Vincent, thank you for all the time you have taken to motivate, encourage and believe in me in the past year. Your immense knowledge and critical perspective about planning, and detailed feedback on my writing has pushed me to go a step further and discover my capabilities. Carola, thank you for your critical feedback and refreshing conversations that challenged the boundaries of my thinking throughout this year. Daniela, thank you for taking the time to provide your insights and knowledge on energy systems and for the all motivating chats to keep me going.

I am grateful to Mr. Omar Thiab from Dubai Creative Clusters Authority for taking the time to discuss planning processes in Dubai and providing me some data to work with.

A sincere thank you to Dr. Jerry Kolo from the American University of Sharjah, Dr. Sgouris Sgouridis from Masdar University, Ebrahim Mahmood from the Roads and Transportation Authority in Dubai, Muhammad Al-Derawi and Mohammed Al-Mulla from Dubai Municipality, Henk Heijkers from Den Haag Municipality and Janki Dalal from Arcadis (Dubai) for taking the time to share their knowledge.

Last but not the least I would like to thank my family, friends and peers for all the support, encouragement, time (and food) throughout this year.

Karishma Asarpota

Motivation

Born and brought up in Dubai and having worked as an urban planner in UAE, my motivation for this research is both personal and professional. During my time as a Junior Urban Planner at Ras Al Khaimah Municipality, I was a part of a very small team and was quickly exposed to the decision-making process in spatial planning. The link between policy making and spatial development in the city always intrigued my interest. Collaborative polices that take into consideration social demographics, cross-cultural differences, environmental concerns and the local context are lacking in the decision-making process in Ras Al Khaimah. Moreover, an Emirate wide strategic plan directing spatial growth was missing. Although smaller and less dynamic than Dubai, the planning system in Ras Al Khaimah is similar its counterparts.

I have been exploring the impact of sustainable development principles in architecture and urban design in Dubai through my blog for the last three years. This led me to investigate the transition of energy systems and its link to spatial planning in Dubai. Policies put forward by Dubai Municipality (DM) and Dubai Electricity and Water Authority (DEWA) such as demand side management to reduce energy consumption, implementation of Dubai Green Building Standards (DGBS) and investment in renewable technology for energy production lack legislative and spatial collaboration. The wider implications of these actions and their relation to each other is missing. The energy transition would require a radical shift in planning culture, resident behavior and policy tone. A process to bring different stakeholders to work towards an energy transition while improving spatial quality in the city is urgently needed for Dubai to realize a more sustainable urban form. This thesis provides me a great opportunity to explore the ways in which this can be achieved.

Chapter 1

Introduction

Globally, energy use is the most important contributor to greenhouse gas (GHG) emissions. Around two-thirds of greenhouse gas emissions arises from energy production which makes the production and consumption of energy a central issue in climate change mitigation (IPCC, 2015). The increase in greenhouse gas emissions is known to be the biggest cause of accelerated climate change today. The human influence on climate change has become an important policy issue over the last decade (IPCC, 2015). Urban areas are receiving increasing attention with respect to the role they should play in tackling climate change. Energy in urban areas can refer to many things. It can be viewed as consumption for mobility, building infrastructure, a set of input and output flows in a place, an infrastructural system through which energy is produced, distributed or consumed or as a policy tool to respond to climate change. Given their scale, density and concentration of activities, urban areas are places of high energy demand and economic activity, benefitting from dense social networks and a comparable decision-making body (Nijkamp and Pepping, 1998; Capello et. al, 1999). This can potentially help to simplify the issues related to implementing energy policies and climate mitigation measures. Urban areas depend heavily on the use of fossil fuels and have expanded with the increasing use of energy (Coutard and Rutherford, 2014). With 66% of the global population predicted to be living in urban areas by 2050 (UN, 2014) and energy related emissions set to increase by almost a quarter by 2040 (OPEC, 2017), the importance of future energy use in urban areas cannot be emphasized enough.

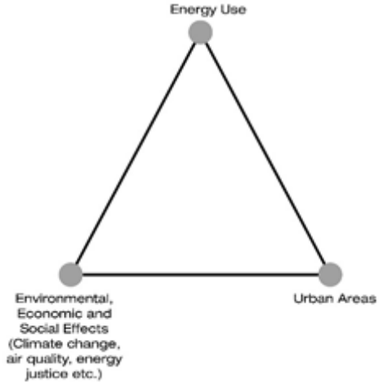


Figure 1.1 –The relationship between energy use, cities and its effects. Source: Adapted from Capello et. al, 1999

The Munich Reinsurance, the United Nations Human Settlements Program and the Clinton Climate Initiative estimate that cities generate between 75-80% of global greenhouse gas emissions (Booth et al., 2012). On the contrary, Satterthwaite (2008) argues that cities contribute to between 30-40% of greenhouse gas emissions. He demonstrates the ambiguity that arises while calculating greenhouse gas emissions. What is the boundary of cities that is used? Is it restricted to the urban core or to the total built up area in cities or its relational regional importance? Moreover, are emissions calculated based on where it is produced or where it is consumed? There is no consensus on these factors and they influence energy use for the production and consumption of goods and services on which calculations are usually based. The question of energy injustice is relevant to this debate. Most economically richer cities will have a higher carbon footprint because of the affordability of higher patterns of consumption (Satterthwaite, 2008; Stern, 2006). If carbon emissions are calculated based on consumption patterns, carbon emissions related to exports may be ignored. Production of products results in emissions, the impact of which is usually local. This implies that the benefits and burdens of the carbon footprint related to consumption and production are not always fairly distributed.

As the UN-Habitat (2015) points out, responding to climate change through more sustainable development is the biggest challenge lying ahead of us today. The urban future of the globe draws attention to the patterns of resource use in urban areas. The ways our cities are planned has a significant impact on energy use. For example, a compact urban core designed to encourage pedestrians and cyclists reduces the necessity of cars and its related energy use and emissions. Solar passive design can reduce energy demand for heating and/or cooling in buildings. The extent to which the planning of cities addresses questions of energy consumption is relevant for all cities, but it is particularly important where there is rapid urbanization in Asia, Africa and the Middle East. What urban principles should be promoted through planning to address energy issues? Spatial or urban planning is the main tool that governments use to influence urban form and development. This research project emphasizes the contribution of spatial planning measures in promoting a more efficient use of energy in urban areas. A strong theoretical framework is developed (chapter 3) which highlights the link between spatial planning measures and energy use.

Cities that have ratified the Paris Agreement and pledged to decrease GHG emissions are adopting strategies to improve infrastructure efficiency, incentivize residents to reduce energy demand and integrate renewables within the existing urban form. These goals are the accepted global norms and is the basis on which energy strategies are devised. Achieving these goals requires initiatives that attempt to modify urban form and the way people interact with it. To understand how cities are implementing this, energy strategies from four cities – Vancouver, Oakland, Oslo and Hong Kong - are examined (chapter 6). It was found that most energy strategies today do not emphasize spatial aspects of the energy transition and leave it for urban development plans to address. Technological breakthroughs in energy systems such as smart grids, CCS or wind and solar farms appear to be at the forefront of most policies. Infrastructural changes to energy systems can help to mitigate GHG emissions, but they don't necessarily change energy inefficient patterns. How does the urban form need to change to incorporate these new technologies? Will it be better than what exists today? And to what extent will these changes address energy demand?

This research attempts to bridge the gap between energy strategies and urban development policies. This is explored within the context of Dubai, a city in the United Arab Emirates. The discovery of oil in the 1960's transformed Dubai from a sleepy port town to the global metropolis it is recognized as today. The recent shift to address environmental sustainability in Dubai draws attention to energy issues in the city. The urban area of Dubai has grown by almost 24 times in the last 44 years (Elessawey, 2017). This makes the pattern of urban development central to discussing the energy transition in Dubai. The economic dependence on oil and gas cannot be ignored while discussing energy use in the city. In many ways this has shaped the city and influenced how places are viewed. Autocratic decision making and dominating economic goals has led to a disconnected urban plan and inefficient infrastructural system which escalated energy demand. The influence of governance, economic conditions and local culture on urban development in Dubai has never been examined from an energy perspective. This project addresses this gap in chapter 5 by highlighting how Dubai's changing relationship with energy has influence urban development.

Dubai faces many challenges to bring about the necessary changes to transition to a more clean, efficient and sustainable energy system. Planning processes and the extreme desert climate are major issues that must be addressed to challenge norms that don't promote energy efficiency and plan for long term benefits. The role of planning in the energy transition is demonstrated at the neighbourhood level in Dubai through an urban retrofit plan. This plan is intended to create conditions that can promote a collective investment in public goods by different stakeholders and create a demand for innovation in climate and cultural appropriate urban design. The recommendations in chapter 9 discuss the ways in which this can be achieved.
The intention of this research and design project is to begin a discussion about the role of spatial planning in the energy transition in cities. Cities need to adopt an integrative approach to developing energy strategies that strongly consider the spatial dimension, the governance model and local societal values. Energy strategies should be aimed at not only reducing GHG emissions but also improving spatial quality and promoting long-term environmental sustainability. This report concludes with an illustration of the main research findings which puts forward a tool that can be used by cities to develop an energy informed urban development strategy.

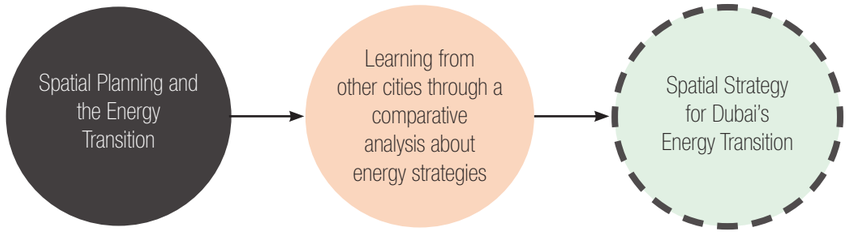
Chapter 2

Research Outline

2.1 Research Approach

This research asks the question: how can spatial planning help Dubai government to facilitate the energy transition?

There are three steps in the project. The first is to explain the relationship between spatial planning and the energy transition. The second step is to draw lessons from energy strategies and policies in four other cities – Oslo, Hong Kong, Vancouver and Oakland. The third step is to propose a strategy for Dubai's energy transition.



Spatial Planning and the Energy Transition

The Paris Agreement which entered into force in November 2016 recognizes the need for a 'cleaner and more efficient energy system' as a core policy goal. To this date, 170 countries have ratified the Paris Agreement and have committed to decreasing GHG emissions and adopting strategies to improve energy efficiency, promote renewables and incentivize residents to reduce energy demand. The goal of all energy strategies is to reduce GHG emissions. Depending on which sector emits the most amount of GHG emissions, policies to reduce GHG are also emphasized in this sector. For example, Oslo has a huge emphasis on transport demand management since 63% of GHG in the city are contributed by the transport sector. On the other hand, in Hong Kong most strategies are directed toward reducing GHG emissions and energy use in buildings since 70% of emissions are from the building sector. The connection between the transport planning and the building sector is less explored in both these energy strategies since it does not contribute to the goals of reducing GHG emissions in an explicit way. The potential to reduce energy consumption through changing urban development patterns is not studied. The way our cities are planned has an impact on energy consumption patterns. The perception of space and its organization in urban areas needs to change for cities to make the transition to more sustainable, clean and efficient energy systems. Spatial planning is the main tool that governments use to impact urban form and development and it must consider the energy question.

Over time a consensus about the fundamental purpose of spatial planning has emerged. Globally, spatial plans have started to adopt the ideals of sustainable development as an objective. The term 'sustainable development' was first defined by the Brundtland Report in 1987 as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). The United Nations first promoted the idea that the core of planning lies in sustainable development at the Earth Summit in Rio De Janeiro in 1992. This idea persisted and represents the accepted standard of what planning should deliver today. Since then, spatial planning has been recognized by many authors and reports as an essential tool to achieve sustainable development and address the causes and consequences of climate change (Barton, 2017; Rydin and Healey, 2012). Explicitly or implicitly, planning emphasizes the need for sustainable development and responds to climate change.

The role of spatial planning can be understood in different ways and can have the following attributes.

- It is a vision created by collective action.
- It deals with space, urban form and the making of places.
- It interrelates different physical systems.
- It is a tool to inform decision makers and the public.
- It facilitates learning between actors and networks related to space.
- It is a tool to coordinate various land uses and functions.

To understand how spatial planning can impact energy use, discussing the link between urban energy policy and urban form is a starting point. Studies in both the fields are reviewed and the overlaps are highlighted.

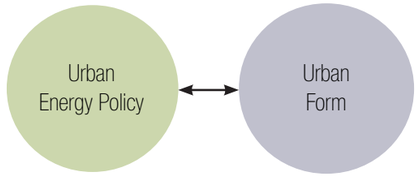


Figure 2.1 – Components of Urban Energy Policy

Urban Energy Policy

Many studies address energy efficiencies as a part of wider strategies for achieving more sustainable development (figure 2.1). Barton (2017) illustrates the broad influence of spatial planning on energy use and resulting carbon emissions. He puts forward three policy areas to address energy use i.e. transport policies, urban form and location policies and development layout and design. The Leadership in Energy Efficiency Design (LEED) reference guide (2014) for neighbourhood development addresses sustainable development, and consequently efficient energy use, in three main categories i.e. smart location and linkage, neighbourhood pattern and design, and green building and infrastructure. Droege (2008) categorizes spatial planning measures to reduce the impact of climate change by promoting energy transition in three categories i.e. transport policy and technology, regional planning and agricultural reform, and institutional change. Lehmann (2008) views measures toward 'green urbanism' in three categories i.e. urban form and design, landscape and building design and traffic planning. Mega (2005) emphasizes land use management, efficient buildings, mobility and waste management as the four areas of focus for the energy efficiency in a resourceful city. Given the wider scope of these studies, energy efficiency in urban areas has not been explicitly addressed, but more efficient energy use to promote sustainable development is highlighted in all the studies.

Transportation and accessibility, and infrastructure are addressed in almost all the studies indicating that it has an important contribution to sustainable development and energy use. The layout and design of urban form is another area of study that has a significant impact on energy savings in the built environment. Although regional planning, landscape design and institutional change appear less commonly in all studies, it can have an impact on planning for energy efficiency.
Figure 2.2 (PTO) shows the most important sections of urban energy policy identified through the overlaps between the different studies.

Interplay of planning policy and carbon emissions

- Transport policies
- Urban form and location policies
- Development layout and design

Barton, 2017

LEED neighbourhood development categories

- Smart location and linkage
- Neighbourhood pattern and design
- Green building and infrastructure

LEED ND Reference Guide, 2014

Spatial planning measures for energy transitions

- Transport policy and technology
- Regional planning and agricultural reform
- Institutional change

Droege, 2008

Measures for sustainable development in cities

- Urban form and urban design
- Landscape and building
- Traffic planning

Lehmann, 2008

Energy criterion for a resourceful city

- Land use management
- Efficient building
- Mobility and accessibility
- Waste management

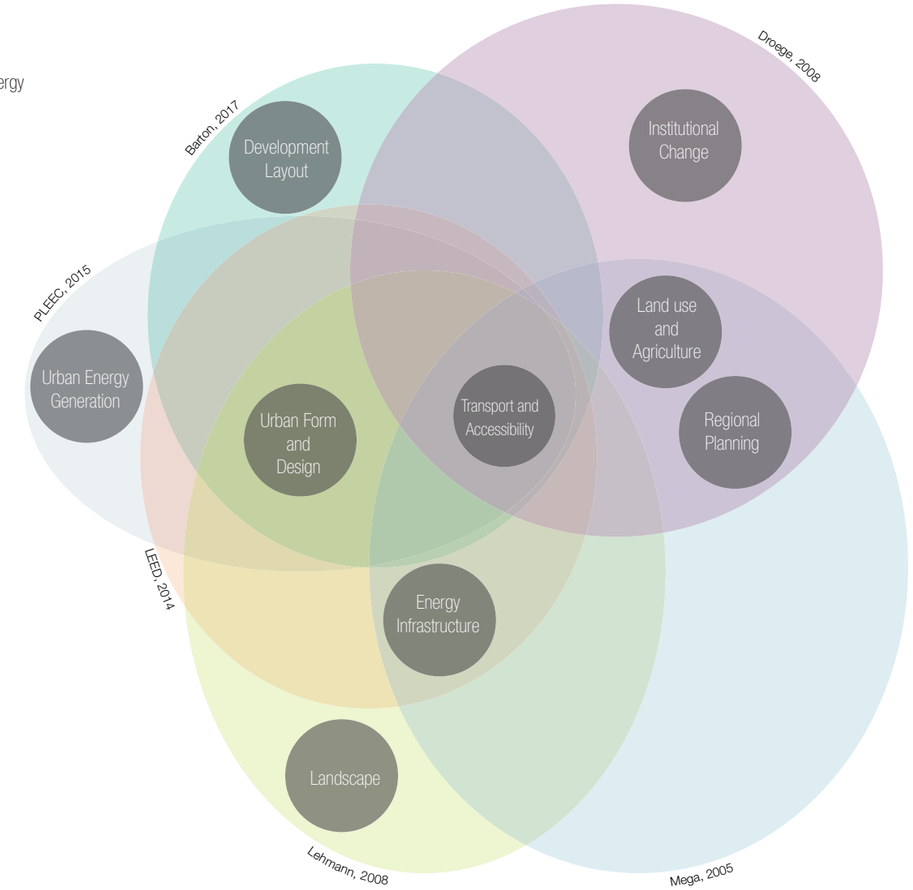
Mega, 2008

Impact of urban planning on energy consumption and production

- Energy consumption Residential, Industrial, Transportation
- Urban energy generation

PLEEC, 2015

Figure 2.2 – Overlaps in Urban Energy Policy



Urban Form

The term 'urban form' can be used to describe a city's physical characteristics. Urban form encompasses many scales and their interaction over time. These include; the layout of streets and blocks, the shape of neighbourhoods, the structure of urban areas, and the wider patterns of regional settlements (Barton, 2017).

Barton (2017) puts forward five decision areas that effect urban form. These are greenspace, movement, jobs and services, housing and density. Jabareen (2006) identified seven areas related to sustainable urban form as compactness, sustainable transport, density, mixed land use, diversity, passive solar design and greening. Dempsey et. al (2010) categorizes the five inter-related elements of urban form as density, transportation infrastructure, housing/building typology, layout and land use (figure 2.3).

Density, transportation and land use is mentioned by all three authors as a crucial aspect of sustainable urban form. Addressing green spaces, solar passive design and housing is mentioned by two authors. These overlaps show the important aspects of urban form that should be discussed while planning for higher efficiency and more sustainable urban areas (figure 2.4).

Barton, 2017

- Transport
- Jobs and services
- Housing
- Greenspace
- Density

Jabareen, 2006

- Compactness
- Sustainable transport
- Density
- Mixed land use
- Diversity
- Passive solar design
- Greening

Dempsey et. al, 2010

- Density
- Transportation infrastructure
- Building typology
- Layout
- Land use

Figure 2.3 – Components of Urban Form

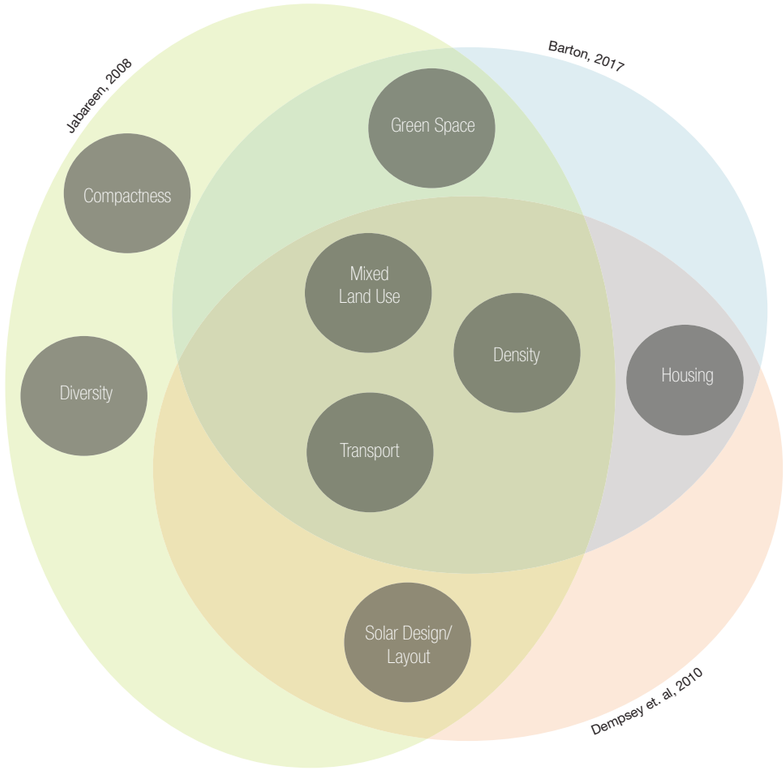
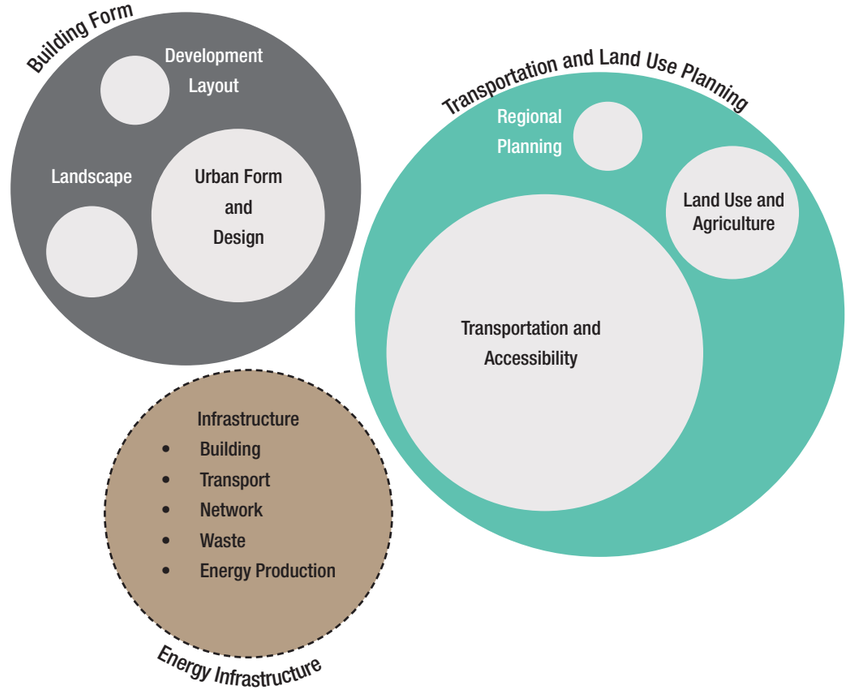
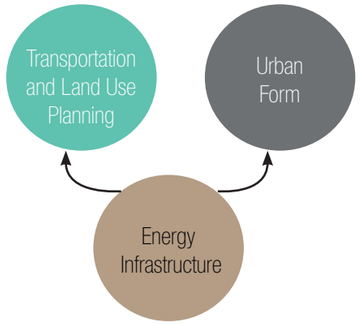
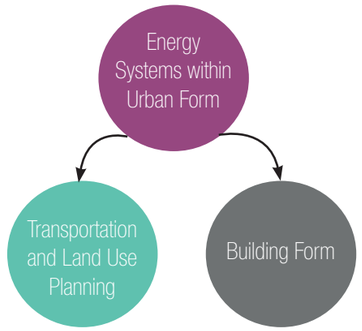


Figure 2.4 – Overlaps in Urban Form



This diagram illustrates the intersections between urban energy policy and urban form. Transportation and accessibility, land use and agriculture and regional planning are energy policy areas which collectively consider transportation and land use planning. Urban form and design, landscape elements and development layout are energy policy areas which can be brought together within building form. Energy infrastructure is another big area that receives attention when discussing urban energy policy. This diagram shows the connection between the previous Venn diagrams (fig 2.2 and fig 2.4).





It was found that there are three big focus areas of urban energy policy within urban form. These are transportation and land use planning, building form and energy infrastructure. Almost all studies about the energy transition view energy infrastructure as a separate 'layer'. This includes infrastructure in buildings such as heating and cooling systems or lighting; upgrading distribution networks with smart grids or neighbourhood energy centres; managing waste infrastructure to include reuse or recycling; promoting electrification or hydrogen as an alternative fuel for mobility; and integrating renewable energy production with rooftop solar panels or CSP plants. While this is a big change that can help with reducing energy consumption and switching to more sustainable fuel sources, it does not promote a transformation of the urban environment to make an energy transition. These solutions don't challenge current norms that promote energy inefficient development patterns. For example, switching to electric cars does not change the need to own a car and travel long distances for daily commute. Energy infrastructure is an integral part of how transport, land use and buildings are organized. While urban energy studies recognize the importance of space in influencing the supply and use of energy, they emphasize changing energy infrastructure rather than promoting urban development patterns that can support the shift to less carbon-based fuels and support alternative forms of fuel. Energy infrastructure is an integral part of both – transportation and land use planning and building form and is considered when putting forward measures to shift to an efficient and clean energy system. These are explained in detail in chapter 3.

The gap in urban energy modelling tools

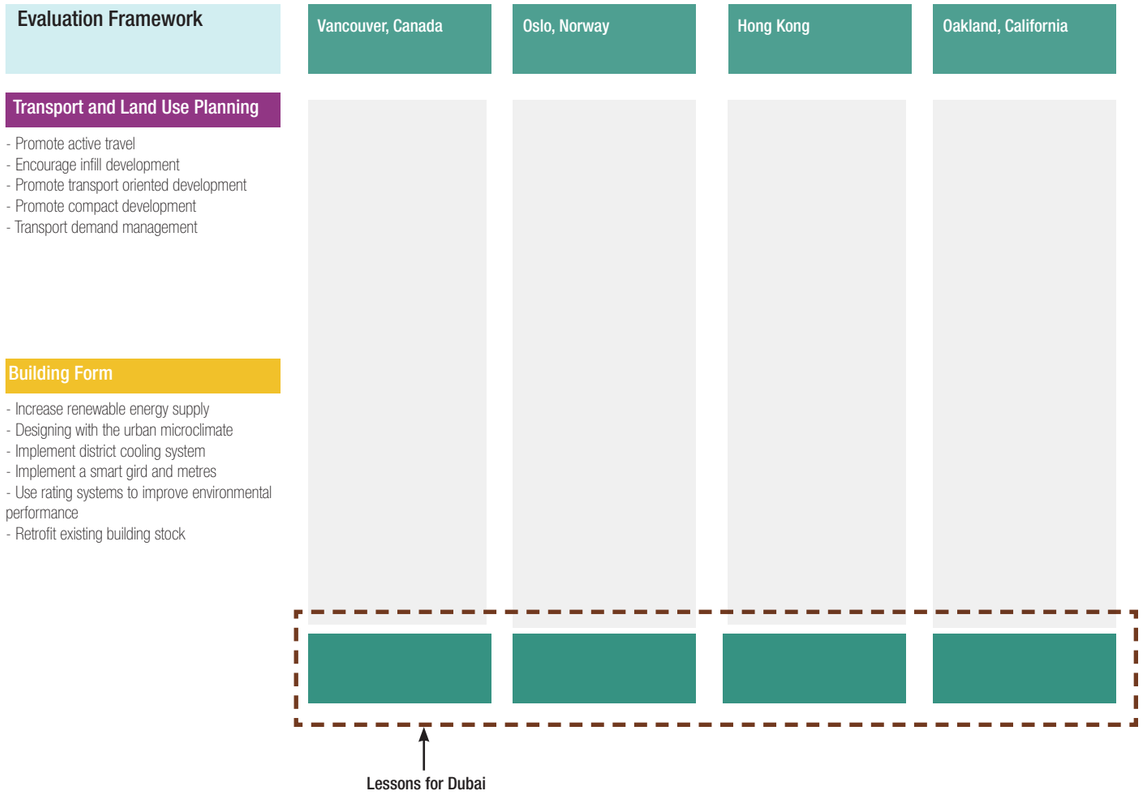
A lot of cities adopt a technologically driven approach to realize the energy transition that emphasizes changing energy infrastructure (such as smart grids or district energy centres) or promoting less impactful alternatives (such as electric vehicles). These are informed by engineered solutions whose feasibility is tested through modelling tools. Modelling tools define targets and provide technology-based solutions to achieve it. For example, reducing GHG emissions, reducing energy demand or increasing renewable energy production by a certain percentage can be achieved by installing x% more solar panels on rooftops, improving insulation on certain walls in buildings or connecting x more buildings to the district energy network. However, modelling tools often lack precision because of data availability or due to the limitation of the modelling tool. Moreover, they are not capable of integrating multiple factors such as urban micro-climate, density or mobility. Keirstead et. al (2012) conducted a review of 219 papers related to urban energy modelling in six categories – technology design, building design, urban climate, system design, policy assessment and transportation. A common challenge among all tools is the availability and relevance of data that is used. A lot of assumptions and uncertainties need to be dealt with. Among 219 studies, 68% found it difficult to acquire data. Another gap that was highlighted in the study is that transportation and land use models related to energy use are lacking and need further development. This is because of the uncertainty of data and complexity of the models. Therefore, solutions to improve energy efficiency through changing land uses or mobility patterns is less common through modelling techniques as urban energy models are not able to say much about the space between buildings.

(Inference from workshop on City Energy Analyst urban modelling tool on May 24-25th, 2018 at ETH Zurich led by Dr. Amr Elesawy and Eng Martin Mostero.)

Comparative Analysis

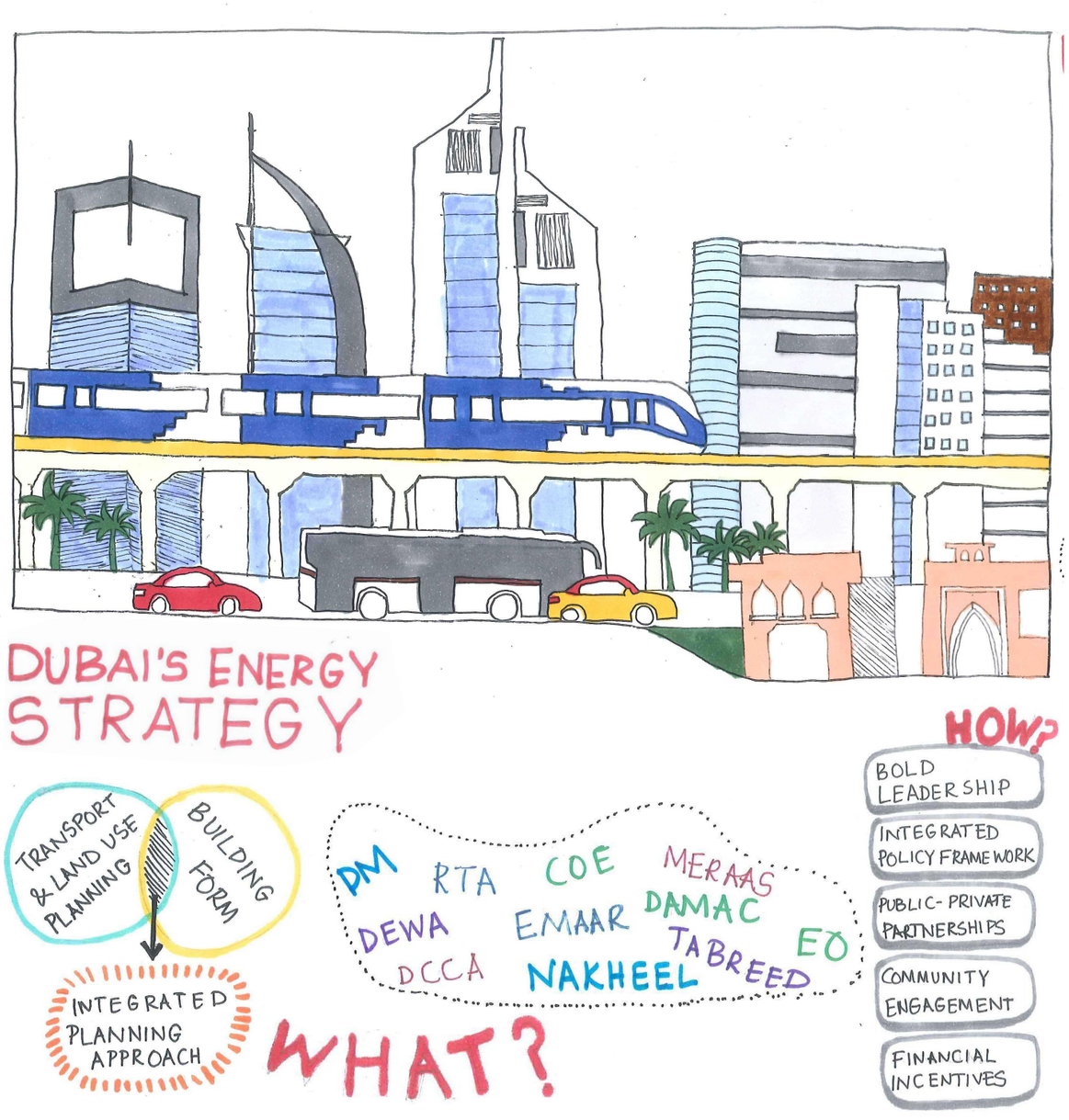
Improving energy efficiency, reducing energy consumption and transitioning to renewable sources of fuels are among the common objectives of most cities. Dubai's objectives are no different and it can learn from the innovative approaches and implementation strategies that other places have chosen.

To evaluate the energy strategies the design principles developed in chapter 3 will be used. These actions present the normative of what cities should be doing through spatial planning to help the energy transition. The analysis comments on the goals and operational framework, common actions and differences, considerations for Dubai's Energy Strategy and criticisms of the four strategies.



Energy Strategy for Dubai

The energy strategy for Dubai will put forward recommendations for two neighbourhoods in Dubai and discuss the wider implications of some of the policies. The evaluation framework will be used to analyse the two neighbourhoods – TECOM and Mizhar. A strategic plan, supporting policies, design codes and an implementation plan will be proposed for both neighbourhoods. The strategy addresses governance, transportation, building form, challenges and tools.



2.2 Research Questions

The main research question is:
How can spatial planning help Dubai government advance the energy transition?

Sub research questions:
There are 6 sub-research questions which fall under three categories– theoretical framework, analysis and strategy.

Theoretical Framework

1. What is the relationship between spatial planning and energy transition?
2. What are the criteria for 'good' spatial planning strategies to facilitate the energy transition?

Analysis

3. With respect to the energy system, how does the existing spatial planning system in Dubai work?
4. What are the spatial planning strategies in other cities that are already on the path of moving away from fossil based energy? How well do they perform?
5. What lessons can we learn from urban energy policies in other cities that can be transposed to the context of Dubai?

Strategy

6. What are the strategies that Dubai can adopt to transition to a more efficient and cleaner energy system?

2.3 Methodology

The focus of this thesis lies in exploring how spatial planning can help Dubai transition to a clean, sustainable and efficient energy system. To do this, firstly the link between spatial planning and the energy transition is made explicit through a thorough literature review. Measures that can help improve energy efficiency in urban areas through spatial planning are deduced and form the theoretical framework of the research. To further understand the implication of planning policies and strategies on the energy transition, an international comparative of energy strategies in four cities is undertaken. The strategies are evaluated against the theoretical framework and help to build upon it. Next, Dubai's urban development pattern, energy system and urban governance model is examined through interviews, literature review, press releases and satellite imagery. The recommendation for Dubai's energy strategy bridges the gap between the energy policy and the urban development plan. This is demonstrated at the neighbourhood scale for two areas with different morphologies, urban decision-making framework, socio-economic demographic and urban character. All these factors influence energy demand and are considered when proposing recommendations for Dubai's energy transition. The wider implications of the proposed policies and its link to the spatial planning measures put forward in the theoretical framework are explained.

2.4 End Products

The intended end-products respond to each sub-research question and are listed below.

- Table of actions to promote the energy transition through spatial planning. This presents a summary of the literature so far and explains the intention, implication and scale of implementation of every action can have.
- The results of the comparative study of energy strategies from 4 cities is discussed within the following themes: goals and operational framework, common actions, differences and criticisms.
- Analysis of Dubai's energy strategy and the two chosen neighborhoods – Mizhar and TECOM.
- Recommendations for Dubai's energy strategy at the neighborhood scale and wider policy context.

Chapter 3

Spatial Planning for Energy Transition

This chapter puts forward spatial planning measures to reduce energy demand and consumption in two categories - transportation and land use planning and building form. First highlights from a detailed literature review are discussed followed by a summary table of actions that can be promoted to improve energy efficiency through spatial planning in cities.

Image source: Edmonton Energy Transition Strategy

3.1 Transportation and Land Use Planning

Transport and energy consumption, and the contribution of spatial planning in reducing energy consumption is a much debated issue. Buxton (2000) and Hickman and Banister (2007) discuss previous studies in this area and highlight the controversy. There is very little consensus on the contribution of transport and land use planning in reducing greenhouse gas emissions and energy consumption. The reasons for this include: definition of the problem, definition of the outcome, data sources, analysis methods, location and period of analysis (Hickman and Banister, 2007). The varying calculations and conclusions about the significance of reduction in energy consumption and greenhouse gas emissions is attributed to these reasons. This controversy has also pushed for increasing research in the field. There is 'medium evidence and medium agreement' that transportation contributes to 14% of global GHG emissions and 27% of global energy use which is expected to double by 2050 (IPCC, 2014). Although energy consumption in the transport sector continue to rise, the potential role of spatial and land use planning in contributing to reduce transport energy consumption is largely underplayed (Hickman and Banister, 2007). Most studies agree that fuel efficient transport solutions, behavioral change, improved infrastructure and comprehensive policies are needed to decrease energy use from transportation and mitigate its associated emissions (Stead et. al, 2003; Williams et. al, 2000; IPCC, 2014).

The following are measures that can be used to improve energy efficiency within transportation and land use planning.

- **Promote walking and bicycling**

Many studies have shown that planning infrastructure to promote active travel i.e. pedestrian movement and bicycling for practical purposes (to get to school, work, shops, friends etc.) within cities has a positive impact on the health and well-being of residents (Barton, 2017; Milner et. al, 2012; Newman, 2009). Apart from health benefits, cities that are more pedestrianized also benefit from reduced air pollution, GHG emissions and less traffic congestions. When more residents choose to walk or use bicycles, this reduces the number of cars on the road, reducing the amount of fuel needed by cars therefore reducing oil based energy consumption. Consequently, this improves air quality, reduces noise pollution and GHG emissions (Newman, 2009; Banister et.al, 2007; Bernardo et. al, 2014).

- **Integrate inefficient sites (i.e. brownfields and vacant lands)**

Policies to promote development on previously developed lands or vacant lands within urban areas should be encouraged before developing a greenfield. These include infill development, brownfields, areas around existing public transit stops etc. This helps to conserve natural and financial resources to build infrastructure to support new developments (LEED, 2014). Infill development is also proved to reduce fuel consumption by cars (Taniguchi et. al, 2005). By developing sites closer to the city center, the dependency on car based travel reduces and consequently reduces the amount of fuel used by cars.

- **Promote development around existing public transport nodes (TOD)**

The concept of Transport Oriented Development (TOD) emerged around 1980's in planning theory (Couch, 2016). Calthorpe (1993) first defined a TOD area as a 'mixed-use community within an average 2000-foot (600 m) walking distance of a transit stop and core commercial area'. Some of the main objectives of TOD are to organize regional growth to be supportive of public transport, place most land uses within walking distances to transit stops, provide mixed used development, encourage re-development along transit corridors within existing neighborhoods. TOD's can be implemented at different scales depending on the area they serve (neighborhood, urban center etc.) and the walking distances can be defined on a case by case basis. Concentrating development and providing mixed uses also contributes to efficient urban form and functions. Implementing TOD is intended to reduce the number of trips needed by cars and its consequent energy use and increase pedestrian movement and the use of public transport.

Residents in walkable neighborhoods can drive up to almost 40% fewer kilometers than their counterparts in less walkable neighborhoods (LEED, 2014). A study in Graz found that if 1/3 of trips were made by bicycles instead of cars there would be a 25% less consumption in petroleum for cars, 37% reduction in hydrocarbon air pollutants and 30% less reduction in traffic congestions (EC, 1999).

Designing with the principles of TOD requires a certain amount of cautiousness. Calthorpe's work questioned the status-quo and was meant to show that community design should be multidisciplinary. One of the first experimental projects of implementing TOD was carried out by him in Laguna West, California. However, Quinn (2006) points out that the economic feasibility and social acceptability of concentrating development around transit nodes was not taken into consideration in Laguna West. He concluded that TOD was not as successful as its intention for the following reasons. (1) consumer taste for pre-existing suburban houses (2) inadequate employment opportunities (3) insufficient provision of consumer needs within Laguna West, and (3) Laguna West is a part of the wider Sacramento urban area which is a conventional suburban landscape that supports car use. Quinn further emphasizes that apart from socio-economic factors, TOD theory also does not take into consideration social and attitudinal responses to car use. It does not account for the forces that continue to drive the inertia of heavy car use.

On the other hand, TOD areas are much more successful in the Netherlands. Although higher pedestrian activity and the widespread use of public transport are more prevalent in Europe than the US, Pojani and Stead (2015) found that local culture and context have redefined TOD areas in the Netherlands. Through a series of workshops engaging stakeholders they conclude that the 'ideal' Dutch TOD is (1) visually appealing, mid-rise, medium-density, mixed-use, landscaped and interconnected neighborhood centers on a multimodal station, (2) historic buildings are combined with new, high quality buildings which employ some traditional materials such as brick, (3) TOD areas blend seamlessly with the rest of the city and do not necessarily have a strong identity of their own. The success of TOD in the Netherlands is contributed by the scale at which TOD was implemented and residents attitude towards public transit and pedestrian movement.
The objectives of TOD can be achieved if socio-economic factors and local preferences and attitudes are considered. It is place specific and can be interpreted differently from one geographic location to the next. Although thorough research is needed to ensure the feasibility of TOD, Jenks et. al (2010) puts forwards a few pre-conditions for intensifying urban development. (1) large enough population density to support public transport, (2) distances between residences, local amenities and public transport is walkable, (3) the proposed intensified area is located along an existing public transport route.

Figure 3.1 – Koragah Town Square, Sydney
Source: http://www.olssonassociates.com.au/project/kogarah-town-square/

Newman (2009) puts forward the idea that TOD's should also be Pedestrian Oriented Development (POD's) and Green Oriented Developments (GOD's). TOD's can reinforce their quality of being an attractive car free mixed-use environment if it is also designed to include and encourage pedestrians. TOD's will also need to be GOD's and ensure that they are energy efficient. An example of a TOD-POD-GOD is the redevelopment of the Koragah Town Square in Sydney. This inner-city development set amongst poorly performing businesses, a transit stop and a car park is a vibrant mixed use development of residences, office and retail space and community space. Not only is the town square oriented towards pedestrians, the buildings have full solar orientation with solar shelves, solar panels cover most roofs, rain water is collected in an underground tank used for toilet flushing and irrigation, recycled and low impact materials were used in construction, and all residents and visitors have a short walk to the train station.

- **Compact development**

The general idea of a compact city includes strategies to create a more compact and dense urban form. This includes intensification of activities, efficient land use planning, diverse and mixed land uses and efficient transportation systems. Elkin et. al (1991) define a compact city as 'a form and scale appropriate to walking, cycling and efficient public transport, with a compactness that encourages social interaction.' The compact city is meant to be more efficient from the environmental, economic and social perspective and therefore promotes sustainable development in urban areas. However, there are counter arguments to this notion. The debate between concentrating urban development and decentralizing urban development is a contentious one.

Dieleman and Wagener (2004) point out that compact development is considered an antithesis to urban sprawl. Four characteristic features of urban sprawl are: low density development, segregated land use, lack of significant centers and poor street accessibility. This increases the need for vehicular based transportation systems which leads to an increase in GHG emissions. They concluded that implementing compact city and multifunctional land use policies have the potential to stem urban sprawl and further growth in car use. This is possible since compact city development promotes a more efficient transportation system.

This is corroborated by Newton (2000) who found that energy consumption from transportation reduces as density increases. One of the key contributions to greenhouse gas emissions in cities is from transportation. The compact city has a denser urban form that promotes the higher use of public transportation and pedestrian movement thereby reducing the number of vehicular kilometers travelled. The compact city has significant environmental benefits as it is the most fuel efficient urban form and improves urban air quality.

Moving to land use planning, Williams (2000) found that achieving more intensive development is a tool to promoting a more sustainable use of land. However, the resulting urban form may not always be sustainable. Therefore, intensifying or compacting development is 'necessary but not sufficient' to achieve sustainable development.

Breheny (1995) and Neuman (2005) also have similar conclusions. They argue that moving away from decentralization by promoting compact city development will not provide significant savings in energy use. Using urban form measures to improve sustainability in cities is counterproductive and can only be possible through draconian policies that combat decentralized urban development. They agree that containing development has broader economic, social and cultural impacts. But as a standalone policy, compact city development cannot result in significant energy savings in cities.

A review of previous studies has made it clear that there are no easy solutions. Although most authors agree that compact development increases efficiency in urban areas, it may not have a significant contribution to reducing energy use and promoting sustainable development.

Compact development does reduce transport demand and therefore energy use and emissions related to it. Addressing this along with intensifying the use of land increases land use efficiency in urban areas. It can be concluded that from an environmental standpoint compact urban form can contribute to efficient energy use in cities if it is accompanied by supporting policies that promote intensification of land use and measures to improve transport efficiency. Integrating land use and transport planning as a forerunner to a more efficient urban form is gaining widespread acceptance (Stead et. al (2003) and Jenks et. al (2010)).

- **Transport Demand Management**

Demand management is an urban transportation policy tool used to manage an existing transportation system in a better way to reduce traffic congestions, noise and air pollution and address environmental concerns. The major focus of demand management is to influence individual travel behavior. There are two environmental policy concerns when it comes to transportation – energy consumption and air pollution (Meyer, 1999). The challenge for policy makers is to find the balance between incentives that will encourage travelers to change their normal travel routine and provide environmental benefits. Some common measures adopted by governments to tackle this are:

- Reducing work related travel by encouraging a flexible work week so that employees can work from home for a part of the week,
- Encouraging car-pooling or ridesharing schemes,
- Adding HOV (high occupancy vehicle) lanes on roads for vehicles that have more than one person,
- Reduce parking availability and increase parking prices,
- Enforcing speed limits to encourage fuel efficient driving behavior,
- Provide incentives to encourage the use of low emissions vehicles and bio-fuels,
- Promote the use of electric vehicles by providing charging stations at regular intervals,
- Subsidize public transport.

3.2 Building Design

Globally, buildings account for over one-third of energy consumption (IEA, 2013). Building design is central to addressing energy use and its consequent reduction. The development patterns of buildings in a neighborhood also contributes to the energy efficiency. For example, compact arrangement of buildings can reduce the amount of heat needed by buildings (Bourdic et. al, 2012) and district energy centers increase the efficiency of energy production in urban areas (Rezaie et. al, 2012). Neighborhood design strategies and combined infrastructure can reduce energy and heating demands. Technological innovation can be used to increase the efficiency and optimize infrastructural processes, saving energy and reducing GHG emissions (Droege, 2006; Naphade et. al, 2011, Capello et. al, 1999).

Below are some actions to reduce energy demand and improve efficiency of buildings and infrastructure in neighborhoods.

- **Urban passive solar design strategies**

Cities and their suburban and rural surroundings have varying climatic conditions. In areas with a hot climate, the central city generally builds up considerable heat under the sun. This is known as the heat island effect and urban areas should be designed to tackle this. The challenge while designing urban areas in cold climates are to retain warmth and reduce carbon di oxide levels in winter (Droege, 2006).

The following are some passive solar design principles at the neighborhood scale;

- Implementing 'cool roofs' can improve energy efficiency and urban microclimates in cities with a hot temperature. Using 'cool' materials that reflect solar rays and expel absorbed heat helps to reduce overheating of roofs in the summer (Droege, 2006).

- Water can cool by evaporation, by absorbing heat (when there is a large water mass) or by transporting heat out of the area (by moving water bodies such as rivers). Water can have an average cooling effect of 1-3° C to an extent of about 30-35 m. Water applications are more effective when they have a large surface, or when the water is flowing or dispersed such as a fountain (Kleerekoper et. al, 2012).

- Shishegar (2013) found that street orientation influences air movement within urban areas. Streets which are straight and parallel to each other will promote air movement into and within urban areas. Lack of appropriate vegetation and covers in straight streets cause severe heat (in hot-dry climates) or cold (in cold-dry climate). Narrow and winding streets reduce cold or hot winds and decrease the influence of stormy winds.

- Kleerekoper et. al (2012) studied the effect of vegetation on cooling the environment and reducing heat stress. Through the process of evaporation and transpiration, vegetation can have an average cooling effect of 1- 4.7° C within urban areas. Vegetation can be used in urban areas in 4 different ways: urban forests or parks, trees on streets, private green areas in gardens and green roofs or facades. An urban forest generally refers to a park within an urban area. The surface and air temperatures of these areas are lower, and they can form PCI (park cooling islands). Trees on streets have a significant impact on reducing heat stress. Although they are dispersed, streets cover a large surface in urban areas and are an effective means to install vegetation. Private green areas in gardens, green roofs or facades form a good insulation for buildings keeping heat out in the summer and inside during winter.

- **Solar design strategies for buildings**

Incorporating passive solar design strategies reduces the demand of energy in buildings. Passive design of buildings starts with understanding the local climatic conditions. It means designing buildings for 'improved internal comfort conditions over externals conditions without the use of any electromechanical systems' (Yeang, 2008). Passive design should precede any other strategies when designing for energy efficiency. Examples of strategies include

- suitable building orientation,
- density and configuration of the block with respect to the climate,
- selection of appropriate building materials,
- solid-to-glaze ratios in façade design,
- thermal insulation values,
- building-integrated photovoltaics (BIPV),
- incorporating natural ventilation and
- the use of vegetation.

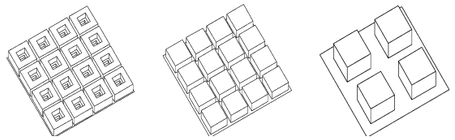


Figure 3.2- Surface to volume ratio indicative of the building envelope that is exposed to the outside environment
Source: Ratti et. al (2003)

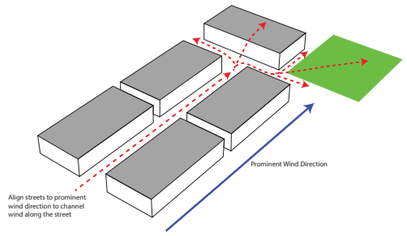


Figure 3.3- Street canyon - orientation and width to promote wind movement
Source: Author

- **Implement district energy systems**

District energy systems involve multi-building heating and cooling, in which heat or cold is distributed by circulating hot water or low-pressure steam through underground piping. District networks incorporate an underground system of piping from one or more central sources to industrial, commercial or residential uses. Rezaie et. al (2012) find that district energy provides environmental and economic benefits to communities and energy consumers.

Environmental benefits
District energy systems can help to reduce GHG emissions in two ways,

- facilitating the use of non-carbon forms for heating and cooling, and,
- replacing less efficient equipment in individual buildings with a more efficient central heating system.

Economic benefits
District energy systems are shown to be financially beneficial for densely populated urban areas, high density building clusters and industrial complexes. The economics of district energy systems depend on three main factors,

- The production cost of thermal energy
- The cost of thermal energy distribution network, which depends on network size and thermal loads
- Customer connection costs, which can be reduced if the district energy system is designed and developed at the same time as a community is built. The cost is much higher when district energy systems are retrofitted in a fully developed site.

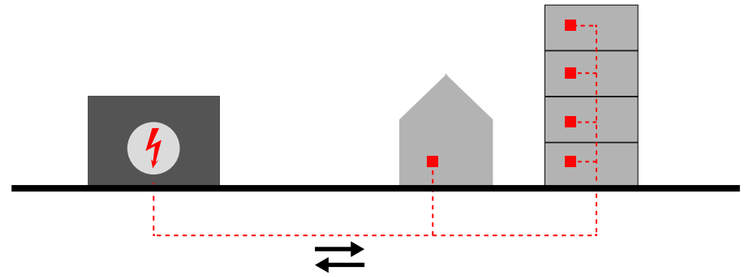
- **Improved environmental performance of buildings**

Building performance rating systems such as LEED, BREEAM, Energy Star and BASIX amongst others can be used to evaluate energy efficiency and greenhouse gas emissions of new and existing developments. These regulations are also applicable to improve energy performance in older structures by retrofitting them with better insulation and renewable energy technology.

- **Smart grids**

The installation of 'smart grids' in cities improves the efficiency of the electricity grid. The smart grid facilitates a two-way communication between the utility company and the electricity meter and uses a demand based approach to manage energy supply (Naphade et. al, 2011). Another advantage of smart grids is that it is capable of integrating different sources of energy within the same network.

Figure 3.4- Smart grid system
Source: Author



- **Water**

The following are recommendations to reduce outdoor and indoor water use adapted from LEED – ND (Leadership in Environmental Efficient Design – Neighborhood Development), v4 guidelines.

Outdoor water use

- Install landscape that does not require permanent irrigation system beyond a 2-year period.
- Choose plant species and a more efficient irrigation system to reduce outdoor landscape water requirements.

Indoor water use

- Use fixtures (for water closets, faucets, showerheads) that are certified as more efficient (for example, WaterSense labeled) by an independent, third-party organization.

Figure 3.5- RO desalination plant powered by solar power
Source: https://ensia.com/features/reuse-the-next-wave-for-water-conservation/

- **Waste**

The following are recommendations to reduce waste generated adapted from LEED – ND (Leadership in Environmental Efficient Design – Neighborhood Development), v4 guidelines.

- Use postconsumer recycled materials and re-use materials on site for construction as much as possible.
- Facilitate recycling of solid waste by including recycling or reuse stations at neighborhood levels that are dedicated to the separation, collection and storage of materials for recycling.
- Retain wastewater on the project site and treat and reuse that water to replace potable water.

Figure 3.6- PET recycling plant, Germany
Source: https://www.bezner.com/projects/pet-recycling-plant/

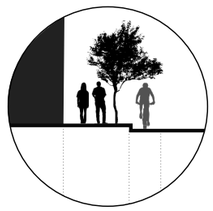
3.3 Summary Table

The table summarizes the theoretical framework from 3.1 and 3.2 and puts forward the following for every principle: meaning, potential, action, scale of implementation and sphere of influence.

Transportation and Land Use Planning

1. Promote active travel

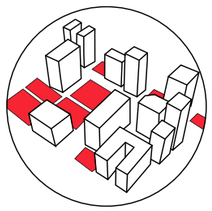
- Encourage residents to change their travel choices to reduce the number of trips made through mechanical means of transportation.
- Increasing walkability at the neighbourhood scale can result in significant savings in energy use and its related greenhouse gas emissions.
- Invest in infrastructure to support active travel with pavements and biking paths.



Scale for implementation:
Neighbourhood
Biggest impact on:
Urban form, User Behaviour

2. Encourage infill development

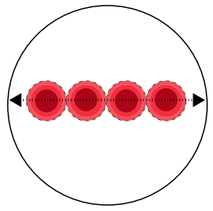
- Infill development i.e. developing vacant sites within existing urban areas should be prioritized before urbanizing open land.
- By promoting this, less resources are needed to provide infrastructure such as transport or utility networks within a new development. This is a necessary condition to provide a compact urban environment and reduce urban sprawl, which can have an impact on reducing travel demand and its associated energy use.
- Identify underused sites and prioritize development to increase the efficiency of land use consumption.



Scale for implementation:
City
Biggest impact on:
Urban form

3. Promote transit oriented development

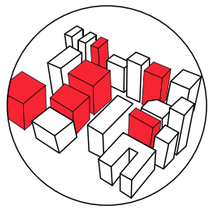
- A TOD area is a mixed-use community that is within the walking distance of a transit stop and commercial activities. It involves the integration of land use and transport planning to concentrate development around transit stops.
- Promoting TOD areas results in an efficient use of land and can potentially reduce car-based travel as jobs are brought closer to homes.
- Plan future developments within proximity to existing transit stops and increase the mixed-use functions around public transit nodes.



Scale for implementation:
City
Biggest impact on:
Urban form

4. Promote Compact Development

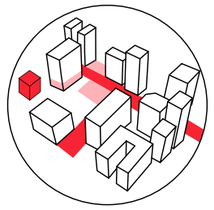
- Compact development refers to a compact and dense urban form in cities.
- Promoting compact development reduces transport demand and its associated energy use and emissions and increases land use efficiency in urban areas.
- Promote policies to intensify land use and measures to improve transport.



Scale for implementation:
City
Biggest impact on:
Urban form

5. Transport Demand Management

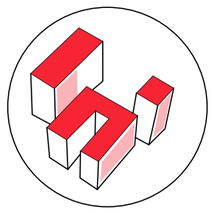
- Demand management is an urban transport policy tool used to manage an existing transportation system in a better way to reduce traffic congestions, pollution and energy use.
- When it comes to energy use, transport demand management helps to increase the use of public transit, reduce the number of trips made by cars, encourage the use of fuel efficient vehicles and increase fuel efficiency.
- Transport demand strategies are a policy tool that should be supported with incentives that are reviewed periodically.



Scale for implementation:
City
Biggest impact on:
Technology, User Behaviour

6. Increase renewable energy supply

- Increase energy supply in urban areas using renewable sources of energy like solar, wind, geothermal, biomass etc.
- The increase in these sites will help to diversify fuel sources and move away from carbon based fuels which have a high emissions rate.
- Sites that have a potential to support renewable energy production should be identified. Depending on the scale, the energy source (solar, wind, geothermal) with the highest potential should be studied and implemented.

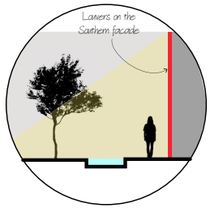


Scale for implementation:
City and Neighbourhood
Biggest impact on:
Technology

Building Design

7. Designing with the urban microclimate

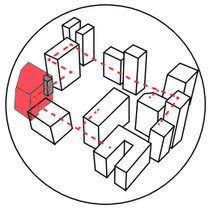
- The design of the urban form can have a significant impact on internal and external thermal comfort. Design principles that respond to the urban microclimate are necessary to avoid heat gain/loss within the building and its immediate surrounding.
- Elements that affect solar gain/loss within the building and in the immediate surrounds are; built form, street canyon, building design, materials, traffic and vegetation and water. This ultimately decides the amount of energy needed to maintain a comfortable indoor environment.
- Mandate the considerations mentioned above through building and urban development regulations.



Scale for implementation:
Neighbourhood
Biggest impact on:
Urban Form

8. Implement district cooling system

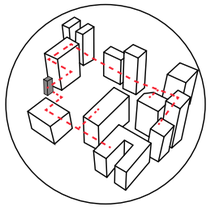
- District cooling systems provide a centralized source of chilled water for air conditioning units through an underground system in a neighbourhood.
- District cooling system can improve energy efficiency by 40% (Berbari, 2016) and reduce carbon dioxide emissions by 1 tonne for every tonne of district cooling refrigeration demand served (DIES, 2014).



Scale for implementation:
Neighbourhood
Biggest impact on:
Technology

9. Implement a smart grid system

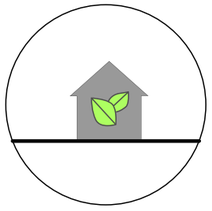
- Smarts grids facilitate a two-way communication between the utility company and the consumer.
- It can improve the efficiency of the network by balancing demand and supply, reducing energy consumption by increasing awareness amongst consumers and can integrate different energy sources within the same network.



Scale for implementation:
Neighbourhood
Biggest impact on:
Technology

10. Use rating systems or benchmarks to improve environmental performance in buildings

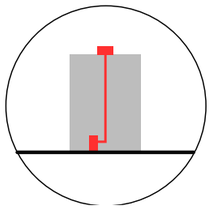
- Enforcing benchmarks or green building rating systems is a regulatory tool to improve energy efficiency in new or existing buildings.
- Buildings must consider design principles and technological standards as put forward by the regulatory body.
- Green building regulations should be climate appropriate and preferably be developed by third-party organizations and implemented by the government for complete transparency.



Scale for implementation:
City
Biggest impact on:
Urban Form, Technology

11. Retrofit existing building stock

- Retrofitting buildings to improve insulation and mechanical heating and/or cooling systems to reduce energy loss and increase efficiency.
- Most buildings in urban areas today were built before sustainable building design principles or rating systems were in place. An evaluation and upgrade of buildings is needed to keep up with required efficiency standards nowadays.
- Evaluate buildings that need to be retrofit and provide incentives to install the retrofits to help save energy.



Scale for implementation:
City
Biggest impact on:
Urban Form, Technology

12. Conserve indoor and outdoor water use

- Conserve indoor and outdoor water use and avoid wasting water.
- Water is a precious resource which should not be misused especially in countries that are water stressed. Some regions employ desalinate sea water which is an energy intensive process.
- Outdoor landscaping should employ only native species and use treated sewage effluence for maintenance. Indoor water fixtures should be upgraded to more efficient fixtures where feasible.

Scale for implementation:
City and Neighbourhood
Biggest impact on:
Urban Form, Technology and User Behavior

13. Reduce and recycle waste

- Reduce the amount of waste produced to decrease its contribution to GHG emissions.
- Waste is the third largest contributor to GHG emissions in cities after transportation and buildings. Reducing waste can have a significant impact on reducing emissions and the infrastructure needed to support it such as landfills, CCS or waste-to-energy plants.
- Waste-to-energy plants are a good strategy to reduce landfill waste and GHG emissions from it in short term. These need to be supporting by policies that encourage reducing waste for a more long term benefit. Providing recycling collection points and investing in a recycling plant should be an integral part of any energy strategy.

Scale for implementation:
City and Neighbourhood
Biggest impact on:
Urban Form, Technology and User Behavior

14. Government as a demonstrator

- Governments in cities need to take the first step in demonstrating change to stimulate the same behaviour among businesses and residents.
- A few examples are; retrofitting existing government owned buildings, transitioning the city owned car fleet to electric cars powered by renewables and providing strong incentives to government employees to travel with public transport and implementing a flexible working schedule.

Scale for implementation:
City and Neighbourhood
Biggest impact on:
Urban Form, Technology and User Behavior

Others

Chapter 4

Dubai - An Introduction

Dubai is one among seven emirates of the United Arab Emirates (UAE). The UAE is in the middle east and shares its borders with Oman and Saudi Arabia. The UAE lies between the Gulf of Oman on the east and the Persian Gulf on the west. Dubai is a coastal city and has the largest natural harbor in the country.

The UAE covers an area of approximately 83,600 square kilometers and has a population of 9.27 million people (2016). Dubai covers about 5 % (4,114 square kilometers) of the total land area of the country and is the most populous emirate inhabited by about 31% (2.89 million people) of the total population of the country.

The UAE has a coastline of 650 km along the Southern shore of the Persian Gulf and about 90 km along the Gulf of Oman which is also known as the Al Batinah coast. The Western part of the Al Hajar mountain range lie in the UAE rising to about 2500 meters in some places. The lowest point is the Persian Gulf at 0 m.

In the south and west of Abu Dhabi, a vast stretch of sand dunes merge into the Rub' al Khali (Empty Quarter) of Saudi Arabia, which is the largest continuous sand desert of the world. The desert area of Abu Dhabi includes two important oases, Al Liwa Oasis and Al Buraymi Oasis, that have adequate underground water to support cultivation and permanent settlements.

Date palms, acacia and eucalyptus trees grow in the desert oases. Other indigenous flora includes sparse grasses and thorn bushes. Indigenous fauna includes the Arabian oryx and leopards. Coastal fish mainly consist of mackerel, perch, tuna, sharks and whales.

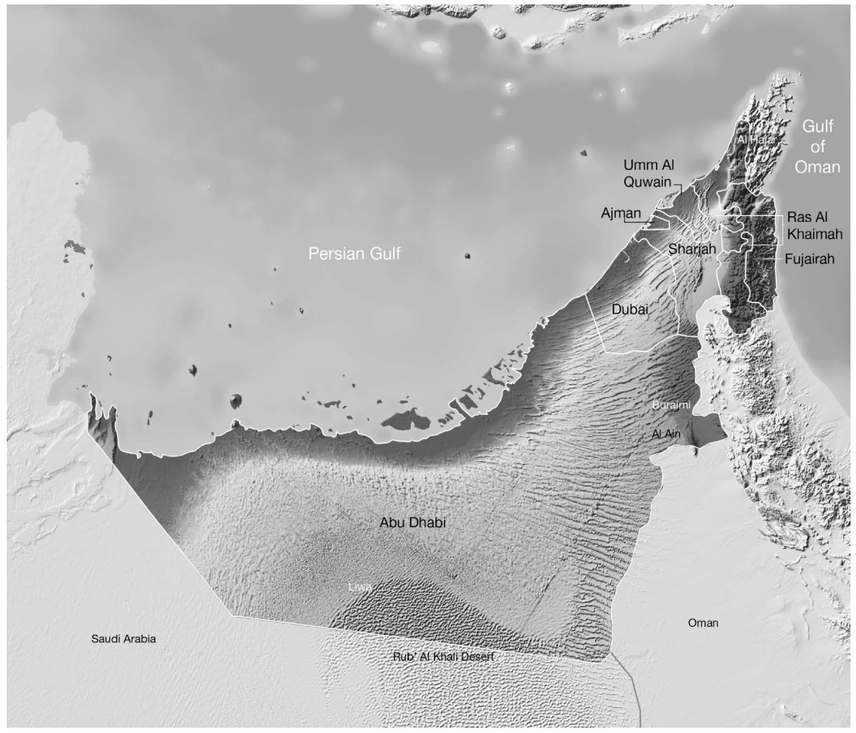


Figure 4.1 – Topographical Map of UAE
Source: Adapted from mapstor.com

Figure 4.2 – Dubai Fort in the early 1970's (left)
Figure 4.3 - Aerial view of Abu Dhabi, 1966
Source: https://gulfnews.com/culture/heritage/forts-of-the-uae-sentries-with-stories-1.2135655
http://www.arabianbusiness.com/photos/step-back-in-time-uae-s-heritage-on-show-in-old-images-432330.

4.1 Climate

Dubai lies in the northern desert belt and has a tropical desert climate. Summers are hot and humid with temperatures reaching an average of 45° C for many days. The temperature along the coast also reaches an average of 37° C with an average humidity of 90%. During winter the average daytime temperature is 25° C and average nighttime temperature is 15 °C. The desert is cooler and can drop to 5° C during the night. The average humidity during winter is between 50-60%.

Rain in Dubai is infrequent and does not last for a very long period. It usually rains in winter between December and March in the form of short downpours. On an average, it rains for five days a year.

During the summer season, a low-pressure area develops over Dubai forcing north-westerly winds to blow from Saudi Arabia. These winds are known as Shamal (north) in Arabic, and can cause sandstorms lasting for several days.

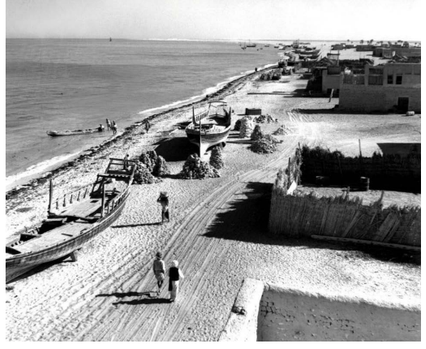
4.2 Historic Origins

Dubai, previously known as Debai, was first recorded in 1822 as being a mud hut town on the Gulf Coast with about 1,200 inhabitants. Although Dubai was not recorded till 1822, the Gulf region has undergone political struggle since the fifteenth century with the Portuguese, followed by the British, as they tried to gain control over parts of what was then known as 'Historic Oman'. The motivation was primarily commercial as the UAE (as it is known today) was an important trading center dating back to 2000BC (Elsheshtawy, 2010). Fishing and pearl-hunting also contributed to the livelihood of the population (Ouf, 2000).

Two rival tribes ruled the area of UAE since the 1700's. The Kasimi (or Qasimi) tribe established their center in Ras Al Khaimah and mostly depended on fishing, pearl hunting and sea trade with India for their livelihood. The Beni-Yas tribe established their center more inland, in Abu Dhabi, and depended on animal breeding, agriculture and caravan trading for their livelihood (Ouf, 2000).

The Portuguese gained control of the Gulf region in 1509, followed by the British in 1622 (Ouf, 2000). The influence of the British occupation was strong as they wanted to maintain ports in the Gulf. The coast of Oman served as a strategic location for two reasons for the British; it lies on the maritime route between Britain and India, and, they wanted to reinforce their presence to prevent the Russian influence on Persia. As opposed to the outright physical occupation, the British preferred to construct a series of treaties with a few select tribal leaders (or Sheikhs). These came to be crucial factors in the formation of the UAE. One significant treaty was signed in 1820 by the Sheikh of Abu Dhabi which officially designated the British as the rulers of Historic Oman. This treaty was extended to the Sheikhs' descendants as well. In 1922 another important treaty was signed which specified that in the case of oil discovery, concessions would not be extended to any non-British entity. This was prompted by oil discovery in Iran in 1908 and in Oman during world war 1. During the British dominance some measures of resistance did exist which eventually culminated in independence (Elsheshtawy, 2010). The United Arab Emirates comprising of seven emirates, each ruled by a different tribal head or Sheikh was formed on December 2nd, 1971.

Cities in the UAE never gained a high urban status before the discovery of oil since their environmental conditions and natural resources were poor as compared to neighboring centers in Oman, Iraq, Iran and India. The oil wealth and wisdom of its rulers made UAE a prosperous, tolerant country in the middle east with a multi-cultural and multi-ethnic society in a span of 35 years (Elsheshtawy, 2010; Darke, 1998).



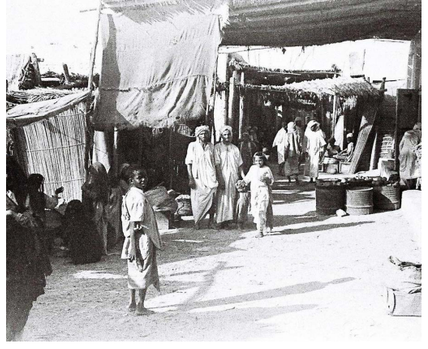


Figure 4.5 – Abu Dhabi Corniche, 1954 (left)
Figure 4.6 - An old souq (centre)
Figure 4.7 - Marketplace in Abu Dhabi in 1970's (left)

Source: https://gulfnews.com/culture/heritage/forts-of-the-uae-sentries-with-stories-1.2135655
https://www.thenational.ae/business/in-pictures-the-evolution-of-retail-in-the-uae-1.328006#3

4.3 Political System

The UAE is a federation of seven constituent emirates: Abu Dhabi, Ajman, Dubai, Fujairah, Ras Al Khaimah, Sharjah and Umm Al Quwain. Under the UAE government system, the president of the federation is elected by a Supreme Council of Rulers which is the highest decision-making body in the country. The vice president of the UAE is also elected by the Supreme Council of Rulers and both the president and vice-president serve renewable five-year terms. The UAE president is also the commander of the UAE Armed Forces, chairman of the Supreme Council of Rulers and Supreme Petroleum Council. The Supreme Petroleum Council is the highest governing body in the UAE hydrocarbon sector.

Sheikh Zayed bin Sultan Al Nahyan was president of the UAE from the country's founding in 1971 until his death in 2004. Following his death, his oldest son, Khalifa bin Zayed Al Nahyan became UAE president and continues to serve until present. Sheikh Mohammed bin Rashid Al Maktoum is currently UAE vice president and prime minister. By custom, the UAE presidency is held by the ruler of Abu Dhabi and hence the position is hereditary to the Al Nahyan clan. Likewise, the vice presidency (and prime minister) is held by the ruler of the Dubai and is hereditary to the Al Maktoum clan.

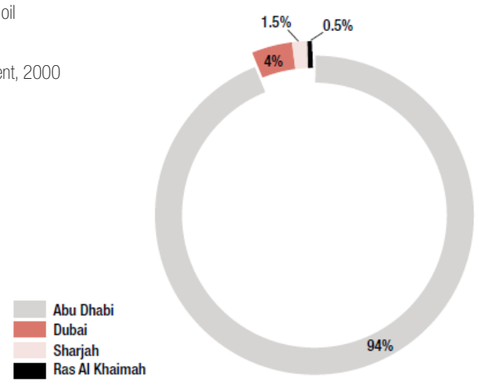


Figure 4.4 – Domestic oil reserves in the UAE
Source: UAE Government, 2000

Energy Governance

Abu Dhabi owns 94% of the oil reserves in the country followed by Dubai with 4%, Sharjah with 1.5% and Ras Al Khaimah with 0.5%. Dubai has 2% of the gas reserves in the country (UAE Government, 2000).

As per the constitution, each emirate has a considerable power over its own energy governance (Sgouris et. al, 2015; Jamil et. al, 2014). The power and water sector, mineral rights and most notably oil falls under the authority of every emirate. While the federal government has exclusive and executive jurisdiction over electricity services, in practice each emirate formulates and implements its own electricity policies and operates independently. The only significant federal level authority for energy governance in the UAE is the administration of transportation fuel prices (Efird et. al, 2017).

In Dubai, power and water is generated, transmitted and distributed by Dubai Electricity and Water Authority (DEWA). It is a state-owned utilities company that is the exclusive purchaser and distributor of electricity in Dubai. Although there might be producers of electricity and water in the private sector, distribution of electricity and water is carried out only by DEWA (Efird et. al, 2017).

Energy policies are heterogenous across the different emirates. Abu Dhabi and Dubai have the most advanced policy and regulatory structure in the power and water sector. Dubai established the Dubai Supreme Council of Energy (DSCE) to centralize and formalize energy decision-making. Dubai's largest energy producers and consumers are represented within the council with an intention to jointly set policies across the emirate (Efird et. al, 2017).

4.4 Economic Drivers

Historically pearl diving and trading provided a livelihood to places along the Arabian Gulf, including UAE, for over 7000 years. In the beginning of the 20th century about 69% of the population in the UAE were engaged in the pearl industry. The industry began to decline around the 1940's. This was due to three major reasons; the Japanese production of cheaper culture pearls in 1921, the 1930's depression which reduced the number of wealthy customers, and the ban imposed by the Indian government on pearl imports from the Gulf in 1947-48 (SMCCU, 2014).

In the 1870's, political instability in Persia gave the ports on the coast of Oman, among them Dubai, an opportunity to become major trading centers of the region. In addition, due to the tax increase in 1902 in Iran, Arab merchants started moving to Dubai to establish a trading base. Even today trading activities are one of the biggest economic drivers of the country, especially in Dubai. Today, the Jabel Ali port (in Dubai) is the biggest and busiest port in the middle east.

The discovery of oil around 1966 paved the way for economic and urban growth in the UAE. Over time the GDP share of oil declined, and the economy was diversified. Apart from exporting crude oil, many other industries were expanded as well. These include construction, petrochemical products, cement, pharmaceuticals, aluminum, transportation and date palm cultivation. Natural gas was added to the energy mix in the early 2000's to reduce energy and economic dependence on oil (CIA, 2007).

The tourism industry is another means to diversify the economy and has been at a rise in the past two decades. It is one of the biggest industries today contributing to 5.2 % of the total GDP and providing 10.4% of the total number of jobs in the UAE (Turner, 2017).

4.5 A Migrant City

In the last two centuries the UAE has become to home to many migrant populations. In the 19th and early 20th century Dubai attracted many Persian merchants who eventually settled down in Dubai. Bahraini pearl merchants also arrived to take advantage of the booming pearl industry during that time. Migrants from Iraq came to work as accountants and clerks for Dubai's merchants. In the 1930's another wave of immigrants known as the Baluchis arrived from what is known as Pakistan today, bordering Iran and Afghanistan. They worked as porters and in low-level employment. By early 20th century Dubai's population was made up of several classes and ethnic groups (Elsheshtawy, 2010).

After 1980's the expatriate population of Dubai grew once again. Today, local citizens or Emiratis constitute about 9.4% of the total population of the emirate of Dubai (Dubai Statistics Center, 2016). With expatriates contributing to 90% of the population, Dubai is the home to one of the highest percentage of immigrants. In 2005, it had the highest percentage of foreign born population at 83%, with Miami ranking second with a much lower 51% (Elsheshtawy, 2010). Dubai is the home to about 200 nationalities. Asians (Indians, Pakistanis, Bangladeshis, Filipinos) are the largest expat population followed by Iranians.

Dubai has always been a migrant city. Although the population of Dubai in the early 20th century was a fraction of what it is today, its habitants were a mix of ethnicities from Bahrain, Pakistan, Iran and Afghanistan. Thus, the Emirati population today is a mix of ethnicities that migrated to Dubai. The influx of people in the past few decades was unprecedented. The population of Dubai grew by 13 times in the last 46 years (Elessawey, 2017) of which 90% are expatriates. To keep the Emirati population from diminishing Dubai tries to promote a strong sense of nationalism among the minority of citizens. For example, the government offers financial incentives to Emirati men to marry Emirati women to maintain a clean blood line (Downes, 2017). Dubai does not allow any immigrants to become citizens, regardless of if they were born there or how long they have lived there. Emiratis are also offered lands to build houses which are generally in the suburban areas of the city keeping them away from the center which is now occupied by immigrants to the city. Over time these

policies have led to the social and spatial segregation of expatriates from citizens. All these reasons have made Dubai a home to a large transient population.

4.6 Urbanization in the UAE

Description of urban structures of cities in the UAE is only available through old maps and sketches drafted by early explorers and adventurers since no written account of urbanization is available. Aerial photography done in the 1930's for the sake of oil exploration presents the first documented form of cities in the UAE (Ouf, 2000).

Settlements in the UAE evolved around a creek (a small body of water branching inland) to provide for easy access to fishing and pearl-hunting activities. This sometimes formed an island like structure inland. The biggest reason for settlements to be at this location is safety from any possible land invasions and raids from other tribesmen in the region. The defensive system of the cities also included a fort, the watch towers, and the walls either as an integrated system or as separate components dispersed all over the landscape. During the 1800's the British banned the erection of any new forts as a means of controlling hostilities in the area. Thereafter, the ruler or Sheikh's residence was integrated within the fort and was symbolic of the Emirates' status and might (Ouf, 2000).

Another important feature of historic settlements in the Gulf is the mosque and its surrounding souqs (markets) which was the heart of the neighborhood. Narrow and staggered pedestrian paths integrated daily activities and suited the local environmental conditions. Modern urbanization changed the way cities in the UAE looked and has also altered the lifestyle of people. Dubai grew almost 24 times in the last 44 years (Elessawey, 2017). This tremedous growth rate could is illustrated in figure 4.8. To achieve a very big change in a short period of time, UAE turned to international planning standards which was not able to pay much attention to the traditional city structure and its basic components. As a result, traditional urban components disappeared with time. A mosque is still provided for every neighborhood unit but the intimacy of pedestrian pathways and properly scaled urban spaces for activities is lost. Traditional layouts and design of buildings may not be desirable today as they cannot provide for the luxuries of modern life. This was a result of globalization and led to a loss in local identity, and, architectural and urban character (Ouf, 2000).

Figure 4.8 - Growth of Dubai

Source: Elessawew, 2017, Satellite images from Google Earth

Chapter 5

Energy Challenges in Dubai

Energy issues in Dubai are embedded within global and national energy issues. Globally, the depletion of fossil fuels and the impacts of global warming are pushing us to transition to a cleaner energy system. Economically, the energy transition is challenging since the global economy depends on the use of fossil fuels. These trends impact the UAE as well, and today energy security is the biggest driver for change. This chapter begins by discussing the biggest concerns with national energy issues. In the last few decades in Dubai, economic growth has relied on urban development which is dependent on a steady (and growing) fuel supply. Dubai's changing relationship with energy is discussed through the lens of urban and economic development patterns. This chapter concludes with a description of the major causes of energy efficiency within the urban form of the city.

5.1 Energy Security

The International Energy Agency defines energy security as 'the uninterrupted availability of energy sources at an affordable price'. The availability of affordable energy sources is essential for the functioning of the economy and national security. In the UAE, there are three major reasons that push for a transition to a more clean and efficient energy system. These are, high energy demand, dependence on imports to meet energy needs and economic dependence on oil and gas.

7th highest consumer of energy worldwide

The UAE has the 7th highest per capita consumption of energy worldwide (Topf, 2014). This is mainly contributed by four aspects (Sgouris et. al, 2015).

- The UAE economy capitalized on the availability of surplus energy and invested in energy intensive industries such as aluminium, steel, cement and construction.

- The UAE has a hot and arid climate that has large cooling demands. Peak demands for air conditioning in the summer account for almost 60% of total energy consumption in the country (Sgouris et. al, 2015; Todorova, 2011).

- High energy inputs are needed for the desalination of water. Electricity production is coupled with desalination of water and is produced in a combined-cycle. However, this process impacts the efficiency of power plants. For example, in winter when electricity demands are lower, the power-to-water ratio (PWR) is lower than optimal efficiency.

- Subsidized energy tariffs have increased the consumption patterns of energy. Although energy and water tariffs have increased in the last 3-4 years, it still does not manage to match the actual cost of production (Sgouris et. al, 2015).

Net Importer of natural gas

Electricity production is fed by natural gas although oil is used during peak energy demands. Since 2008, the UAE has become a net importer of natural gas and is dependent on imports to meet its energy demands (Jamil et. al, 2014). There are three major reasons for this (Sgouris et. al, 2015).

- About 26% of the gross natural gas production is injected back into the oil fields for EOR (Enhanced Oil Recovery) techniques.

- The natural gas in the UAE has very high Sulphur content making the extracting process technologically challenging and economically expensive.

- The electric grid in UAE is mainly powered through natural gas and the growing electricity demand cannot be met with locally sourced natural gas.

Economic dependence on oil and gas

UAE has the 7th largest proven oil reserves in the world with 8% of the world crude oil reserves (OPEC, 2016). A half of the exports of the country is contributed from petroleum products (OEC, 2015). The country relies on these resources to fuel its continuing economic growth as well. The heavy dependence of the UAE on carbon-based fuels is undeniable.

Background image - same as front cover

5.2 Urban Development in Dubai

Urban development in Dubai is divided into four time-periods or episodes. Development patterns and its relation to energy use is discussed within each. The aspirations of the city within each time-period is defined by the economic and urban development plans of that time. The time-periods are selected based on major events (such as the discovery of oil), political ambitions, data sets (about population or urbanization) and previous studies about urban development in Dubai. The four episodes are: urban origin (until 1971), planned suburban growth (1971-1984), modernization (1984-2003) and 'a city of cities' (2003-2015). Fig 5.1 places urban development plans (or masterplans), economic strategies and energy policies on a timeline to highlight its link with the four time-periods.

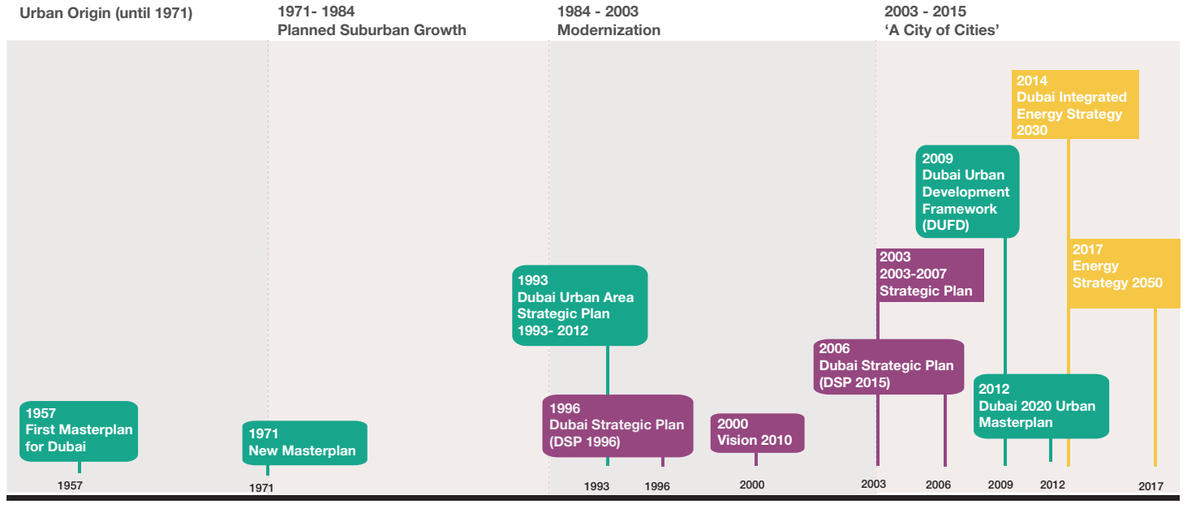


Figure 5.1– Development in Dubai
Source: Author

Urban Origin (until 1971)

As the city of Dubai emerged along the shoreline of the Arabian Gulf, the need to have a body managing urban development was recognized and the Dubai Municipality was formed in 1957. Soon after, in 1960, His Highness Rashid bin Saeed Al Maktoum, the late ruler of Dubai, appointed Ar. John Harris to design the first master plan of Dubai. This was Dubai's first step from a rural tribal society to a planned urban area.

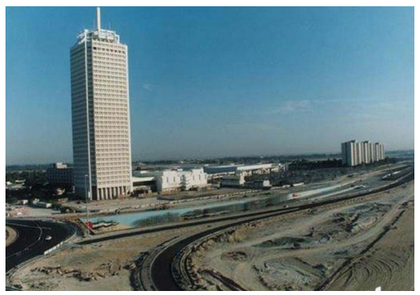
Dubai at that time did not have any proper infrastructure such as roads or utility networks. The master plan put forward a road system, a new town centre and proposed building structures using concrete blocks as opposed to palm fronds, which were used at that time. Fig 5.2 shows the first master plan of Dubai that promoted compact development, major infrastructural development and a distribution of land uses for different functions in the city. The urban area expanded along the northern side of the creek, towards Sharjah. This laid the basis for urban development in Dubai.

The vision of Dubai during this time can be described as 'modest, compact and inspired from the past' (Elshestawy, 2010). The discovery of oil in 1966 changed things. This made Dubai energy rich and helped them to start building new infrastructure in the city with oil revenues. Energy in this era empowered Dubai to improve living conditions in the city. Oil was being discovered in other Emirates too, and this mobilized the states to achieve independence from the United Kingdom and form the United Arab Emirates in 1971.

Planned Suburban Growth (1971-1984)

Achieving independence in 1971 and the discovery of oil changed the aspirations of the ruler of Dubai and another masterplan (figure 5.5) was designed once again by Ar. John Harris. Dubai had more resources post oil discovery, and this reflected in the new masterplan. Major infrastructural growth in the transportation network was seen with the building of more connections across the creek (Shindagha tunnel and Garhoud bridge) and a ring road with radial roads extending into what can be considered the 'suburban' area of the city. The

Figure 5.2 – Masterplan for Dubai in 1960 by John Harris. Source: http://www.dubaiasitusedtobe.com/pagesnew/JohnHarrisMasterPlanner.shtm



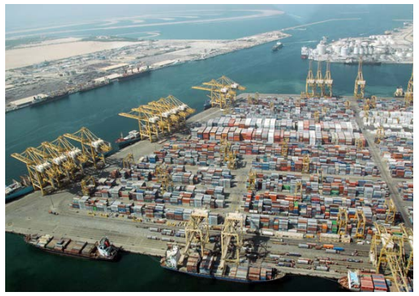


Figure 5.3 – World Trade Centre in the mid-1990's (left)
Source: https://www.pinterest.com/citispi/old-photos-of-dubai/

Figure 5.4 – Jabel Ali Port (right)
Source: www.pbase.com

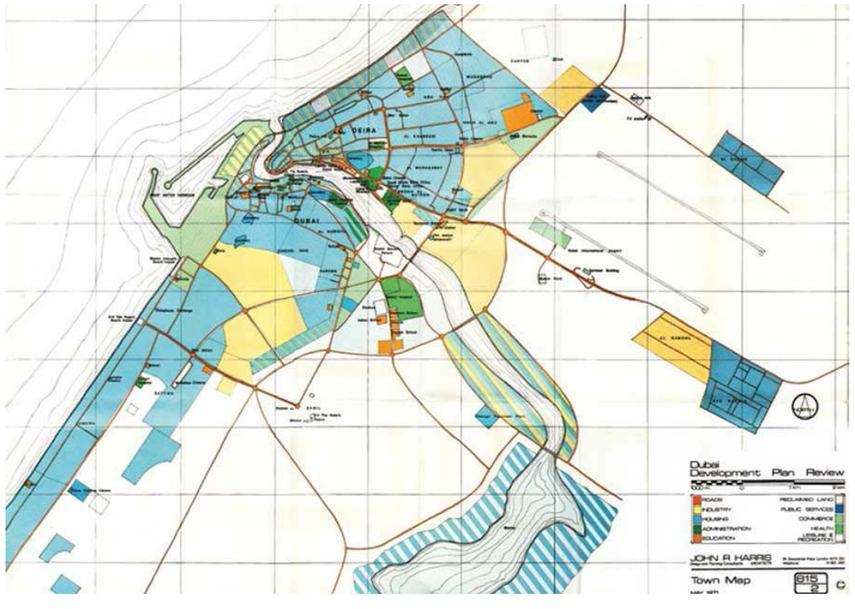


Figure 5.5 – Masterplan for Dubai in 1971 by John Harris. Source: http://www.dubaiasitusedtobe.com/pagesnew/JohnHarrisMasterPlanner.shtm

population of Dubai doubled during this period with the influx of migrants who came to Dubai looking for work. The city had to accommodate them, and different axes of growth were introduced. Deira, north of the creek, rapidly developed into the banking and administrative centre handling coastal and shipping activities. The city started expanding along the southern coastline around the Dubai-Abu Dhabi road (known as the Sheikh Zayed Road today). This was known as 'new Dubai' and started becoming a financial and commercial centre of the city.

The completion of Dubai World Trade Centre in 1970 (fig 5.3) (which was the tallest building in the middle east for the next 20 years) and the port of Jabel Ali in 1979 (fig 5.4) (which is the biggest and busiest port in the middle east even today) are notable economic initiatives built during this time. These marked the beginning of Dubai's global success.

National housing policy for UAE nationals

In the early 1990s a new national housing policy was released. According to this every Emirati male above the age of twenty is eligible to receive a plot of land with an area of 1400 sq. m. Any land owner with less than 935 sq. m. of land to his name is eligible to receive a plot of land with an area of 1400 sq. m. in addition to what he already owns. Land titles in those days were generally granted to men only. The distribution of plots is not based on the number of households but on the number of individuals. This led to an oversupply of land allocated for national housing.

Figure 5.6 – Location of native-born neighbourhoods in Dubai in 2013. Source: Alawadi et. al, 2017

Modernization (1984-2003)

Decision making shifted from the late ruler to his sons in the early 1990s which resulted in Dubai' vision to become a globally recognized metropolitan city. Economic success and population growth continued during this time-period as well.

Between 1985-1990, the urban area grew by approximately 35% and the population grew by approximately 60%. The city had to cope with this growth contributed once again by an influx of migrants. This, in addition with the new national housing policy dramatically increased the demand for land. These changes provoked the Dubai Municipality to prepare a 20-year strategic plan to guide economic and urban development in Dubai. The Dubai Urban Area Structure Plan 1993-2010 was drawn to accommodate urban expansion by allocating additional land to meet the current and future needs of residential, industrial and commercial uses.

New residential areas were allocated at the periphery of the urban area as shown in fig 5.7. The areas away from the city centre were generally allocated for national housing as Emirati's wanted to be away from the business of the city centre. This resulted in nationals abandoning their houses in the centre for better and bigger houses in the suburbs. The location of national housing today is similar to what was proposed in the 1993 structure plan (fig 5.6). The housing policy did not address housing needs of the growing expatriate population and left it in the hands of the market. Suddenly there was an increase in vacant houses with no owner in the centre. These houses began to deteriorate and had to be upgraded by the municipality and were then occupied by the new expats in the city.

Compactness as advocated in the previous masterplan was associated with the limited financial resources that Dubai had at that time. Oil was discovered in larger quantities and it contributed to roughly 30% of the GDP during this time. This increased the financial resources of Dubai and the urban area spread out into the desert. The new plan promoted 'planned suburban growth' (Pacione, 2005). More energy was needed to build infrastructure that supported this pattern of development. A public transport system was still not talked about, which made automobiles a primary means of transport. Electric bills and petrol for cars was very affordable and contributed to the lavish consumption of energy. A surplus of energy made its consumption seem heavily subsidized. This was the beginning of the energy intensive urban and travel pattern of Dubai which was fuelled, literally and financially, by the discovery of oil.

Development occurred in a 'leap-frog' pattern (Pacione, 2005). This trend led to another development challenge – provision of an efficient transport system and public utilities for a rapidly expanding city. Traffic congestion was growing during peak hours especially along the creek crossings. Implementing and promoting a public transport system for the far-reaching developments in the city was challenging making Dubai an automobile dependent city. As development was not contiguous, the provision of waste disposal, electric and water supply and sewerage was also difficult.

Another change during this time-period was the decline of oil and consequently its contribution to the GDP. This prompted the Dubai government to diversify economic activities into other sectors. In 1996, the Dubai (Economic) Strategic Plan (DSP 1996) created in collaboration with the Department of Economic Development (DED) and the United Nations and was based on Michael Porter's 'Competitive Advantage of Nations'. The outcome of this resulted in a 'cluster' strategy of economic growth. According to this Dubai would develop five major economic clusters – tourism, trade, transport, high level services and manufacturing (Helmond and Montford, 2007). The vision of the DSP 1996 was translated into operational tasks for the next decade divided into three major categories: economic, market and social. The DSP 1996 laid the basis for the next economic strategy which was released four years later in 2000, called the Vision 2010.

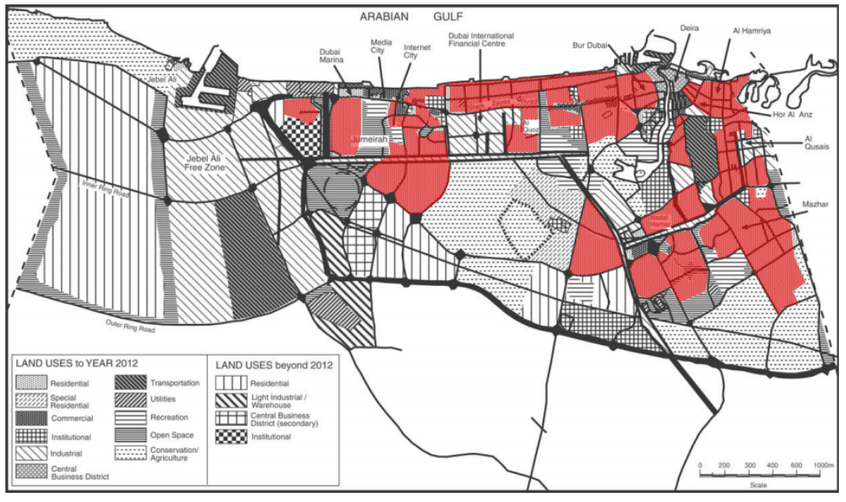


Figure 5.7 – Dubai Urban Area Structure Plan 1993-2012 showing the newly assigned residential areas. Source: https://www.researchgate.net/publication/228885428_The_Effects_of_the_New_Development_Projects_on_the_Urban_Macroform_of_Dubai/figures?lo=1

Although the economic 'cluster' strategy did not address spatial conditions, it had a big demand on land as it promoted the development of the real estate sector. The Dubai Municipality had to keep up with allocating plots for national housing, upgrading the vacant housing stock and pushing for new developments. They lacked the institutional capacity to get things done at the pace demanded by the economic vision. To help promote real estate, EMAAR, a semi-private business development company was established in 1997. 'Master planning' authority was transferred to EMAAR for the areas that fell within their boundaries. This marked the beginning of the change in planning processes in Dubai.

Changing economic conditions and the new citizen housing policy led to a suburbanization and the emergence of a city composed on 'disjointed archipelagos or islands' (Elsheshtawy, 2010). There was a heavy policy emphasis on economic diversification during this era. Urban development and transport planning were not integrated. This trend exacerbated energy consumption patterns. While economic diversification helped to compensate for declining oil revenues, energy was needed to sustain the high urban growth rate and consumption. It is during this decade that Dubai started becoming dependent on its neighbours to meet its energy needs.

'A City of Cities' (2003-2015)

Following the interest in pushing for real estate development, in 2002, the government decided to allow freehold ownership of land and property for non-GCC (Gulf Cooperation Council) residents in certain areas of the city. These were known as 'free-zone' areas. Properties in Dubai are not taxed (Reillo, 2004), thus increasing the attraction of international investment into real estate developments. In 2003, 'Dubailand' was launched, which consisted of 45 mega projects aimed at tourism and living covering an area of 278 sq. km. This was also the turning point for Dubai's economic and spatial growth. As described by Pacione (2005), Elessawy (2017), Helmond and Montford (2007) and Al Sheikh (2012), after this point Dubai became a 'city of cities'. Mega projects often coincided with 'free-zone' areas which have different economic (and sometimes urban) laws and regulations. Fig 5.8 shows the mega projects in Dubai in 2005. This approach proved to be very successful for Dubai's economic goals. Vision 2010, which was released in 2000, put forward economic targets for the next 10 years. Dubai realized these targets in 5 years, by 2005. The next economic strategy, Dubai Strategic Plan 2015 was released in 2006 (Helmond and Montford, 2007). The average GDP in non-oil sectors in Dubai rose from 6.2% in 2003 (Alabbar, 2004) to 17% in 2004 (Gulf News, 2005).

This decade also saw the biggest changes in the planning process. 'Dubailand' (known as Dubai Creative Clusters Authority today) was also granted 'master planning' authority, in 2003. Slowly, the Dubai Municipality started to have a passive role within the

Figure 5.8 – Mega Projects in Dubai.
Source: Pacione, 2005

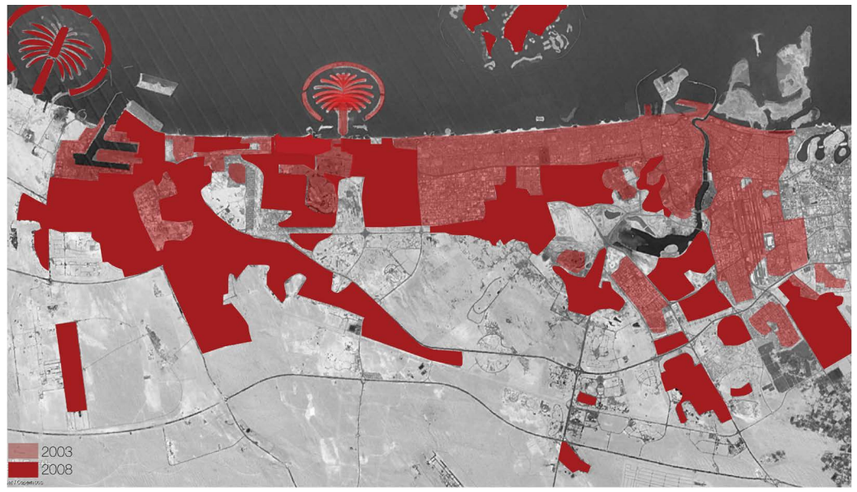


Figure 5.9 – Growth in Dubai between 2003 and 2008.
Source: Author

planning process. The process generally started with business organizations (such as Dubailand or EMAAR) taking the initiative for urban or industrial development. The Dubai Municipality assigns the boundary of the area to be developed and provides some basic guidelines related to the number of buildings, height restrictions, parking facilities etc. After this a design consultant develops a detailed design which is considered by the Dubai Municipality only on major aspects before 'building approval' is given. This is a fast process as detailed feedback with the Municipality is not necessary (Helmond and Montford, 2007) and was needed to keep up with the vision and target of economic growth.

Between 2003-2008, Dubai experienced its biggest rise in population growth with an average annual population rise of 7.5%. This also reflected in its urban extension. Dubai had been expanding along the coastline from the creek to Jabel Ali Port, taking a shape as a linear city. The tendency to spread inland towards the desert is guided by the previous structure leading to a wide-spread urban area. Fig 5.9 illustrates the direction of growth between 2003-2008.

The rise in population led to the growth of the urban area and inevitably a rise in energy demand. The real estate sector led to a rise in the construction sector, which is an energy intensive industry. In 2006, 24% of the world's construction cranes were in Dubai (Gulf News, 2006). Lack of a strong public transport system meant that the city was still heavily dependent on cars. Between 2005-2008 the number of cars increased by 30% (Corder, 2008). This increased greenhouse gas emissions, traffic jams, air pollution and fuel consumption.

The need for integration

The fast-paced developments and competing interests soon made it clear that a more comprehensive vision was needed (Elsheshtawy, 2010). In 2007, the Dubai Urban Development Framework (DUFD) was initiated. According to the report the plan 'seeks to create an innovative, flexible and fully integrated development, planning and management framework for Dubai to the year 2020 and beyond'. The plan was to be developed by the Urban Planning Committee (UPC) of Dubai Government which was represented by key stakeholders such as Dubai Municipality, the Roads and Transport Authority, Dubai Electricity and Water Authority (DEWA), Dubai Land Department, and the Executive Office as well as developers including Dubai Holdings, Emaar and Nakheel. The plan was to be developed by the consultancy URBIS and WSP group in collaboration with the above stakeholders (Elsheshtawy, 2010).

The DUFD was published in 2009 and put forward 12 benchmarks for the spatial development of Dubai to be achieved by 2020 (Mantia, 2020). The benchmarks are related to mobility and land use, open space and environment and, community and culture. The DUFD was never fully implemented but set the base for the Dubai 2020 Urban Master Plan which was published three years later, in 2012. The feasibility of the targets was re-visited by all the stakeholders after the financial crash in 2008 and AECOM was commissioned to prepare the plan (Mantia, 2012).

The plan aims at promoting a 'vibrant and competent city, flexible and responsive land uses, and a high quality built environment that considers that principles of sustainability' (Dubai Municipality, 2012). The need to promote a more sustainable and efficient urban development pattern is recognized and ideas to achieve this are put forward. These include;

- Consolidating land use and prioritizing mega projects,
- Preventing urban sprawl and limiting the development of man-made islands,
- Complementing a long term economic base by promoting activity centres to support different uses (such as tourism, trade, retail, business and finance),
- Developing a more integrated housing policy that addresses the needs of nationals and provides more affordable housing options for expats,
- Integrating land use and mobility by adopting the principles of Transit-Oriented-Development (TOD),
- Protecting the environment,
- Prioritize infill development and devise a legislative framework to better support Dubai's unique context.

The Dubai 2020 Urban Master Plan promotes a more sustainable and comprehensive urban development approach. This is one step closer towards a more efficient land use and consumption pattern. However, the plan does not address energy use or the modification of energy systems explicitly. Some ideas to achieve this are put forward in the Dubai Integrated Energy Strategy, 2014 (or State of Energy Report) and will be discussed in detail in chapter 7.

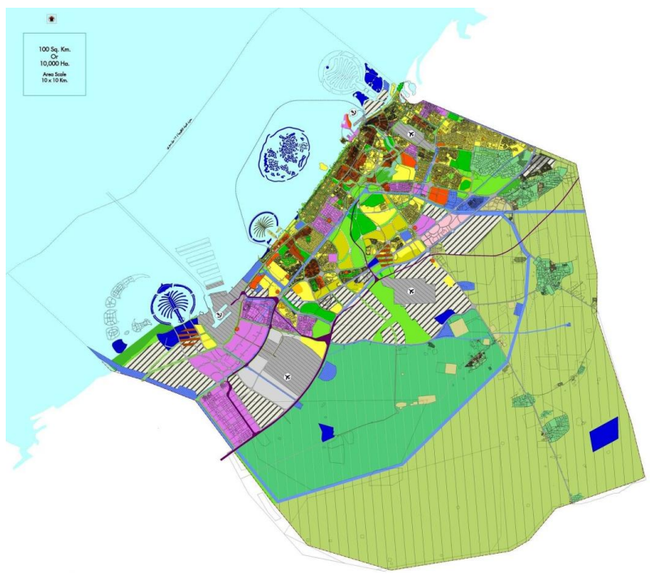


Figure 5.10 – Dubai Master Plan 2020
Source: https://login.dm.gov.ae/wps/wcm/connect/52ee5cab-66bb-463f-afbd-8ca3c46cc0c1/Dubai+2020-+broshure%2C+A4-+english+24.4.2012.pdf?MOD=AJPERES

Dubai in the 1950s
Photo source: The Telegraph (https://www.telegraph.co.uk/travel/destinations/middle-east/united-arab-emirates/dubai/galleries/Dubai-old-and-new-incredible-pictures-of-the-changing-skyline/)

World Trade Center in the 1980s
Photo source: https://www.pinterest.com/pin/163325923960273020/

View from the Burj Khalifa
Photo source: Luca Locatelli, Institute for National Geographic

Palm Jumeirah and Dubai Marina
Photo source: Luca Locatelli, Institute for National Geographic

Urban Origin (until 1971)

Discovery of oil in 1960s

1 Basis of urban development
2 Political Mobilization

Planned Suburban Growth (1971-1984)

Larger quantities of oil were discovered

1 Dubai' economic and global sucess
2 Beginning of an energy intensive urban development and travel pattern which was fuelled, literally and financially, by the discovery of oil

Modernization (1984-2003)

Decline of oil and its contribution to the GDP

1 Change in Dubai' vision
2 Increased demand of urban areas
3 'Leap frog' development pattern which exacerbated energy consumption patterns (Pacione, 2005)

'A City of Cities' (2003-2015)

Dependent on exports to meet energy needs

1 Delegation of development authority
2 Population and urban growth resulting in increased energy use
3 Economic growth depended on urban growth which resulted in large energy consumption

Dubai's Relationship with Energy

The urban area of Dubai has grown by almost 24 times in the last 44 years (Elessawey, 2017). This makes the pattern of urban development central to discussing energy use in the city. The discovery of oil in the 1960s empowered Dubai to improve their urban conditions and develop infrastructure. Increased oil revenues in the following decades resulted in financial initiatives that marked the beginning of Dubai's global success. Ambitious master plans after this spread urban development along the coastline and inland in the desert. This started the trend of an energy intensive urban development and travel pattern in the city which was fuelled literally and financially by the discovery of oil. Economic diversification triggered by the decline of oil in the 1990s resulted in the growth of many new sectors, one of which was real estate. Economic growth depended on urban growth which increased energy demand. Urban development had to keep up with the pace demanded by the economic vision. Fast population growth and the rapid expansion of the urban area were an inevitable consequence of these policies. To help manage this growth, urban decision making began to be delegated to semi-private and private entities, resulting in the change of planning processes. The lack of an integrative approach to urban and transport planning led to a non-contiguous pattern of development. This resulted in an inefficient use of land which made the provision of infrastructure (such as transport, cooling and water) a big challenge. All these factors – population rise, energy intensive industries (such as construction), expansion of infrastructure – have led to a high energy demand making Dubai dependent on imports to meet its energy needs.

5.3 Energy inefficiency within the spatial form of Dubai

Energy inefficiency within the spatial form of Dubai is contributed by three major reasons – fast growth, the planning process and the non-integrative policy framework.

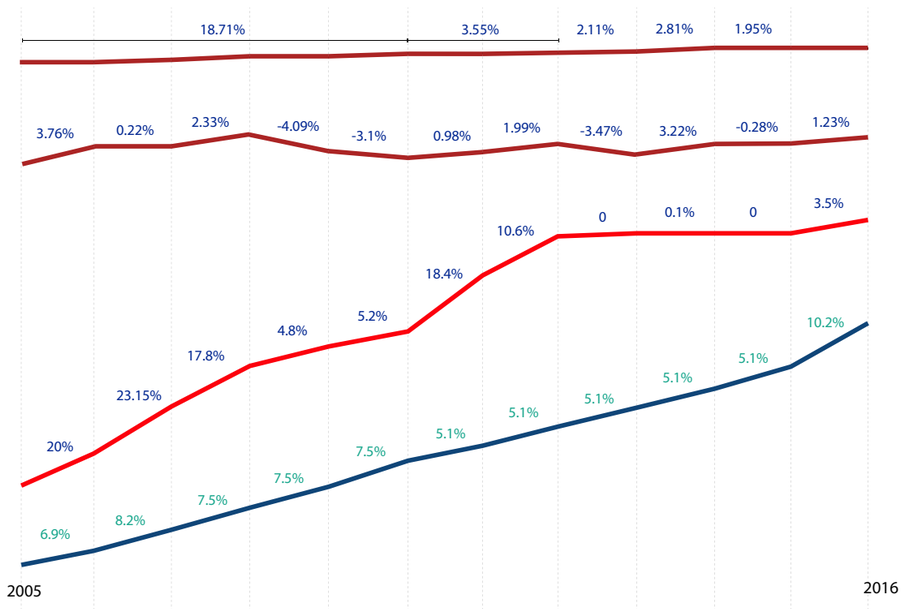
Consequences of fast growth

The urban area of Dubai has grown by 24 times in 44 years, from 40 sq. km in 1971 to 976.6 sq. km in 2015. Between 2005 and 2010 the population of Dubai grew by an average of 7.5% annually. This led to a sudden demand in infrastructure and energy. Between 2006 and 2016 energy demand grew by 2.6 times. When compared to other cities such as Singapore or Los Angeles Dubai has seen a dramatic increase in energy demand in a very short time. Singapore saw a big energy demand between 2005-2010 with an increase of 18.71% in 5 years. In Dubai a similar rise in energy demand is experienced in consecutive years between 2005 and 2008. Los Angeles has not seen a big fluctuation in energy demand. The maximum decrease or increase has been by about 4%. This is not the case in Dubai. The reasons for energy demand fluctuations in other cities could be different from Dubai, but one thing is evident. Dubai had to cope with a very high demand in energy for many years (between 2005 – 2012).

The steady rise in population growth in Dubai is a big contributor to energy demand. But the population growth does not always correspond to the energy demand. For example, between 2005-2008 and 2009-2011 there is very high increase in energy demand even though the annual population increase is not as high. One explanation for this could be the construction (and completion) of mega projects that were planned around the same time. Economic growth depended on urban growth which in resulted in tapping into energy resources in a big way.

The emirate is 100% dependent on desalination to meet its water needs for drinking, irrigation and other uses. About 30% of the total power of Dubai is needed to produce water through desalination. Moreover, the per capita consumption of water is about 740 cubic meters per annum which is roughly 50% higher than the world average water consumption of 500 cubic meters per annum (Karlsson et. al, 2015). This added to the challenge as energy is needed to meet water needs as well.

The graph shows the percentage increase of energy demand between consecutive years. Energy Demand is calculated based on installed capacity of the grid.



Energy Demand in Singapore
Source:Singapore Energy Statistics

Energy Demand in Los Angeles
Source: California Energy Commission

Energy Demand in Dubai

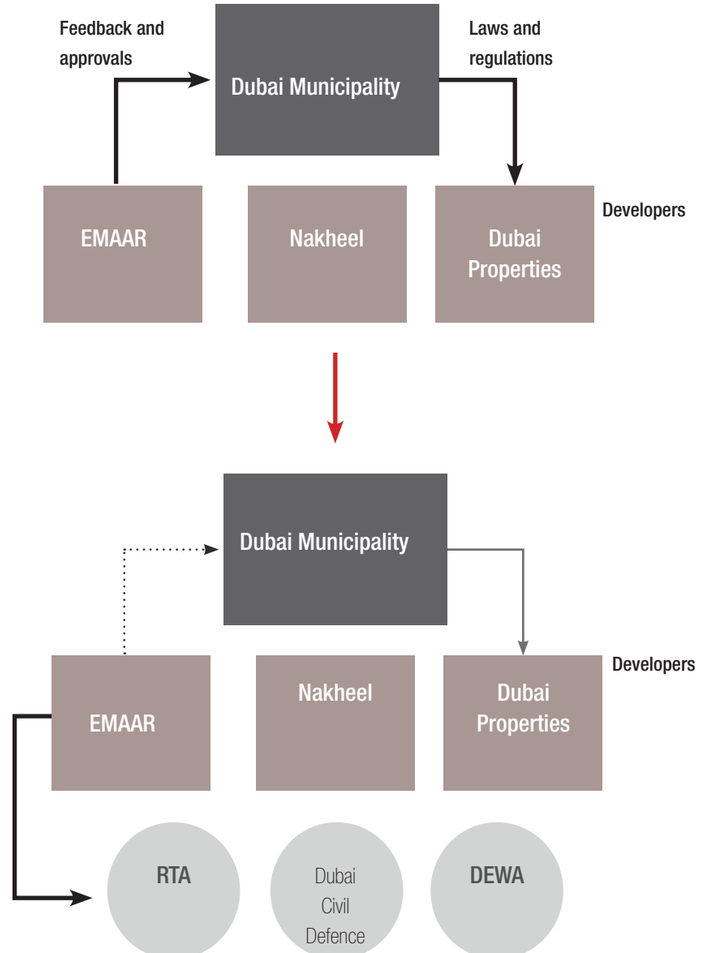
Population Growth in Dubai

Source: Dubai Statistics Centre

Figure 5.11 – Free-zones in Dubai.
Source: Author

The Planning Process

Planning processes in Dubai began to change as early as 1997 with the formation of EMAAR. EMAAR and other developers such as Nakheel and Dubai Properties were in-charge of developing mega-projects within the free-zones of Dubai. Free-zones are areas where non-GCC residents could own property. Figure 5.11 shows the location of the very first free-zones in Dubai. Projects in the free-zones were endorsed and approved by a higher authority (such as the executive Council) and began construction. Initially, the Dubai Municipality was given the task to coordinate among the different free-zone projects and provide approvals before construction. With time, the free-zone areas began to gain development control to implement projects faster and the Municipality started to have a passive role in the planning system. As power was delegated among other organizations feedback from the Dubai Municipality was minimal resulting in poor coordination among development projects. Approvals for roads (RTA), civil defence and utility connection (DEWA) lie with other government entities and is required for all projects.



Today there five other authorities apart from the Dubai Municipality who have development rights within the city. These are the Dubai Creative Clusters Authority (DCCA), Jabel Ali Free Zone (JAFZA), Dubai Airport Free Zone Authority, Dubai Multi Commodities Centre and Dubai Silicon Oasis. The areas within their boundaries is shown in figure 4.11. A lot of these projects were implemented within the same decade and were competing to achieve a unique architectural and urban character and contribute to the urban character of the city as it exists today. Without an authority to enforce principles of sustainable development or to provide guidelines for the aesthetic character, every project looked different from each other. This resulted in diverse morphological characteristics, socio-economic demographic and most importantly urban decision making. All these factors contribute to energy consumption patterns and will impact efforts to change this.

A lot of new developments were about 30 km away from the CBD increasing the dependence on cars for transportation. Dubai has a car ownership rate of 0.54, which means that there are 540 cars for every 1000 persons. This is much higher when compared with Singapore (0.15) and Guangzhou (0.21). The increase in number of cars on the roads was recognized as an issue and the Roads and Transport Authority was officially formed in 2005. Soon after the first phase of the Dubai metro was inaugurated in September 2009.

An integrated spatial plan for the city was not considered a priority. Inefficient use of land increased the financial and environmental costs of providing infrastructure especially energy and water supply. This is recognized as a problem and efforts to change this are seen in the Dubai Urban Development Framework published in 2009. A proposal to create a new institution to oversee a wider Emirate-wide development strategy with clearly defined roles for the Dubai Municipality, developers and other government bodies is highlighted. This is discussed further in chapter 9 (page no. xx).

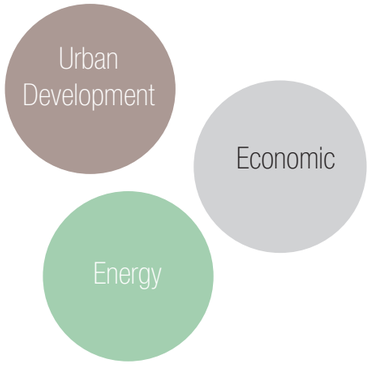
Figure 5.12 – Regulatory Authorities in Dubai.Source: Author

1 Jumeirah Beach Residence

2 Dubai Sustainable City

3 Dubai International City

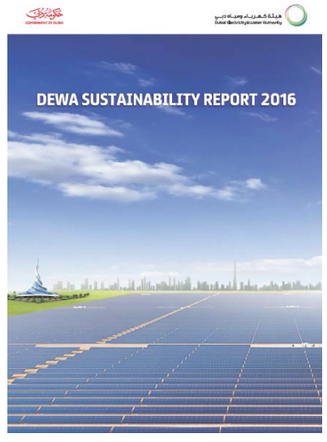
Lack of integrative and sustainable policies



The first mention of sustainability in Dubai was around 2006 and was introduced by TECOM, a semi-private business developer. To gain a competitive edge a few buildings within their project were mandated to be approved by U.S. Green Building Council's LEED rating system. The government has begun to mandate city wide regulations such as Dubai Green Building Regulations in 2008. DEWA and RTA put forward their own regulations towards environmental sustainability. While all these initiatives are a step in the right direction, they leave Dubai with a piecemeal approach towards sustainability.

In an interview with an official at DCCA (which is the second largest regulatory authority after the Dubai Municipality), it was clear that although Dubai Municipality or DEWA put forward initiatives for the rest of the city to adopt, it is not mandatory. For example, there was a rule to implemented 50% of the roofs of residences as 'green roofs'. The economic and environmental costs of installing a green roof in Dubai's desert climate was not fully considered in this case and the DCCA decided not to implement it. Eventually, adopting 'green' design principles or energy saving mechanisms is left to the developer or regulatory body.

Blurred planning processes and lack of a strong regulatory framework pushing for long term sustainability goals leaves a lot of questions unanswered. How many initiatives such initiatives are not realized? And who should be accountable for this? If developers are left to decide what they can or cannot do, Dubai will probably not be able to achieve an energy transition.
Urban development policies, economic strategies and energy policies do not respond to each other. Without addressing the direction of economic growth within urban development strategies, reducing energy demand is not possible.



Skyline of Dubai
Source: Zuhair Lokhandwala

Urban Governance in Dubai

The local impact of global trends

This chapter discusses the change in planning processes in Dubai and illustrates its relationship to energy use. The discovery of energy (or oil) has impacted planning processes that have shaped the city of Dubai. Energy changed the view of the leaders which influenced how Dubai placed itself on the global map.

The executive council in Dubai is the main decision-making body which sets the vision for development of the city in almost all sectors including urban development. The council is chaired by the Crowne Prince of Dubai and has a representative from all government entities. Among other decisions, the executive council holds power to endorse urban development projects, change laws about land ownership and implement national level policies. These decisions laid the basis for urban development on many occasions. For example, the national housing policy in the early 1990's provided free land and financial grants for nationals to build homes. This suddenly increased the demand of urban areas in Dubai and is reflected in the structure plan published in 1993 where the provision of housing was prioritized. Another example is the change in land ownership law in 2002, which allowed free-hold ownership of property for non-GCC residents. To create a real estate market, urban development projects or mega projects (led by semi-private entities) were endorsed by the executive council in different parts of the city once again increasing the amount of urban areas in the city. Land was urbanized as per the changing vision and goals of the government, and dictated the role of the Dubai Municipality, developers and 'free-zones' in Dubai.

Although the Dubai Municipality holds the power to envision and implement the 'masterplan' for Dubai, they also need to cope with changing political and economic decisions that could override their plans and targets. Change occurs much faster as most decisions are made by a single government body and is not influenced by residents, opposing political parties, the private sector or any other body as in the case of a democratic governance system. The governance system in Dubai is autocratic, where decisions made by the executive council or the Ruler of Dubai are not contested. The work of sociologist John Urry (2013) argues that this is the case with many other countries where oil was discovered. Except for Norway, Denmark and Canada, most countries where oil was found did not transition to a more democratic society and governance system. While the main reasons for this lie in political and social organization, the spatial consequences, as seen in the case of Dubai, are drastic.

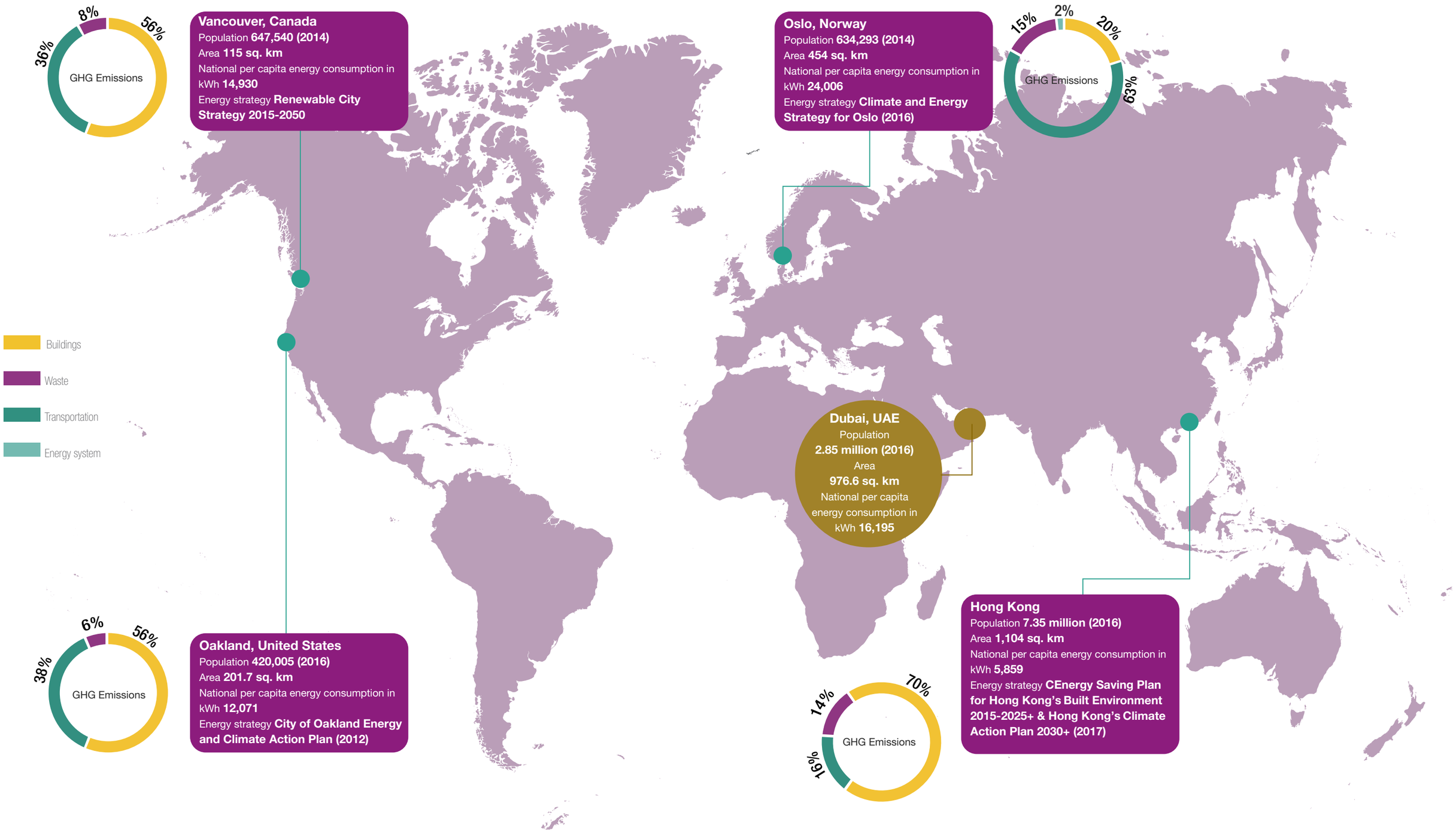
In parallel, Dubai was emerging as a global city, which fuelled the growth of mega projects and attracted a large migrant population. Mega projects were aimed at high-end luxury real estate and added to the economic and social divide as this cannot be afforded by everybody. Dubai wanted to become a global and *metropolized* city and set the vision for what globalization meant for Arab cities (Elsheshtawy, 2010).

In a way both these phenomena i.e. autocratic governance system and globalization, complement each other as they resulted in the creation of spaces that build for a consumerist society. Places are themed, branded or collected and experienced through being consumed rather than belonged to or lived within. Some of these include landmark buildings, beaches, clubs, conferences, food, hotels, entertainment venues etc. Urban areas become disconnected from each other and don't have a sense of community. This is further examined in the final chapter of this report.

Chapter 6

Comparative Analysis

The results and lessons for Dubai



This chapter presents the results of the comparative analysis of energy strategies and action plans from 4 cities, Vancouver, Oslo, Oakland and Honk Kong. The aim of the analysis is to derive lessons that can be a starting point for Dubai's energy strategy. What works and what doesn't? The common actions, differences, criticisms and a starting point for Dubai's strategy is discussed. Although the cities chosen are geographically, politically and demographically worlds apart from Dubai, they all share common goals when it comes to addressing energy issues. Improving energy efficiency, reducing energy consumption and transitioning to renewable sources of fuels are among the common objectives of every city. Dubai's objectives are no different and it can learn from the innovative approaches and implementation strategies that other cities have chosen.

6.1 Goals and Operational Framework

All the cities measure their greenhouse gas emissions and use it as a mechanism to set goals and objectives for the energy strategy. The reduction of greenhouse gas emissions is the central objective of all 4 strategies. Other goals such as increasing renewable energy production or reducing carbon intensity can also be a part of the objectives. This is seen in the case of Vancouver or Hong Kong. The strategies have an operational framework or theme that define the biggest drivers of change and intended working mechanisms.

The Paris Agreement and GHG Emissions

One of the core components of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping the global temperature rise well below 2 degrees Celsius. All the 4 cities chosen in this study have ratified the Paris Agreement and this is reflected in the orientation of their energy policies. This global agreement to limit global temperature rise can be equated to a certain amount of allowable GHG emissions. Since two-thirds of GHG emissions arise from energy production (IPCC, 2015), this is probably the reason why cities chose the reduction of GHG emissions as a core objective of their energy strategies.

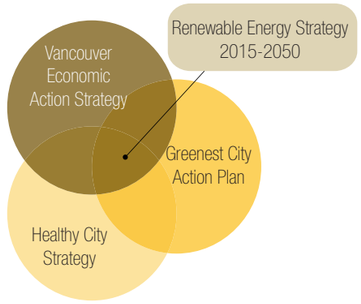
VANCOUVER

The Renewable Energy Strategy for Vancouver puts forward two main goals. First, reduce greenhouse gas emission by 80% by 2050 (taking 2007 as a baseline), and, second meet energy needs using only renewable sources of energy by 2050.

The Renewable City Strategy is a continuation of the previous environmental strategy, the Greenest City 2020 Action Plan. It complements the city's economic plan (Vancouver Economic Action Strategy) and social plan (Healthy City Strategy). The Renewable City Strategy that addresses energy issues is where the three pillars of sustainability – environmental, social and economic – meet. The plan makes a strong statement linking sustainable development and energy use in the city.

100%
Transition to renewable sources of energy

80%
reduction in GHG emissions by 2050 (2007 as a base)



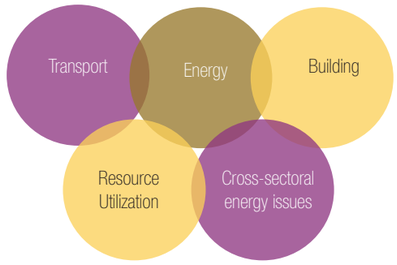
OSLO

The Climate and Energy Strategy for Oslo aims to reduce greenhouse gas emissions by 50% by 2020 and 90% by 2050. The strategic approach of the plan emphasizes the need to develop a multidisciplinary way to implement the 'green shift'. Forty organizations from the City of Oslo, the business community and state-owned enterprises participated in developing the strategy. This was undertaken in five sectors: transport, energy, building, resource utilization and cross-sectoral energy issues.

50%
reduction in GHG emissions by 2020

95%
reduction in GHG emissions by 2030

Strategic Approach
Collaboration between 5 sectors



OAKLAND

The emphasis on collaboration between sectors is a core part of Oakland's Energy and Climate Action Plan. The main goal of the plan is to reduce greenhouse gas emissions by 36% by 2020. A main driver for this change is the risk of climate change. Oakland's strategy puts forward concrete goals and actions to be achieved first within 3 years and then within 10 years. Every action contributes to either climate mitigation or climate adaptation. Local and community action as well as regional and federal collaboration is heavily emphasized.

36%
reduction in GHG emissions by 2020

Climate
Mitigation and Adaptation

HONG KONG

Hong Kong's Climate Action Plan 2030+ picks up where the Energy Saving Plan for Hong Kong's Built Environment 2015-2025+ left off. The former is published 2 years later and is a result of Hong Kong's participation in the Paris Agreement.

There are two main goals in Hong Kong's Climate Action Plan. The first one is to reduce greenhouse gas emissions by 20% by 2020 and by 36% by 2030. The second one is to reduce energy intensity by 50-60% by 2020 and 65-70% by 2030. Energy intensity is the amount of energy it takes to produce a dollars' worth of economic output. It is calculated by dividing energy demand with the GDP.

Key actions are carried out in 4 sectors: economics, regulation, education and societal. The plan is heavily influenced by the goals of the Paris Agreement which are comprehended into an operational framework that sets targets with timelines, ensures transparency to track results and brings people to work together.

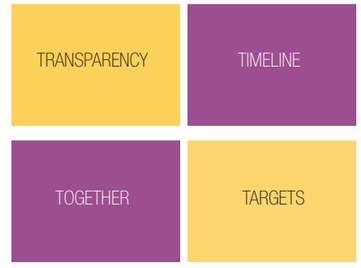
20%
reduction in GHG emissions by 2020 and

36%
by 2030

50-60%
reduction in carbon intensity by 2020 and

65-70%
by 2030

4 T's



6.2 Common Actions

Transportation and Land Use Planning

All the actions that relate transportation patterns to land use planning aim to reduce the need to travel by creating more compact communities and bringing jobs closer to homes. Technological advancement in infrastructure and transport fuels is also promoted to reduce greenhouse gas emissions from current transportation infrastructure.

• ***Promoting pedestrian movement and bicycling for short daily trips***, i.e. as a mode of active travel, is advocated for in all 4 cities. This reduces the need to use mechanical travel modes thus saving energy use associated with that. Oslo and Oakland prioritized the completion of infrastructure to support active travel through regulatory actions. Honk Kong is known for its robust transportation system and has a huge number of pedestrians. To keep this number up and increase it they need to improve their public realm design. Although the energy strategy does not address this explicitly, encouraging pedestrian movement is a vital part of the urban development strategy in Hong Kong.

• ***Improving and extending the public transit system*** is an ongoing task in almost every city worldwide. Vancouver, Oakland and Hong Kong have specific targets and locations of where they want to extend public transit infrastructure. To ensure that residents are aware and make use of the new infrastructure line, Oakland has decided to run the newly constructed metro line for free for a certain amount of time. While Oslo also decided to extend its public transit infrastructure, transport-oriented development is emphasized as a long-term goal and is used to determine the geographic location of extending transport lines.

• ***Demand management*** is used as a strategy in the 4 cities for different reasons, either to increase the use of public transit, reduce the number of trips made by cars, increase fuel efficiency or encourage the use of electric cars. For example, Oakland adopts strategies to encourage the use of public transit and the number of pedestrians and cyclists by providing free access to public transit, enabling telecommuting, flexible work schedules, car sharing programs and better bicycle access. In Vancouver existing car—sharing schemes are encouraged to take up the use of renewably powered vehicles. Switching to electric or hybrid cars powered by cleaner fuels is a fast and definite way to reduce greenhouse gas emissions. Although all 4 cities strongly advocate for this switch by investing in infrastructure to support charging electric vehicles, Oslo and Hong Kong are supporting this switch through concrete regulatory and fiscal measures. Oslo introduced low/zero-emissions zones, environmentally differentiated tolls and lanes reserved for environmentally friendly transport. Hong Kong has an annual car growth rate of 3% and provides tax reductions on registration of new cars that are electric and have no tailpipe emissions. This incentivizes all new cars to be more fuel efficient and cleaner. Hong Kong pushes for car owners and bus drivers to adopt 'eco-driving' skills which improve fuel efficiency. These include, driving at constant speeds, avoiding over speeding and harsh acceleration and braking, shifting gears at the correct time, moderating the use of air conditioning and ensuring proper maintenance of the vehicle.

Figure 6.1 - Cover page from the Climate and Energy Strategy, Oslo

Source: https://www.oslo.kommune.no/getfile.php/13166797/Content/English/Politics%20and%20administration/Green%200slo/Plans%20and%20programmes/Climate%20and%20Energy%20Strategy%200slo.pdf

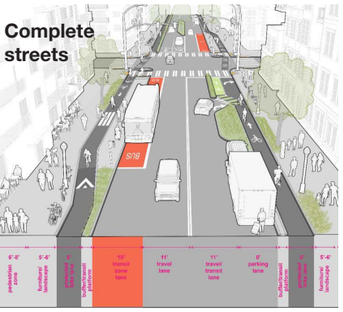
Building Form

Globally, buildings account for over one-third of energy consumption (IEA, 2013). Building design is central to addressing energy use and its consequent reduction. The strategies put forward ideas to address this through increasing renewable energy supply in buildings, upgrading existing building stock to be more efficient and implementing strong regulatory frameworks.

• ***Increasing renewable electricity supply*** is a goal of every city and is implemented in different ways. In Vancouver supplied electricity is targeted to be produced 100% by renewable sources and is a government led action in collaboration with power generation companies. In Oslo a 'lighthouse' project or pilot project was launched to power one neighborhood entirely by renewable sources of energy. This is meant to demonstrate the viability of using renewable power for electricity generation and to influence other developments to adopt the same principle. In Oakland community programs are launched through collaboration with local partners. Hong Kong is trying to move away from generating electricity by coal and moving towards natural gas. It has a realizable potential of generating 3-4% of its total electricity through renewable power. Hong Kong's policies and targets to shifting to renewable fuels are not as progressive when compared to the other cities.

• A lot of buildings in cities were built at a time when energy efficiency or sustainability was not a priority. Therefore, ***upgrading existing building stock*** with more efficient heating and/or cooling systems is necessary given the current global emphasis on reducing energy consumption. All 4 strategies recognize this and have a heavy emphasis on retrofitting existing mechanical heating or cooling systems, promoting solar upgrades, improving insulation and upgrading elevators, lights etc. to be more efficient.

• Except for Oslo, ***building rating systems*** to improve energy and environmental performance are a preferred regulatory approach to monitor and ensure energy efficient building design. Vancouver mandates energy benchmarking and labeling requirements. Oakland enforced stricter building energy codes that require all new building stock to be 10% more efficient than the state's (California's) requirement of building energy performance. BEAM is the green building rating system that is widely used in Hong Kong. Apart from this the city developed two additional regulatory tools, the B(EE)R (or Building Energy Efficiency Regulations) and the BEEO or (Building Energy Efficiency Ordinance) to ensure energy use is studied and improved.



What stands out?

Vancouver put forward design strategies such as the ‘passive house’ or ‘complete streets’ to promote solar design in buildings and safe streets in neighbourhoods. The ‘Passive House’ certification confirms that a building is designed to achieve high energy performance. Complete streets policy helps to promote a safe, well maintained and environmentally responsible street design in Vancouver at the neighbourhood level. Through this program communities can come together and design the components of the ‘complete street’ in their neighbourhood.

In Oslo, lighthouse projects or pilot projects are used to demonstrate the feasibility of technological solutions. For example, implementing CCS at the waste plant in Klemesrud, installing a micro-energy system at Furuset and launching the first ‘energy station’ to provide renewable powered fuels for transportation. These projects are meant to inspire other initiatives in the city.

In Oakland community engagement is the core part of every action. This is to encourage community energy and climate actions, track and promote community action, create new opportunities for community engagement and develop the workforce to support green businesses.

The link between urban development plans and energy strategies

To make the link between energy strategies and urban development plans, two plans have been considered – Vancouver and Hong Kong. Although the study of the urban development plans is less extensive than the energy strategies, the plans have been analyzed with a perspective to highlight the links to energy systems.

Vancouver

The urban development goal of the City of Vancouver is to plan a lliveable and sustainable city. Urban development in the city has different areas of focus. These are urban planning, zoning plan, sustainable development guidelines, land use development guidelines, street change and citizen involvement. Within these themes energy and water efficiency are advocated for through the zoning plan which put forward regulations about electric vehicles charging points and a toolkit for passive solar design and water efficiency in buildings. The zoning plan also promotes compact development which helps to reduce transport related energy use and emissions. Major urban planning projects such as the plan for the neighbourhood of West End addresses energy and climate change through design guidelines and policies. This includes land use (density, mixed use, passive design), neighbourhood energy network, green building design and climate change adaptation of infrastructure and open spaces. Although the West End plan highlights important aspects to promote efficient energy systems, it does not guide urban development. The policies and guidelines are not illustrated or spatialized to show how change can occur. Energy inefficient patterns of urban development are not explored and the space between buildings is not addressed.

Hong Kong

The Hong Kong 2030 Planning Vision and Strategy is divided into four broader sections – the planning process, planning vision and future challenges, planning choices and planning strategy. The planning vision has seven areas of focus. These are (1) creating good quality living environments, (2) conserving natural landscapes, (3) enhancing the economy, (4) land use for housing, (5) promoting arts, (6) culture and tourism and (7) strengthening the link between the mainland. However, the future challenges of the planning vision do not recognize energy as an issue even though Hong Kong has only 3% of energy generated from renewables and has committed to reducing GHG emissions and carbon intensity. The population dynamic, changing economy, relationship with mainland China and housing are highlighted as bigger challenges for Hong Kong’s planning vision. The planning strategy prioritizes growth axis related to housing, employment nodes, transportation and density. Energy is an important aspect of determining growth but is not considered in the evaluation framework that determines planning choices, which looks at environment, economics, land use planning, social issues and transportation.

The absence of emphasis on energy efficiency in the urban development plan of Hong Kong is not surprising since the energy strategy focuses on predominantly reducing energy consumption in buildings. This is done through developing extensive regulatory tools for building rating system such as the B(EE)R or BEEO. The emphasis on building related energy use and emissions is bigger than transport related energy use and the link between both is not talked about in the energy strategy. Recognizing this link is a pre-requisite to develop an integrated urban development strategy that considers the energy question.

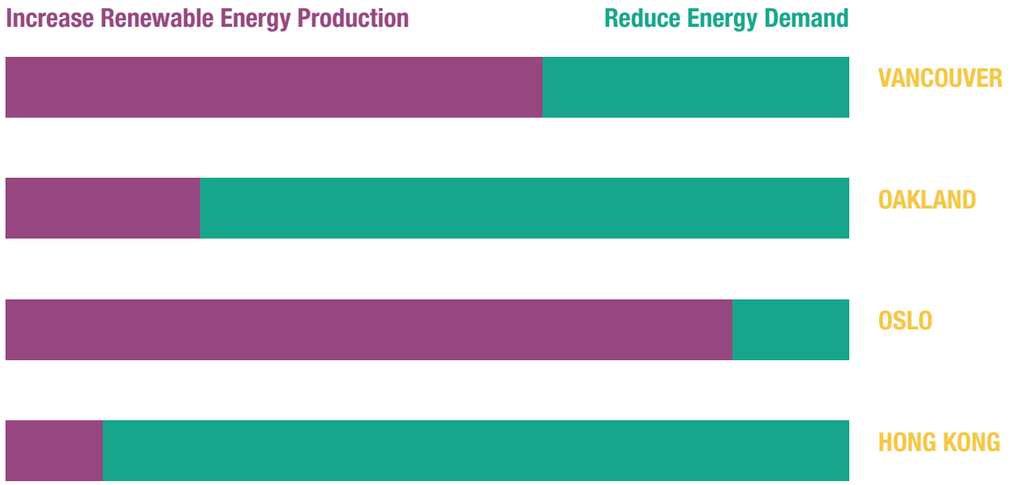
Demand or Supply?

What do the strategies focus on - reducing energy consumption or increasing renewable energy supply? All the strategies tend to gravitate towards either reducing energy demand or increasing renewable energy supply. Honk Kong’s strategy focuses on managing the demand for energy. Most of the electric supply is met by coal powered plants and from the strategy it is evident that this is not likely to change soon as no steps to phase out coal are being taken. All new developments are required to generate 1% of their total energy needs from renewable power. This is a conservative target when compared to steps being taken in other cities. The potential for generating power from alternatives sources such as solar, wind and hydro are being studied but there is no stringent action plan to deploy these technologies when compared to managing energy demand.

Oakland’s strategy focuses on bridging the gap between local action and regional collaboration. Community centered design and strategies are employed under almost every action, relying on user behavior to push for long term change. It is easier to innovate and deploy strategies to reduce energy consumption rather than renewable energy production. Therefore, it appears that there is a smaller emphasis on increasing renewable energy production. However, Oakland does set a target to supply 33% of total electricity from renewable energy sources and this is propagated through community-based action.

Vancouver has the goal to phase out fossil fuels completely and consequently focus on both, reducing energy demand and increasing renewable energy supply. Vancouver adopts policies to increase renewable energy supply at the building and neighborhood scale through pushing for neighborhood scale renewable energy centers, encouraging smart grids and providing strict building regulations to install solar panels and use efficient infrastructure.

Among the 4 cities, Oslo has the strongest emphasis to shift to an energy system powered entirely by renewables. For example, fossil-based building heating is banned from 2020, petrol stations are to be replaced with ‘clean energy stations’ powered by renewables, public transport is targeted to be entirely powered by renewables and all the building owned by the city have already made the shift to renewable based power generation. The interesting thing to note is that in some cases Oslo integrates the goal of increasing renewable energy production and reducing energy demand within the same action. Although Oslo’s strategy places a heavy focus on transportation and land use planning, integrating demand and supply is extended to building and infrastructure as well.



6.3 Considerations for Dubai's Energy Strategy

• ***The emphasis of the strategy is related to the contribution from greenhouse gas emissions.*** For example, in Oslo, 63% of greenhouse gas emissions are contributed from transportation. This is reflected in the strategy as well where most of the actions are related to reducing impact from transportation. In Hong Kong, 70% of greenhouse gas emissions are caused from generating electricity almost entirely used in buildings. The strategy for Hong Kong places a heavy emphasis on reducing building related energy use and greenhouse gas emissions. The Dubai Integrated Energy Strategy 2030 or the State of Energy Report Dubai 2014 does not link greenhouse gas contribution to the actions that are put forward. National estimates indicate that electricity and water demand, and road transportation contribute to a half of greenhouse gas emissions. This should be reflected in the energy strategy.

• ***Comprehensive approach towards urban development and transportation planning.*** Oakland and Hong Kong emphasize the impact of a comprehensive planning approach addressing urban development and transportation patterns to reduce the need to travel. More compact communities with homes and jobs closer to each other can reduce the number of daily trips thereby reducing travel demand and its associated energy use and greenhouse gas emissions. The energy strategies of Oakland and Hong Kong do not discuss this integrated planning approach in detail but leave it to the urban development plans to tackle.

• ***The City or Government demonstrates leadership to and adopts the use of alternative fuels to push for change.*** Existing (and new) government owned buildings and facilities are retrofitted to be more energy efficient and compliant with strict regulations. Government owned car fleet should transition towards using more renewable fuels. All 4 cities adopt actions to show the viability of using alternative fuels within building infrastructure and transportation choices.

• ***Energy use from visitors should be considered.*** Hong Kong had 54.3 million visitors in 2013. Even though the number of visitors is not considered while estimating energy demand or calculating per capita greenhouse gas emissions, visitors do contribute to energy consumption especially in transportation and commercial uses (hotels, tourist sites). In Dubai, tourism has a big contribution to the economy and in 2016 14.87 million people visited the city. This will inevitably impact energy use and should not be ignored.

• ***Compact development and fast urban development can occur simultaneously.*** Vancouver doubled its population in 20 years and Dubai doubled its population in 10 years. The urban development patterns in both cities have a stark contrast. Vancouver adopted policies to promote compact development through zoning regulations, while Dubai's urban landscape spread into the desert. Vancouver's urban policies show that planning for compactness is possible even when confronted with a fast population growth rate and consequent for urban extension.

Figure 6.2 - Tourists at Burj Khalifa, Dubai

Source: Luca Locatelli, Institute for the National Geographic

6.4 Criticism's of the 4 strategies

• ***In all the 4 strategies, none of the actions or interventions are mapped or 'spatialized'.*** Interventions to reduce energy consumption or increase renewable energy production can be seen in three different areas - interventions within the urban fabric or form, through user behaviour, and/or through technological advancements. Apart from changes to the urban form or fabric, it is very difficult to 'show' how technological breakthroughs or user behaviour can impact energy use. This can be why mapping is not an obvious choice.

• ***None of the strategies can say if they will achieve their goals through adopting the proposed measures.*** The strategies have concrete targets to reduce greenhouse gas emissions or decrease the amount of energy use. However, the actions are not equated to any numerical data. There is no (confident) conclusion or projection in any of the strategies about being able to achieve their set-out targets with the proposed actions.

• None of the strategies mention adopting ***passive solar design*** as a mandatory action to reduce energy consumption. It is left for building regulations to address or is considered as an inevitable consequence of advancement in building design. Many studies (below) have shown that passive solar design strategies have the potential to reduce energy demand in buildings and improve energy efficiency. (insert the quotes in report)

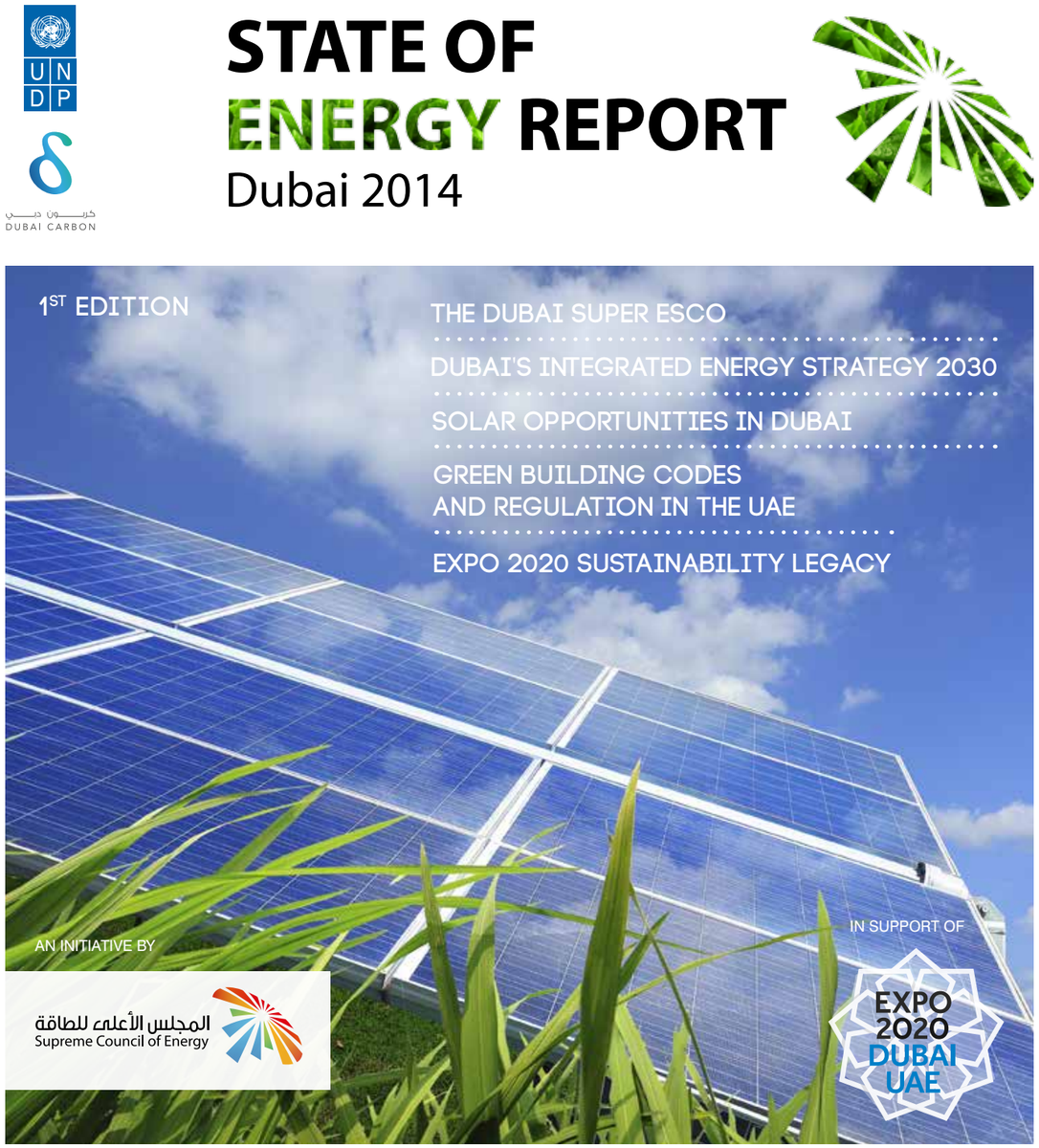
• ***Designing for compactness and infill development are not considered crucial to improve energy efficiency.*** These principles can help to reduce travel demand and associated energy demand and emissions related to it. Vancouver and Oakland try to promote compact development through zoning policies, but these are not crucial to the energy strategy.

• Although waste contributes to the greenhouse gas emissions, only Oakland mentions taking steps to reduce waste and promote recycling. Vancouver, Oslo and Hong Kong focus on building waste-to-energy plants or removing waste emissions through CCS (carbon capture and storage). In the short term these might help to reduce emissions but may not be sustainable in the long run as they would always rely on the generation of waste to function.

'Passive solar design can reduce demand for energy and provide the best use of passive energy.'
Jabareen, 2006

Bio-climatic design enhances energy efficiency of buildings.
Yeang, 2008

'Designing with microclimatic conditions reduces the need for internal space heating or cooling by conventional mechanical systems.'
Owens, 1992



Platinum Sponsors

WETEX 2014
WATER, ENERGY, TECHNOLOGY AND ENVIRONMENT EXHIBITION
At The Forefront of Sustainability

هيئة كهرباء ومياه دبي
Dubai Electricity & Water Authority

Gold Sponsors

dubal Dubai Aluminium

Emirates NBD

بلدية دبي
DUBAI MUNICIPALITY

RTA

الاتحاد Etihad لخدمات الطاقة Energy Services

اينوك ENOC

EMPOWER ENERGY SOLUTIONS

Silver Sponsors

ABB

OXFORD BUSINESS GROUP

SOLARWORLD

Chapter 7

Dubai's Energy Strategy and Urban Development Plan

This chapter presents an evaluation of Dubai's energy strategy – State of Energy Report, 2014 and the Dubai 2020 Urban Masterplan. The energy strategy is the outcome of the first coordinated policy efforts towards the energy transition in Dubai. The importance of collaboration among key stakeholders is recognized and the document drives a unified strategy for all aspects of the energy sector. Current efforts in the energy sector and the challenges for Dubai going forward are highlighted. It should be noted that this document is referred to as the State of Energy Report or the Dubai Integrated Energy Strategy 2030 depending on the context within which it is used. The components of this document include; The Dubai Super ESCO (Energy Service Companies), Solar opportunities in Dubai, Green Building Codes and Regulations in the UAE and the EXPO 2020 sustainability legacy.

Although the document is quite large the content is easy to grasp as every topic/section is very precise and is contributed by either a government entity, private sector company or research institute. Every sub-section presents either a strategic goal, incentives for change, policy orientation, private sector initiative, examples from other places or interviews with key people.

Five themes have been chosen for this analysis - governance, subsidies, building design, transport and challenges. The key components for each aspect will be explained and conclusions are drawn upon by linking this to the comparative study in the previous chapter.

It should be noted that the Dubai 2020 Urban Masterplan is analysed with a view to understand its contribution to energy efficiency. The summary report published by the Dubai Municipality has been considered for this analysis. The conclusion of this chapter highlights the fragmentation of policies in Dubai.

Dubai's Energy Strategy

7.1 Governance Framework

Policy Development and Governance
Dubai Supreme Council of Energy

↓

Execution
Dubal, Dubai Petroleum, Dubai Municipality, DUSUP, Dubai Nuclear Energy Committee, Dubai Petroleum Affairs, ENOC and Dubai Electricity and Water Authority

↑

Regulation
Regulatory and Supervisory Bureau, UAE

The Dubai Supreme Council of Energy was formed in August 2009 to oversee the planning of the energy sector in Dubai. The Council has members from different organizations who are also key stakeholders of the energy sector in Dubai. These are: the Department of Petroleum Affairs, Dubai Aluminium Company (DUBAL), Emirates National Oil Company (ENOC), Dubai Supply Authority (DUSUP), Dubai Petroleum Establishment (DPE), Dubai Nuclear Energy Committee (DNEC) and Dubai Municipality (DM).

The Supreme Council of Energy is responsible for setting the strategic direction of policy development and governance. The execution of these policies into actions is with the different stakeholders and the translation of these into regulations lies with the Regulatory and Supervisory Bureau for Electricity and Water (RBS). The RBS supports the strategic framework of the Supreme Council of Energy, which is to position energy at the heart of the economy while addressing environmental and social concerns. Although reducing the demand of energy is also emphasized, advocating private investment in energy production (renewable or non-renewable) to reduce the reliance on natural gas is the core aim for both organizations.

The operational framework of energy governance in Dubai is proposed to have four components: governance and policies, energy efficiency and demand reduction, energy security and sustainable cost of gas and financial mechanism and capacity building. Increasing energy efficiency within the existing city, reducing energy demand and CO2 emissions are the components of the strategy that could directly influence spatial conditions in the city.

7.2 Goals of the energy strategy

Figure 7.1 - Goals for diversification of fuel mix

Energy Production

As per the energy strategy, the fuel mix is targeted to be diversified by 2030 so that the total power is supplied by 5% solar, 12% clean coal, 12% nuclear power and 71% natural gas. Natural gas still has a very large part of the fuel mix and the targets for renewably sourced energy is very conservative when compared to other cities such as Vancouver, Oslo and Oakland.

The UAE ratified the Paris Agreement in September 2016 and soon after a national energy strategy was released in January 2017. In response to this Dubai decided to adopt more aggressive policies to increase renewable energy production to 44% by 2050 and reduce the reliance on natural gas. To help with this goal energy and water production, which is currently a state-owned program, has been opened to the private sector. Public-private partnerships are also encouraged for energy production.

Reducing Demand

Dubai plans to support the strategy of increasing renewable energy supply by accompanying this with a goal to reduce energy demand by 30% in the next 20 years. There are eight 'pillars' or areas of focus for the demand management strategy. These are, building regulation, building retrofit, district cooling, labels for equipment, water reuse and irrigation, outdoor lighting, tariff rates and demand response.

The Supreme Council of Energy also adopts three measures to reduce electricity and water demand. The first is through deploying the ESCO model (Energy Services Companies) and implementing the Green Building Code. Al Safat which is the new green building code is mandatory for all new buildings to adopt. Certain older buildings also need to be retrofit to match the new standards. To help implement this the ESCO model is used by RBS. The RBS provides an accreditation system to certify energy service and energy auditing companies. One of their goals is to increase the number of such companies.

The second measure is through engaging with the 33 government organizations in Dubai to reduce their electricity and water use by setting strict targets.

The third measure is through promoting the Emirates Energy Award, which recognizes best practices in energy efficiency and energy diversification.

Current GHG Emissions

Dubai's GHG emissions contribute to about 25% of the UAE's GHG emissions. The main sectors that contribute to the emissions are: electricity and water production (35%), transport (26%), industry (21%) and waste (12%). The share from electricity related emissions is close to the global average, but road transportation and waste are unusually high.

From the comparative study, it was found that all cities adopt actions that directly reflect the contribution from GHG emissions in their energy strategy. This means that if GHG emissions from a sector is higher, the energy strategy emphasizes actions to reduce energy use and its related emissions in that sector. For example, in Oslo, transportation (62%) has the highest contribution to GHG emissions and the energy strategy emphasizes actions that can reduce this. A similar trend is noticed in Hong Kong as well where the biggest contribution to GHG emissions is from the building sector (70%).

Although reducing GHG emissions is not an aim of Dubai's energy strategy it does indicate which sectors might be consuming the most energy. These sectors should then become a focus while setting the policy tone to reduce energy demand. These numbers indicate that both transport and the building sector should be focused on equally.

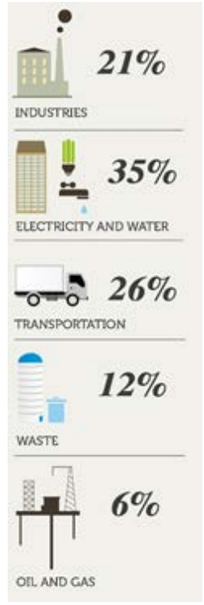


Figure 7.2 - Current GHG emissions

7.3 Subsidies

Expats in Dubai pay approximately 4 times the electricity and water tariffs as UAE nationals (ADDC, 2017). Electricity and water is 'subsidized' for UAE nationals who comprise of about 10% of the population. The percentage of households where energy is subsidized might not reflect the demographic distribution. This is because of the national housing policy (explained in chapter 5). It is speculated that there is an oversupply of housing for nationals as development plots (or houses) are distributed as per individuals and not per household. On the other hand only Emirati males (50% of the national population) and some females are eligible to receive these housing grants. Still, there might be more households that are eligible for pay lower energy tariffs than what is seen in the demographic data. Figure 7.3 shows the parts of the cities where native population generally live. The uneven distribution of energy tariffs adds to the socio-economic divide among Dubai's population.

International Comparison

When compared to electricity pricing of other cities Dubai has one of the lowest energy tariffs. Table 7.4 shows the pricing of electricity in (US cents/kWh) and fuel for transportation (USD per litre) of the United States (California), Norway, Canada, Hong Kong and Dubai.

Fuel subsidies have contributed to the UAE becoming the 7th highest consumer of energy worldwide (Topf, 2014). Also, Dubai has an annual car growth of 8.2% (Shahbandari, 2015) which is one of the highest in the world.

Figure 7.3 – Location of native-born neighbourhoods in Dubai in 2013.
Source: Alawadi et. al, 2017

	Electricity Pricing (USD per kWh)	**Fuel for transportation (USD per litre)**
Canada	0.116	1.18
California	0.130	0.79
Norway	0.125	2.07
Hong Kong	0.112	2.08
Dubai	**0.081**	**0.6**

Table 7.4 – Electricity and fuel pricing of a few cities
Source: From the research of Neven Valev et. al titled Global Energy Pricing, retrieved in April 2018.

7.4 Transport

The number of cars on the road causing traffic congestion and adding to air pollution was recognized as a problem and the Roads and Transportation Authority was formed in 2005 in Dubai. Soon after the first phase of the Dubai Metro was opened in 2009. This helped to increase the share of public transport from 6% in 2006 to 15% in 2015 (Tesorero, 2016). The Dubai Metro has about 329,365 daily commuters which is just about 10% of the city's population (Tesorero, 2016). This is much lower when compared to Hong Kong, which is about 90% (Environment Bureau, 2017) or even Vancouver which is at a much lower 20.4% (Kerr, 2017). While these steps show progress in the right direction, Dubai still has a long way to go in reducing the dependence on cars and radically shifting the mobility pattern when compared to other cities.

Dubai's energy strategy proposes reducing transport related GHG emissions through improving fuel properties, promoting electric and hybrid cars and changing travel behaviour through education. However, there are no incentives to help with this. In fact, the strategy specifically mentions that financial incentives will not be used to push for promoting electric cars or changing travel behaviour. This has changed and today there are incentives that provide free road tolls and parking for electric cars. Certain electric charging points around the city will be free for a certain amount of time (Baldwin, 2017).

Figure 7.5 – Riders on the Dubai Metro
Source: Luca Locatelli, Instiute of the National Geographic

7.5 Building Design

Before the Dubai Green Building Regulations were mandated in 2014, US LEED Green Building System was extensively used. There are 650 LEED certified buildings in Dubai. This is the 3rd highest in the world following by London (2600) and New York (900) (Deulgaonkar, 2017). Many government buildings in Dubai are also LEED certified indicating that the government supports and encourages the use of the LEED building rating system. However, the LEED is not always suitable to fit within the climate and urban fabric of Dubai. For example, the installation of bicycle racks and green roofs helps to increase the points one can achieve in the LEED rating structure. But Dubai has a very poor bicycle infrastructure with hardly anyone bicycling to work. Green roofs are economically expensive to maintain in Dubai's hot and arid climate. LEED is probably not the most appropriate building rating system that should be used in Dubai but is popular and encouraged by the government, perhaps because of a lack of a more climate appropriate system.

The Dubai Green Building Regulations (DGBR) were developed recently and made mandatory for all new buildings in 2014. The three major components of the building rating system are: ecology and planning, building vitality and resource effectiveness. These regulations have been recently revised and renamed as Al Safat. Although it seems like the DGBR are more climate appropriate and being advocated for at a wider scale, anecdotal evidence suggests that it lacks a stringent implementation framework to ensure it helps buildings to reduce their energy use.

Figure 7.6 – A street in Dubai Sustainable City
Source: Luca Locatelli, Instiute of the National Geographic

7.6 Challenges

• The State of Energy Report recognizes that Dubai's infrastructural development and rising population has increased energy demand. The population will continue to rise challenging Dubai to cope with the rising energy demand.

• The strategy focuses on increasing renewable energy supply and decreasing energy demand. However, reducing energy demand is very challenging in Dubai because of the demographic composition. About 90% of the population of Dubai are not citizens and are long term or short term 'residents'. A residence permit is linked to the employment contract and needs to be renewed every 3 years. There are very few exceptions through which expats can be residents in Dubai without being employed. Therefore, most of Dubai's population is considered as 'transient'. The property market in Dubai is thought of as a good investment opportunity and most home owners (apartment or villas) don't always live in the houses they purchase. This trend is similar across other 'property hotspots' like New York, London or Paris. About 15-20% of property owners in Dubai are out-of-towners (Nair, 2015). In a poll with 11,000 residents of Dubai it was found that about 70% live in rented apartments (Barnard, 2016). Utility bills are always paid by the tenant in Dubai who are not always long-term residents. The motivation to take steps to upgrade an individual home to be more energy efficient is therefore very low and poses a big challenge for decision makers.

• Studies have shown that solar power is the renewable energy source with the largest potential in the UAE. However, to make it a viable solution for centralized and decentralized energy production, some technological challenges still need to be overcome. An efficient cleaning system is needed for the proper functioning of solar panels. Improper cleaning of panels can reduce efficiency by almost 30-40 % in just one month (DIES, 2016). Additionally, the energy footprint of solar power is still much higher when compared to fossil-based energy.

• The strategy does not take a strong position about desalination of water. This is an important area that should receive more attention. Desalination of water uses about 30% of the city's power. Currently, electricity generation and desalination of water occur in the same cycle. Natural gas (or oil) is used to produce electricity. Heat is a by-product of this process and is used to desalinate water. It was found that if renewable energy is used to replace natural gas the savings in GHG emissions is not significant. With 10% of renewable energy input a 2.46% reduction in GHG emissions is observed and with 80% renewable energy input 16.70% of GHG emissions is observed. The efficiency of these plants is measured as per the power to water ratio of the cycle. Electricity needs to be supplied as per the demand and water is desalinated as an outcome of this process. In summer the electricity demand for cooling is much higher than in winter (almost double). However, the water demand remains steady. In winter, more energy is needed for desalination to meet water demands. There are two options to overcome this – reduce water demand in winter or split the cycle. Electricity can be produced using CSP (concentrated solar power) or PV (photo voltaic). These technologies can also be scaled down and used for decentralized electricity production. Reverse osmosis is a process that requires only electricity to desalinate water and requires the least amount of energy when compared to other options (MSF and MED). When the cycle is split, the input of renewable power has a bigger impact on energy savings and reducing GHG emissions (P.Lin et. al, 2011). Making a big technological shift in the current energy system will be beneficial for Dubai and they must take steps to prepare for this.

7.7 Key take-aways – What are the considerations going forward?

• Within the energy governance model, the Dubai Municipality plays a role in executing the strategic direction of energy policy as set out by the Supreme Council of Energy. Changes in the planning processes in the last few years have resulted in the passive role of the Dubai Municipality in urban decision making as development rights were delegated to other entities (chapter 5). The Dubai Municipality is still considered the central decision body for enforcing regulations when it comes to environmental sustainability such as buildings codes (for example Al Safat). But they do not always have the power to influence where development can occur and what urban characteristics it holds. These decisions are heavily influenced by the market and economic policy orientation. Spatial conditions of a city have a big influence on energy demand and without addressing that, the goal to decrease consumption by 30% through demand management may not be possible. The Dubai Municipality is the only stakeholder in the energy governance model that can have an influence on the spatial pattern of the city. Most of the other stakeholders work within economic or political conditions that impact energy use. For example, the RBS is pushing to create a market for Energy Service Companies, Energy Auditors and increasing private sector share in energy generation. Other stakeholders such as Dubai Petroleum Affairs or ENOC are more concerned with securing the energy supply for the city. The forms and functions of the urban fabric can impact energy demand and efficiency and the role of the Dubai Municipality should not be underestimated. They should take a bigger role in integrating planning processes and strengthening environmental and energy regulations.

• Energy subsidies for electricity and transportation fuel has exacerbated energy consumption patterns in Dubai. Also, about 10% of the population (UAE nationals) in Dubai pay a fourth of the price of electricity and water tariffs when compared to the remaining 90% (expats). When the price of energy seems 'subsidized' the tendency to consume it is much higher. As our global society faces the serious threats posed by climate change, we need to ask ourselves if we can bear the environmental costs of subsidizing the use of energy which is mostly powered by non-renewable fuels.

• Some policies and goals put forward in the energy strategy in 2014 changed in just a few years r. For example, the contribution of renewables in the energy mix was increased to 44% (in January 2017) or providing financial incentives to encourage the switch to electric cars (in September 2017). The policies moved towards increasing renewable energy production and reducing transportation related emissions – aspects that are favourable to the energy transition. This can be because the UAE ratified the Paris Agreement in the previous year (September 2016) and felt the pressure to respond to that.

• Financial incentives were not the first choice to promote a change in travel behaviour for Dubai's residents. This is clearly stated in the Energy Strategy, showing that transport policies to reduce GHG emissions and energy use are not aggressive enough. However, three years after the publication of the energy strategy incentives to promote the switch to electric cars were implemented. Financials incentives were recognized as a necessity, but these incentives are still not strong enough to tip the scales in a big way.

• In the energy strategy, Mohamed Bin Rashid Solar Park is considered as a breakthrough in Dubai's energy transition. The first phase of the park covers about 59 acres which can power about 500 residences. No new projects that push for renewable energy power have been announced after this park. The reliance on MBR Solar Park to carve the pathway to cleaner and efficient energy system in Dubai is very large. But, this solar park doesn't contribute meeting Dubai's energy needs (less than 1%) in a big way.

Background Image – Masdar City
Source: Luca Locatelli, Instiute of the National Geographic

Note: All facts and figures in this chapter are sourced from the State of Energy Report, 2014 (unless mentioned otherwise) sourced from this website: http://www.undp.org/content/dam/rbas/doc/Energy%20and%20Environment/The%20State%20of%20Dubai's%20Energy%20and%20Its%20Path%20to%20Green%20Economy.pdf

Dubai Urban Masterplan

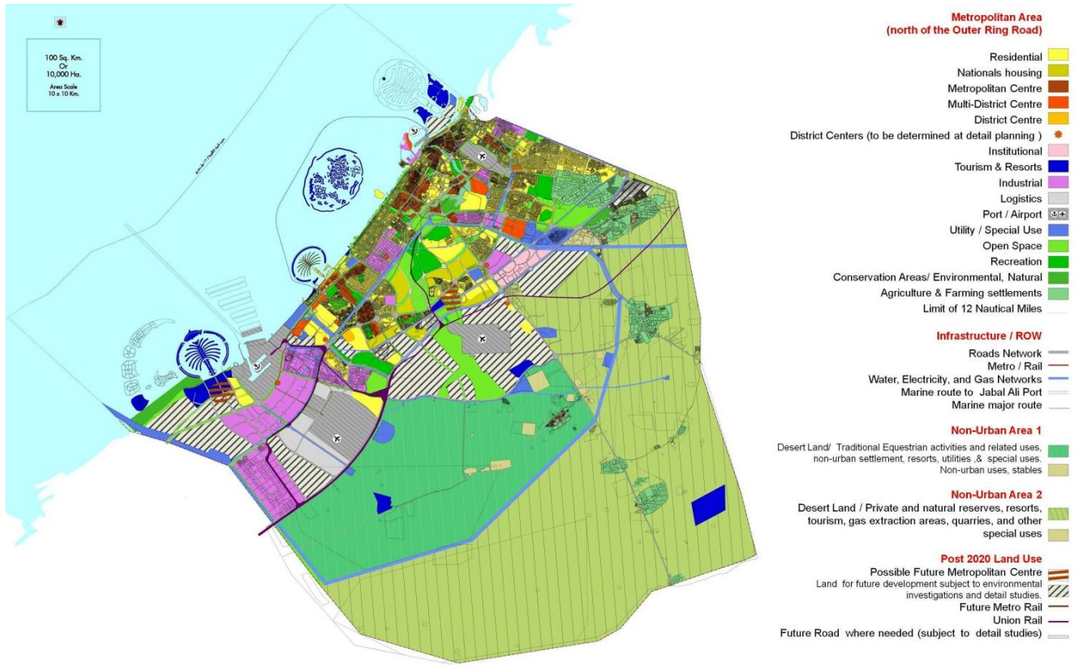


Figure 7.7 – Extracts from the Dubai 2020 Urban Master plan

The 2020 Dubai Urban Masterplan was officially published in 2012. The summary report highlights the important aspects of the plan and the details of this are discussed in chapter 5 on page 36. This analysis will focus on discussing aspects of the plan that might contribute to energy efficiency. It should be noted the Masterplan does not discuss any aspects of energy systems to be incorporated within the urban development plans. Economic and transportation infrastructure form the backbone of the plan. In a lot of ways this Masterplan is a follow up of the pre-2008 plan and lays out a framework of megaprojects that are still feasible to implement after the financial crash.

Compact development

The original planned aimed to cater to a population of about 9.5 million inhabitants. The compact growth scenario that was chosen in this Masterplan suggest a more conservative population growth of about 1.5 million. This can also have a beneficial impact on energy efficiency as transport related energy use will be reduced.

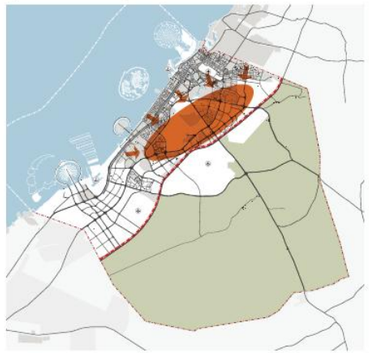
Transit – Oriented – Development

The plan promoted the need for transit-oriented-development especially along new corridors. This is strongly advocated for from an economic perspective as infrastructure to support economic activity such as tourism or industrial development is prioritized in the plan.

Emissions from economic development

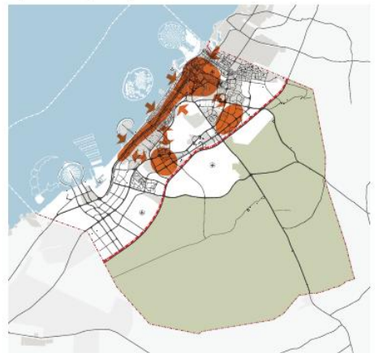
Dubai's GDP is contributed to in a big way from aviation related activities (25%) from the two airports, real estate development (22.6%) in mega projects and trade at Jabel Ali Port and finance (40%). These industries require a large amount of energy and have high GHG emissions. The impact of these economic activities concentrated in a few parts of the city cannot be ignored.

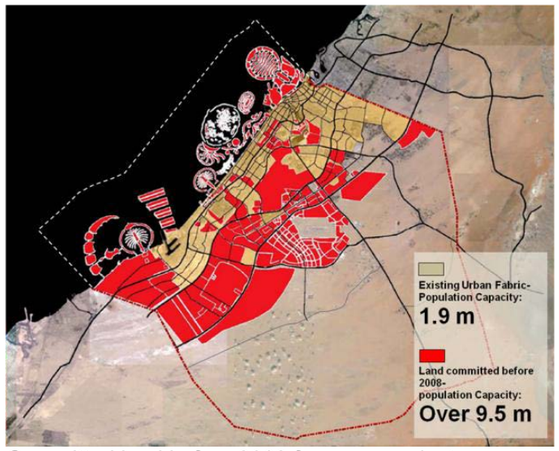
Option 1- Suburban Expansion



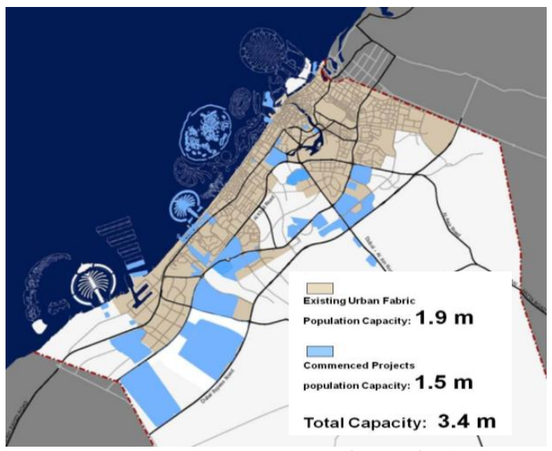
Option 2- Compact City

Option 3- Compact City



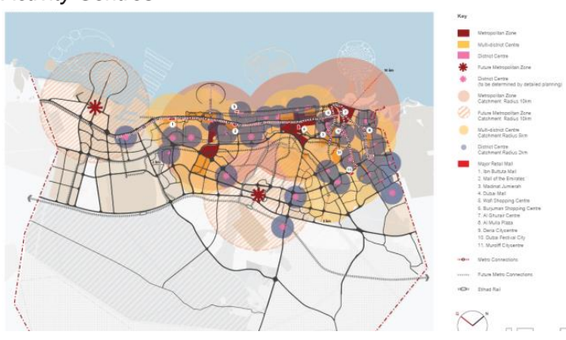


Committed land before 2008 for mega projects

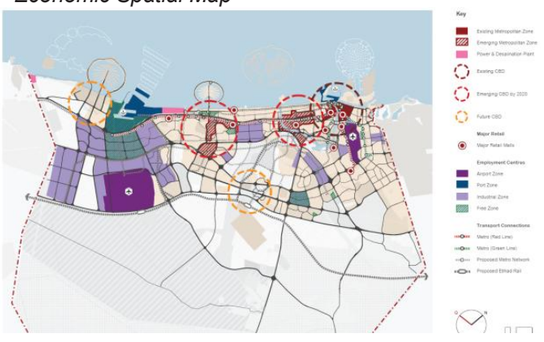


ongoing projects

Activity Centres

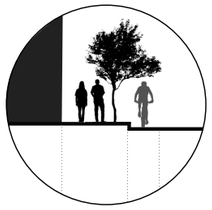


Economic Spatial Map



Fragmentation of policies

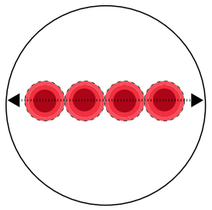
To further illustrate the disconnection and fragmentation of decision making and planning processes in Dubai, the different aspects of the evaluation framework are linked to documents or policies put forward by different government entities in Dubai. Although all these policies are not discussed with the intention to help with the energy transition, they contribute to improving energy efficiency as well.



1 Promote active travel

Dubai Bicycle Masterplan

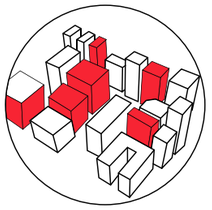
Authority
Roads and Transporation Authority



3 Promote Transit Oriented Development

Dubai 2020 Urban Masterplan

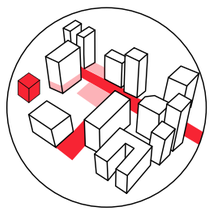
Authority
Dubai Municipality



4 Promote Compact Development

Dubai 2020 Urban Masterplan

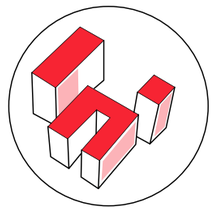
Authority
Dubai Municipality



5 Transport Demand Management

Dubai's Energy Strategy

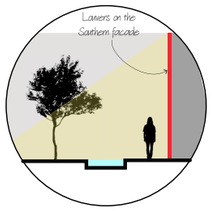
Authority
Roads and Transportation Authority & Dubai Supreme Council of Energy



6 Increase RE supply

Dubai's Energy Strategy

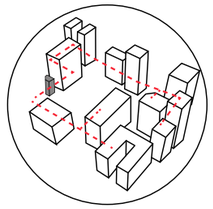
Authority
Dubai Supreme Council of Energy & Regulatory and Supervisory Bureau



7 Designing with the urban microclimate

Al Safat Building Regulation

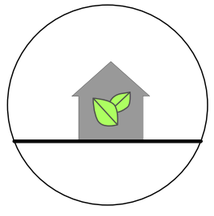
Authority
Dubai Municipality



8 Implement district energy systems

Dubai's Energy Strategy

Authority
Dubai Supreme Council of Energy



10 Using building rating system

Al Safat Building Regulation

Authority
Dubai Municipality

Chapter 8

Neighbourhood Analysis

This chapter present the analysis for two neighbourhoods in Dubai – Mizhar and TECOM. The analysis discusses the urban decision-making model, stakeholders, energy demand and tariffs, public transit connectivity, pedestrian walkability, building form and energy systems. The situation in both neighbourhoods are compared and issues that need to be considered for the energy plan are highlighted. The results of the analysis have helped to inform the proposed recommendations for both neighbourhoods. The chapter concludes with a summary table of the analysis.

TECOM

Figure 8.1 (left)- TECOM C
Source: http://whatson.ae/dubai/2016/06/tecom-has-been-renamed-as-barsha-heights/

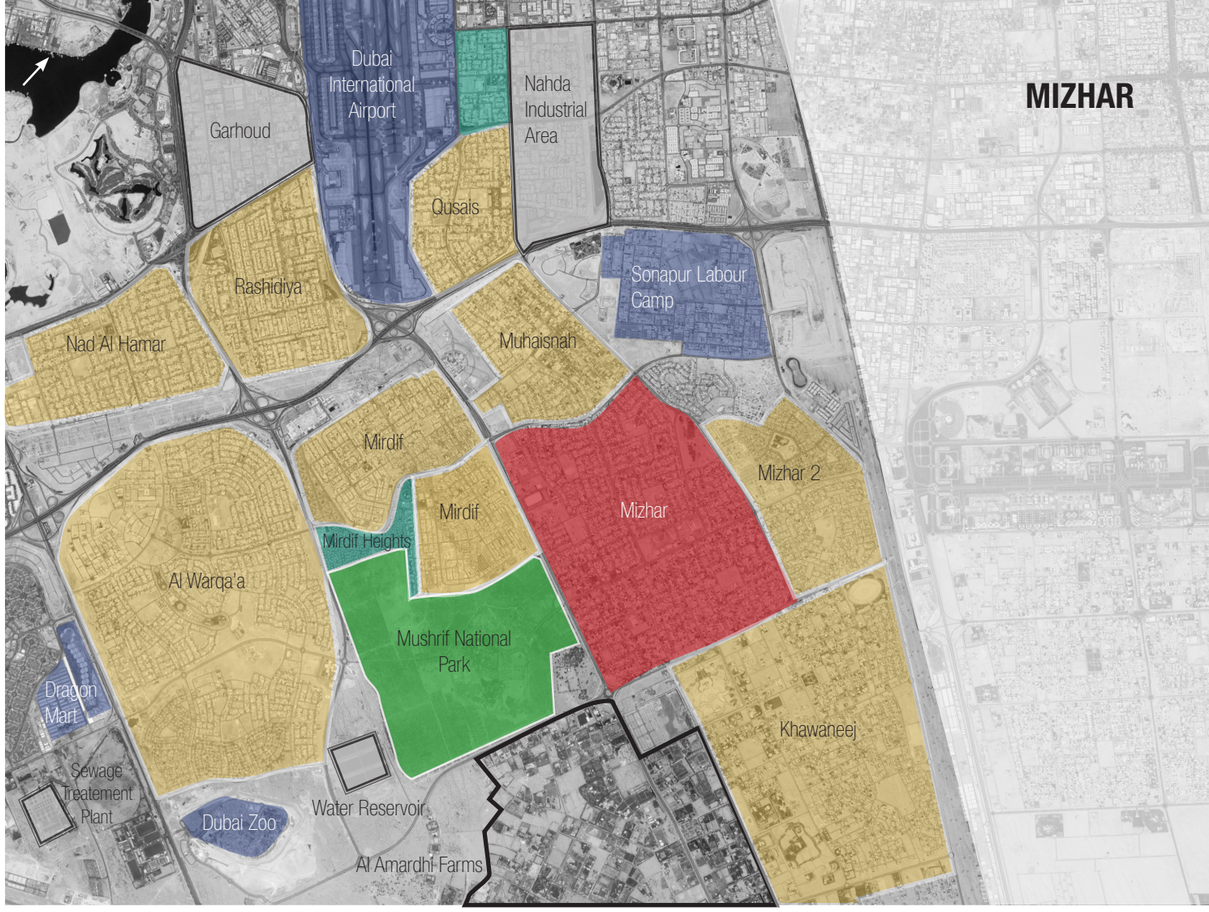
Figure 8.2 (right)- TECOM A - Dubai Internet City aerial view
Source: http://tecomgroup.ae/media-gallery-dubai-internet-city/

TECOM is located along the coast just off the Palm Jumeirah. The Sheikh Zayed Road, which is one of the major highways in the city runs through TECOM. TECOM is divided four zones called TECOM A, TECOM B, TECOM C and TECOM D and is intended to be a TOD area. In this project, the two bigger sites – TECOM A and TECOM C will be considered.

TECOM A lies on the northern side of Sheikh Zayed Road and is has predominantly commercial land use with many office blocks and hotels. A few schools and residential buildings are also a part of this area. This area has mostly medium to high rise buildings with a few (manmade) water bodies. The main highway that connects to Palm Jumeirah runs through TECOM A. DIC (Dubai Internet City), DMC (Dubai Media City), KV (Knowledge Village), American University in Dubai, Dubai College, Choueifat School and residential villas are a part of TECOM A. TECOM C lies on the southern side of Sheikh Zayed Road and is predominantly residential land use and has some hotels and hotel apartments. This area has mostly high-rise buildings with apartments (fig 8.1).

Dubai Marina, a high rise residential mixed-use area, the Emirates Golf Club, Jabel Ali Racecourse and residential areas of Al Soufouh, Al Barsha and the Green Village are the neighbourhoods in the immediate surrounding of TECOM.

MIZHAR



Mizhar is located inland in the south-east of Dubai just south of the 311, a major highway that connects the northern emirates (Dubai, Sharjah, Ajman, Umm Al Quwain and Ras Al Khaimah). It is close to the border between Dubai and Sharjah.

Mizhar is a low-density, low-rise area with a dominant residential use. Two malls – Arabian Centre and Mizhar Mall are the biggest commercial uses in this area. Other uses include government offices, a convenience store, petrol station and schools.

Al Mushrif Park (a national park), the residential areas of Khwaneej, Muhaisnah and Mirdif, farms in Al Amardhi and Sonapur, the biggest labour campsite in Dubai are in the immediate surroundings of Mizhar. The northern side of the 311 connects to Dubai Airport, Rashidiya, Nad Al Hamar and Qusais. Most of the residential areas surrounding Mizhar have similar characteristics as Mizhar i.e. low-density, low-rise residential areas except Sonapur, Mirdif City Centre (a big mall) in Mirdif and uptown Mirdif heights (medium rise residential area).

Figure 8.3 (left) - The entrance of a residential villa in Mizhar

Figure 8.4 (centre) - Shops outside a Mosque

Figure 8.5 (right) - Street view of an inner road

Source: Author

URBAN DECISION MAKING

TECOM

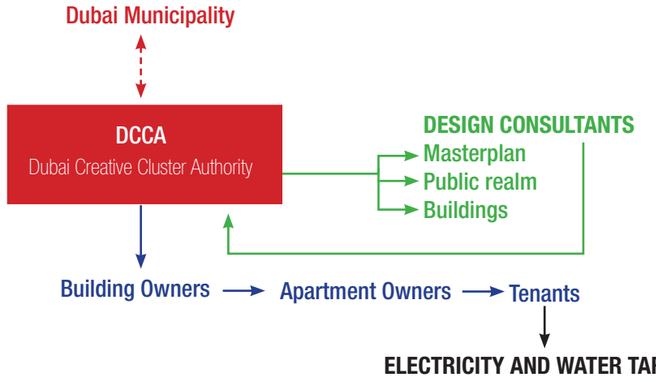


Figure 8.6 - Urban decision making model in TECOM
Source: Author

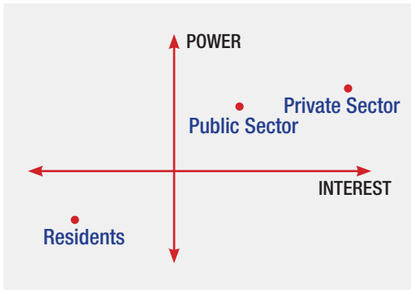


Figure 8.7 - Stakeholder Analysis
Source: Author

The land use map of TECOM is developed and maintained by the DCCA. It lays out the allowable land uses, permitted building heights and plot boundaries within TECOM. Communication and feedback with the Dubai Municipality about the design and implementation of TECOM is minimal.

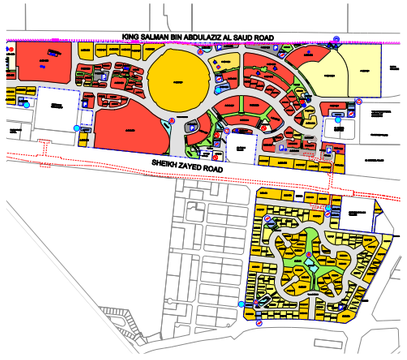


Figure 8.8 - Land use map of TECOM
Source: DCCA

TECOM falls within the jurisdiction of Dubai Creative Clusters Authority (DCCA), which means that they hold the responsibility to coordinate the design and implementation of the neighbourhood. The DCCA is a free zone authority and is responsible to issue building permits and business permits in the area. The DCCA appoints design consultants, generally for three different parts – masterplan, public realm design and building design. The consultants are expected to adhere to the requirements put forward by DDCA and follow up with them for approvals, but follow the basic mandatory requirements for building heights, parking, set-backs and building codes as per the requirement of the Dubai Municipality.

TECOM is a free zone area which means that properties in the area are available for sale to the private sector.

Buildings and apartments can be bought by individuals or businesses. These are then rented out to tenants who generally live here for a short period of time. The tenants pay the electricity and water tariffs (fig 8.6).

Although the DCCA is a public entity, being a free zone area gives the private sector a stronghold as well. Residents in this area (TECOM C) are usually expats who live here on a short-term basis. TECOM A is mostly an office area which is generally occupied only during work hours and does not have many residential buidings. Residents therefore don't have much of a power or interest to influence change (fig 8.7).

MIZHAR

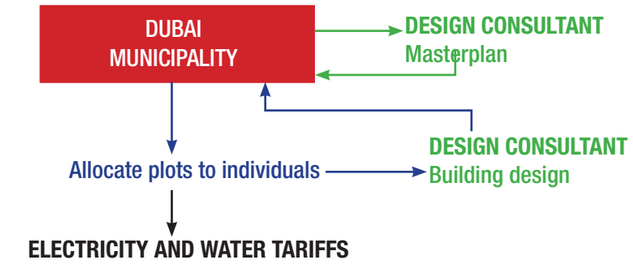


Figure 8.9 - Urban decision making model in TECOM
Source: Author

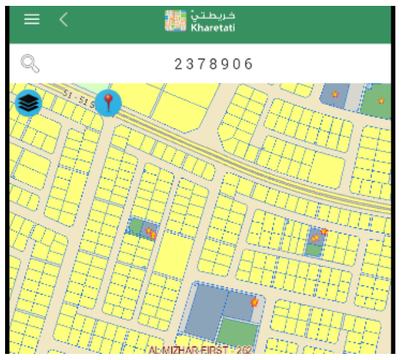


Figure 8.10 - Land use map of Mizhar
Source: Kharetati

The land use map of Mizhar is prepared and updated by the Dubai Municipality. This image was retrieved from the app 'Kharetati' which is the first open source database about plot details provided by the Municipality. The area of TECOM is not available on this app suggesting that the Dubai Municipality has a small role to play in areas that fall under the DCCA.

Mizhar falls within the jurisdiction of Dubai Municipality and is a residential area for Emiratis. Housing in this area falls under national housing scheme (details in box). The Dubai Municipality is responsible of designing the masterplan and assigning individual building permits. Individual plot owners are responsible to appoint an architect and contractor to build and construct their home. The land outside individual ownership belongs to the government who builds and maintains the public realm. This responsibility is generally shared between Dubai Municipality and the Roads and Transportation Authority. Privately owned land in this area belongs to Emiratis. The public sector has a stronger hold than the private sector in Mizhar. Although residents can demand change, the interest to do so is generally quite low.

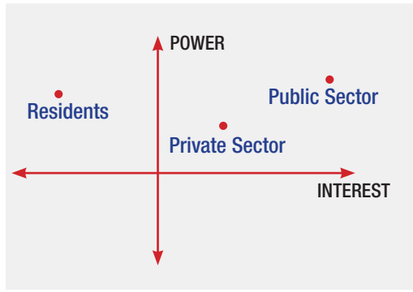


Figure 8.11 - Stakeholder Analysis
Source: Author

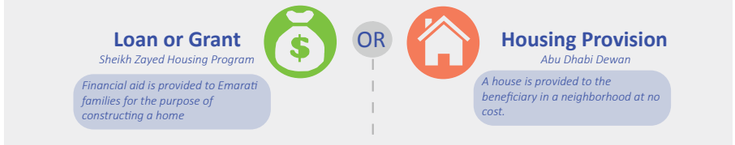


Figure 8.12 - National Housing Scheme
Source: Author

The national government housing scheme provides either a loan or grant to build a house or provides a built home. In the former scheme, land to build houses are assigned to beneficiaries (married Emirati males above the age of 20 or unmarried Emirati females above the age of 30). Homes must begin construction within one year of the assignment to avoid revoking of the provided plot. Land and a loan or grant (depending on the income range) for construction are provided. The eligibility criteria for both schemes are similar, though a preference is given to families with children, widows and females in the latter option. The waiting time for both schemes is where they differ the most. Approvals for financial aid and receiving land for the former scheme takes up to a few months while the latter can take a few years.

ENERGY TARIFF'S AND ENERGY DEMAND

SEASONAL FLUCTUATIONS IN ENERGY DEMAND IN DUBAI

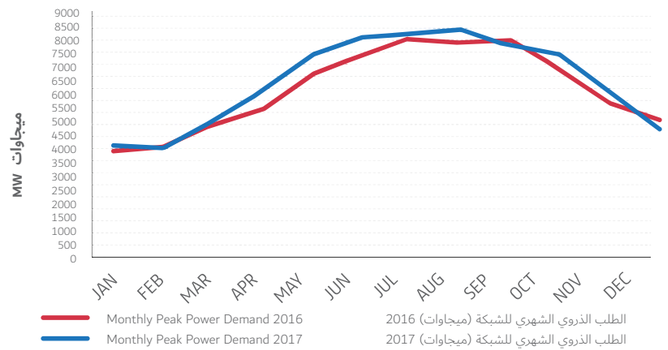


Figure 8.13 - Energy demand per month in Dubai in 2017
Source: DEWA (Dubai Electricty and Water Authority) Aunnual Statistics for 2017

There is a dramatic difference in energy demand in summer and winter months in Dubai as seen in figure 8.13. This is because summer months have a higher cooling demand than winter. This increases energy demand by almost double during summer.

ENERGY TARIFF'S

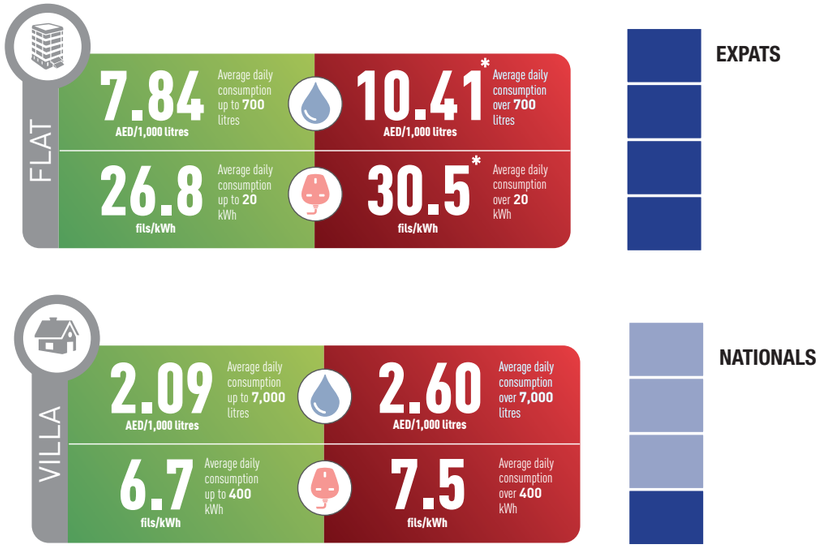
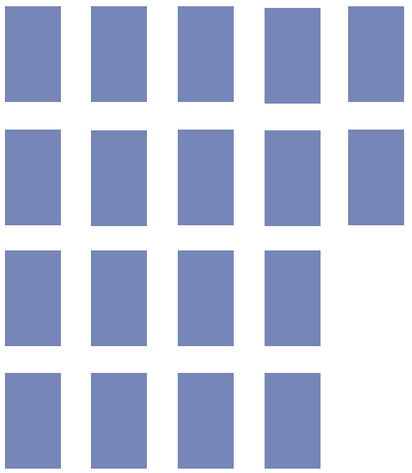


Figure 8.14 - Electricity and water tariffs for nationals and expats
Source: ADDC, 2017

Electricity and water tariff are not the same for nationals and expats in UAE. Nationals pay a fourth of the price for electricity and water as compared to expats. The consumption of energy is subsidized nationals, who comprise of 10% of the total population of Dubai. The tariffs for flats and villas are same, pricing only differs as per nationality. Mizhar is an area with mostly national population and therefore lower energy tariff than TECOM, which has mostly an expat population.

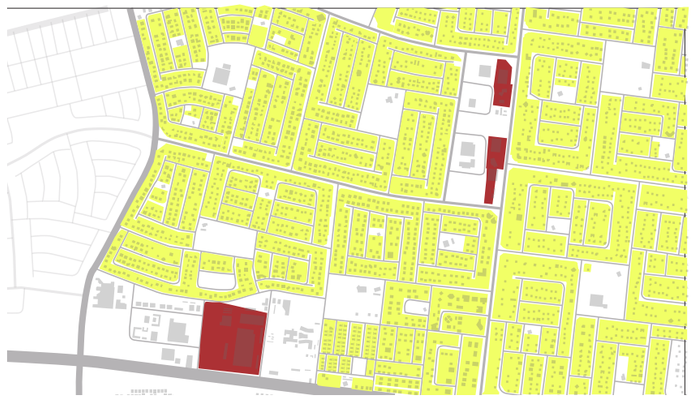
ESTIMATED AREA OF SOLAR PANELS NEEDED TO MEET ELECTRICTY DEMAND

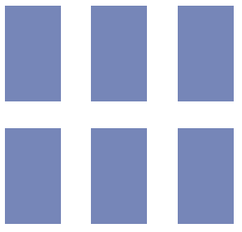
TECOM



Area in square meters = 4,191,923
Area in acres = 1,035
(approximately 784 football fields)

MIZHAR





Area in square meters = 1,432,590
Area in acres = 354
(approximately 268 football fields)

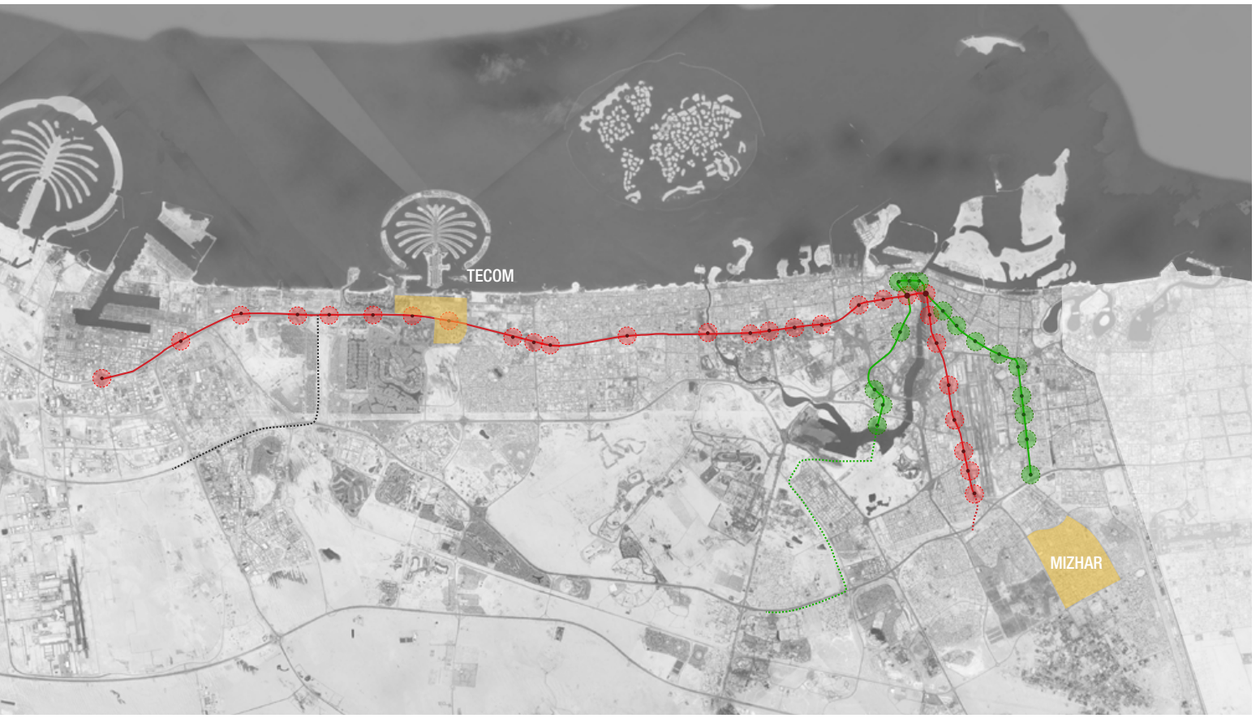
The energy demand for both areas is estimated based on the number of solar panels that are needed to meet electricity supply in the neighbourhoods. The calculation was carried out using the following data.

1. The capacity of the existing solar park in Dubai. As per the DIES (Dubai's Energy Strategy), 59 acres of solar panels can supply electricity to 500 residences.
2. Average daily electricity consumption estimates for different land uses (residential, commercial and hotels) provided by the DCCA. These estimates are used to calculate the total electricity load to determine the capacity of the sub-station.
3. Gross floor area of the different land uses (also provided by DCCA for TECOM) and their associated electricity demand.

The estimated electricity demand was then equated to the number of solar panels that will be needed (from 1). Mizhar required about a third of the number of solar panels as compared to (a major area) of TECOM. This helps to indicate an estimate of the energy demand of both neighbourhoods which can be attributed to land use and morphological differences.

TRANSPORT

PUBLIC TRANSIT CONNECTIVITY



The Dubai Metro was inaugurated in 2009 and has two lines- the green line and the red line. The red line runs along Sheikh Zayed Road and ends at the Dubai Airport. The green line runs along both sides of the creek in the denser city centre. The tram line in Dubai cover a much smaller areas and connects Dubai Marina with Al Soufouh. Apart from the metro and tramline, Dubai also has a bus transport system.

The proposed extension of the metro will reach the EXPO 2020 site and Mirdif City Centre. Currently, the extension that connects to the EXPO site is 50% complete. Other proposed extensions are yet to be approved.

TECOM lies along the red line and has two stops along the Sheikh Zayed road serving both TECOM A and TECOM C sites. The closest metro station next to Mizhar lies on the other side of the 311 and is not easily accessible or walkable. This is not likely to change anytime soon as there are no proposed metro extensions that will be able to serve Mizhar.

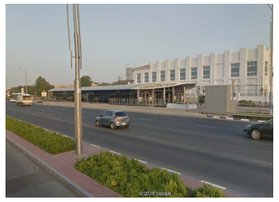
Figure 8.15 - The neighbourhoods impacted by the extension of the red metro line
Source: RTA
https://www.thenational.ae/uae/transport/tunnelling-for-route-2020-metro-extension-50-per-cent-complete-1.711786

TECOM

The red line of Dubai metro runs along Sheikh Zayed road and through TECOM with two stops in the neighbourhood. The tram line runs along Al Soufouh and has four stops that connect to TECOM A. There are bus stops in both TECOM A and C. Overall, TECOM is well connected through public transport. The assumed accessibility radius for the metro is 500m and the tram and bus stops are 300m. Figure 8.16 shows the accessibility radius of all the public transit nodes.

Metro

Tram



Bus

Figure 8.16 - Accessibility of public transport in TECOM
Source: Author

Photo source: Google Street View

MIZHAR

When compared to TECOM, Mizhar is poorly connected through public transport. The closest metro stations are on the other of the 311 and the bus system does not run through all local collector roads. Therefore, a large area of the neighbourhood does not have easy access to public transport and would need to rely on cars or walking (for short distances).

Bus

Figure 8.17 - Accessibility of public transport in Mizhar
Source: Author

Photo source: Google Street View

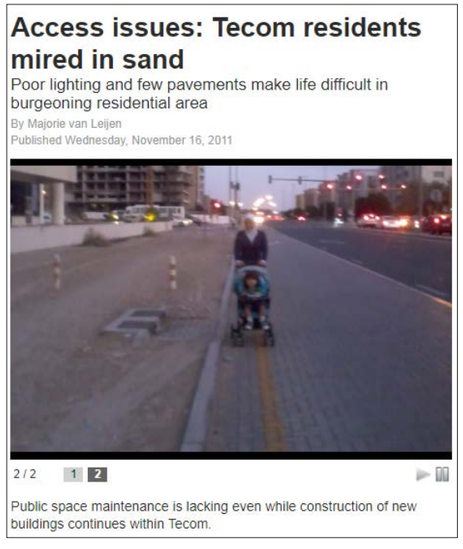
TRANSPORT

PEDESTRIAN WALKABILITY

TECOM

Figure 8.18 - Roads in TECOM
Source: Author

There are four types of roads that vary in the width of the right-of-way in TECOM. The first one is about 100 m wide and has a 16-lane highway. This is the Sheikh Zayed road, which is one of the major highways in the city. Spatially, it divides TECOM A and TECOM C with only two pedestrian connections through the metro stops. The second highway is about 18-23 m wide and connects the outer edge of TECOM with Sheikh Zayed road. The highway that leads to the Palm Jumeirah (which is the only access by road) from Sheikh Zayed road runs through TECOM. None of these highways contain any bicycle or pedestrian infrastructure. The next two roads are inner collector roads. One of them has a wider right-of-way of about 15-18 m and can have either 4 lanes or 6 lanes. This connects to inner streets that are about 10-12 m wide. Pavements along these streets are not always continuous and lack uniformity and quality. Vegetation is sparse with poor lighting (Leijen, 2011 and Teh, 2012). There is no separate bicycle infrastructure on these streets and cyclists need to share the road with cars.



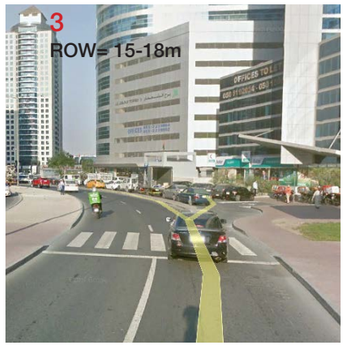
Access issues: Tecom residents mired in sand

Poor lighting and few pavements make life difficult in burgeoning residential area

By Majorie van Leijen
Published Wednesday, November 16, 2011

2 / 2 1 2

Public space maintenance is lacking even while construction of new buildings continues within Tecom.



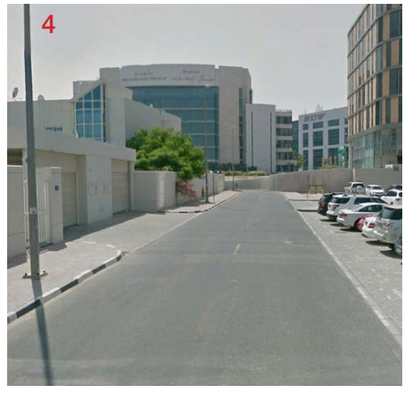


Photo source: Google Street View

TRANSPORT

PEDESTRIAN WALKABILITY

MIZHAR

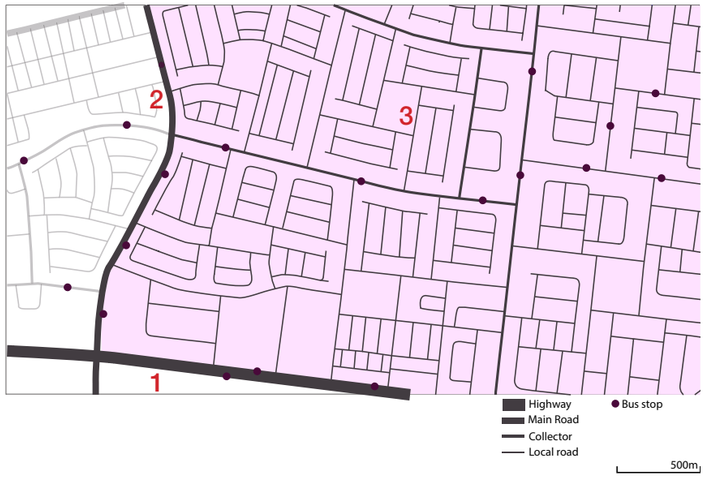
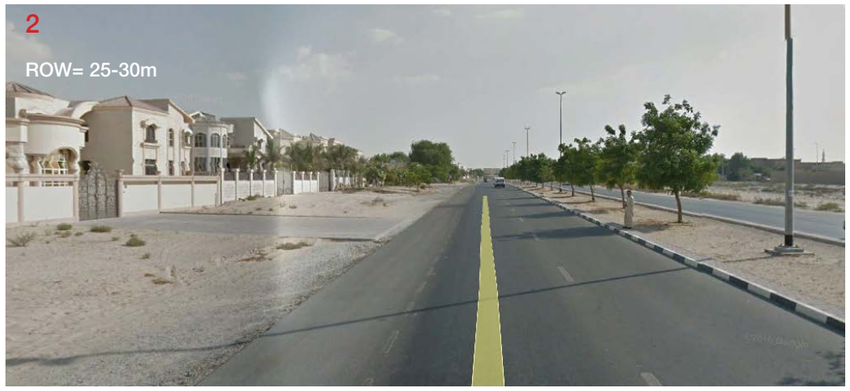


Figure 8.19 - Roads in Mizhar
Source: Author

In Mizhar there are three types of roads that vary in the width of the right-of-way. The first one is between 35-40m wide and is a 6-lane highway that runs on the southern edge of the neighborhood connecting it to the 311. There is no pedestrian or bicycling infrastructure or pedestrian crossings along this road. The next road is about 25-30m wide and connects the inner collector streets of Mizhar to the bigger highways. These streets also lack pedestrian pathways or bicycling infrastructure or pedestrian crossings. There is often a large amount of space between the edge of the road and the property line (up to 15m). This area is often not uniformly managed with no continuous pavements or landscaping. It can either be paved, unpaved or landscaped depending on the property owner. The inner collector roads have a right-of-way of about 15-18m and have similar characteristics. The only difference is in the area between the edge of the road and the property line which is between 3-5m wide. Boundary walls of residences in this area is about 2.75m-3m high.

Photo source: Google Street View



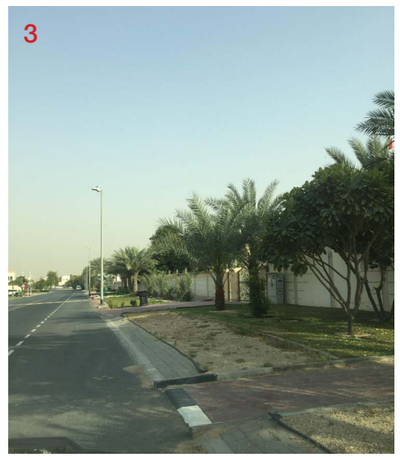


Image captions and sources
Pedestrian crossings in Dubai (top left and bottom left)
Sources: Sathish, 2013 and http://dubaithoughts.blogspot.nl/2009/01/dubai-driving-tips.html

People crossing the road at undesignated areas (top right and bottom right)
Surces: https://gulfnews.com/xpress/pedestrian-deaths-who-s-to-blame-1.1169146 and http://meconstructionnews.com/7220/new-government-campaign-to-discourage-jaywalking-amongst-dubai-labourers

Road Safety in Dubai

Pedestrians account for 30% of road deaths in Dubai (Shahbandari, 2017). Most of these are run-over accidents. Pedestrian safety is a big cause for concern in Dubai and the Roads and Transportation Authority is taking steps increase awareness about pedestrian safety among drivers and pedestrians. Jay-walking – i.e. crossing the road in places apart from a designated pedestrian crossing area- is common and a fine is imposed on offenders.

BUILDING FORM

BUILDING MORPHOLOGY AND FLOOR SPACE INDEX

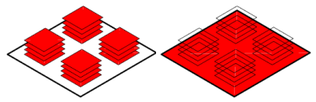


Figure 8.20 - Gross floor are and total area
Source: Berghauser. P & Haupt, P.A. (2009)

Mizhar has mostly low rise residential villas with a few larger commercial buildings and schools. The maximum height of any building in this neighbourhood does not exceed 3-4 storeys as it also falls within the aviation restriction of Dubai Airport which is about 5 km away. TECOM has predominantly high rise residential and commercial buildings. Commercial buildings have a large footprint and are generally medium-rise buildings. Some low rise residential villas are also a part of TECOM although they are not administered by the DCCA.

FSI can be viewed as a tool to measure compactness of both the neighborhoods. More compact development reduces the transport demand and its related energy use and emissions. Therefore, higher the FSI or land use intensity, higher is the efficiency of land consumption and lower is the transport demand associated with it.

FSI is a measure of building intensity that is calculated by dividing the gross floor area by the total floor area. This calculation does not consider the program of the area (Berghauser and Haupt, 2009).

TECOM has a higher FSI as compared to Mizhar which is much lower. Public transit connectivity is also much higher in TECOM than Mizhar indicating that transport related energy use and emissions are much lower in TECOM.

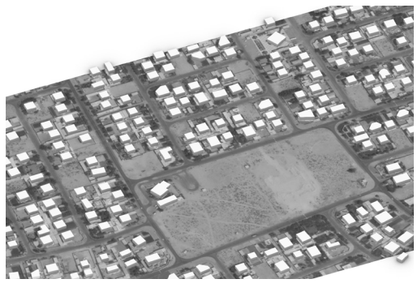
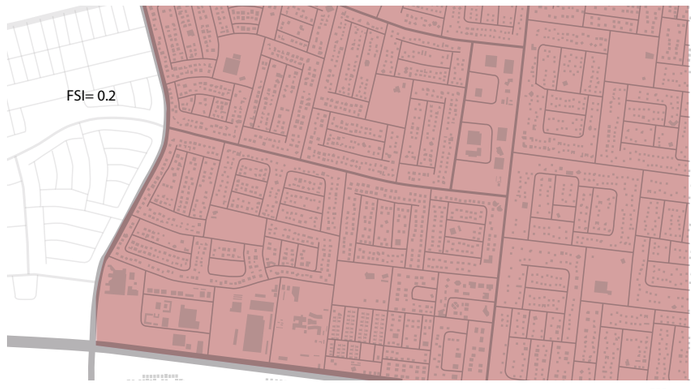


Figure 8.21 - FSI and building morphology
in MIZHAR
Source: Author

MIZHAR



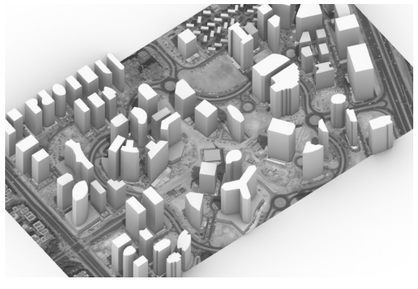
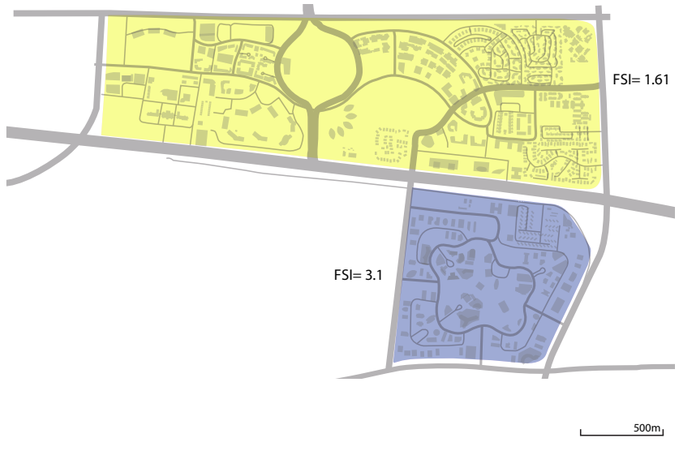


Figure 8.22 - FSI and building morphology
in TECOM
Source: Author

TECOM



BUILDING FORM

URBAN MICROCLIMATIC DESIGN

Jabareen (2006) puts forward six areas that need to be considered while designing for the urban microclimate. These are built form, street canyon, building design, materials and surfaces, vegetation and water and roads.

Built form

The surface to volume ratio (fig 8.23) is indicative of the building envelope that is exposed to the outside environment which needs to be treated. Different configurations can have a differing effect on shadow density (fig 8.24) and should be considered while designing the building. Transitional spaces between indoors and outdoors require extra attention.

Street canyon

The street canyon needs to consider the width-to-height ratio of streets to buildings which determines the SVF (sky view factor) of streets. The orientation of streets according to the prominent wind direction can help with increased ventilation to improve on surface temperatures.

Building design

Figure 8.28 shows the different passive design techniques implemented in a villa in Dubai Silicon Oasis. The results of the study found that when these techniques were employed, cooling demand decreased by 9% and total energy consumption by 23.6% (Taleb, 2014). This is a significant amount and should be incentivized in building design.

Vegetation and water

Figure 8.27 should the land surface temperature mapped in Dubai on a summer morning (July 13th, 2013 at 10:40 am) in °C. Areas closer to the coast are generally cooler than neighborhoods inland. Vegetation and the presence of water bodies can impact this and should be considered. A study by Wong et.al (2010) found that between the three parameters - vegetation, building footprint and building height, vegetation has the biggest impact on improving local microclimate.

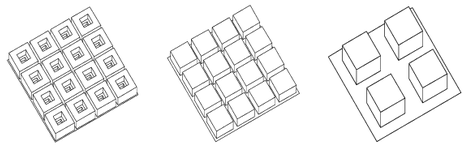


Figure 8.23- Surface to volume ratio indicative of the building envelope that is exposed to the outside environment

Source: Ratti et. al (2003)

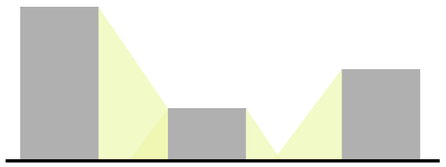


Figure 8.24- Shadow density on streets due to building heights and form

Source: Author

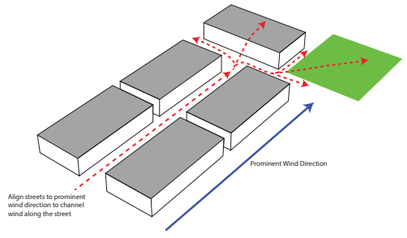


Figure 8.25- Street canyon - orientation and width to promote wind movement

Source: Author

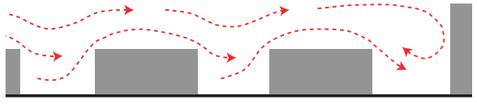


Figure 8.26 -Free-standing buildings also intensify incoming winds and should be considered in public space design

Source: Author

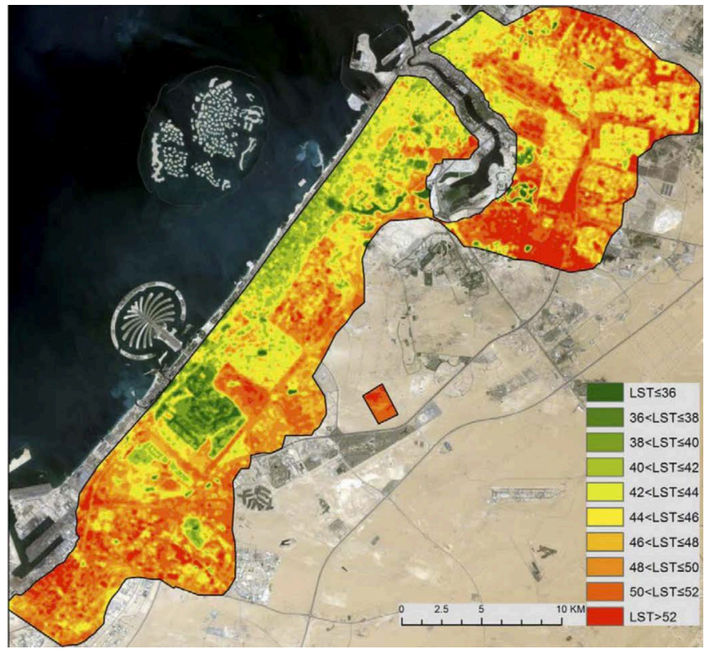


Figure 8.27- LST (land surface temeperature) map for Dubai recorded on July 13th, 2013 at 10:40am.

Source: Nassar et. al, 2016

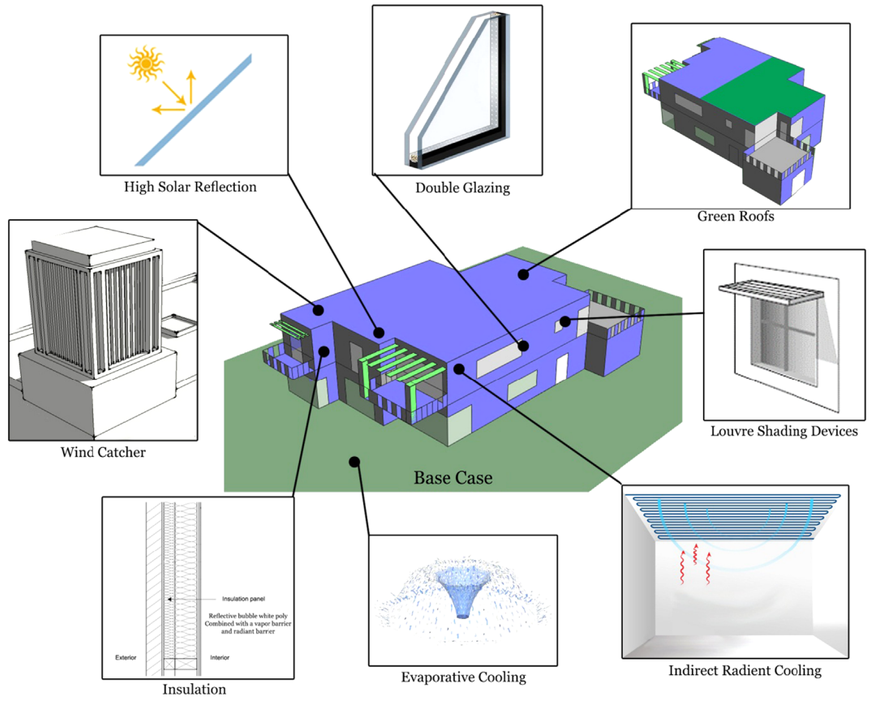


Figure 8.28- A study of the impact of passive design techniques on a villa in Dubai Silicon Oasis.

Source: Taleb, 2014

BUILDING FORM

DISTRICT ENERGY SYSTEM

In Dubai, district cooling systems increase the efficiency of cooling networks as chilled water is produced centrally and then distributed to buildings to be utilized in individual AC (air-conditioning) systems. The functioning of AC systems generates warmer water which is sent back to the district cooling plant to be chilled. District cooling plants can increase their efficiency by installing a thermal storage unit (figure 8.32). A thermal storage unit helps to manage demand better as it is capable to store chilled and warm water. This helps to reduce the size of the cooling plant as added storage means that the plant can produce chilled water at night when ambient temperature is low and chiller efficiency is high. This way the plant needs to be designed as per average demand and not peak demand (Berbari, 2016).

When TSE (treated sewage effluent) is used the cost of district cooling is significantly lowered as TSE costs one-tenth the price of desalinated water. Since TSE is rich in nitrates and other dissolved minerals it increased the efficiency of the district cooling plant (Berbari, 2016).

In Dubai, the thermal storage plant is generally located about 7-9m below the district cooling plant. District cooling plants also prefer to be located next to the electrical sub-station. As per the regulations in Dubai, a district cooling plant needs a separate 11kV connection to an electrical sub-station which is 2.5m wide and 2m deep. Only soft landscaping is permitted on the surface (figure 8.33).

TECOM has district cooling plants in three locations. These are shown in figure 8.31. The cooling plants are located very close to the electrical sub-station.

Figure 8.29- Empower district cooling plant (above)
Source: Google Street View

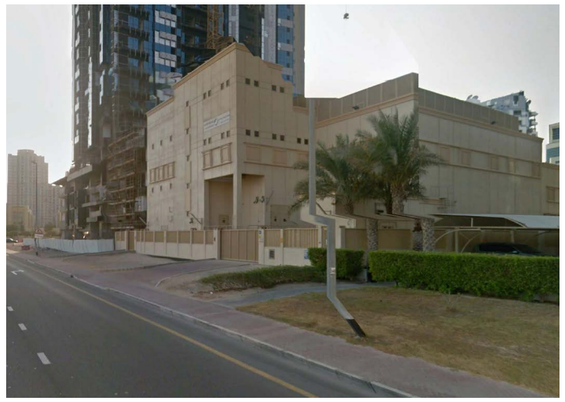


Figure 8.30- DEWA electrical sub-station (above right)
Source: Google Street View

Figure 8.31- TECOM location of district cooling plants and electrical sub-station (right)
Source: Author

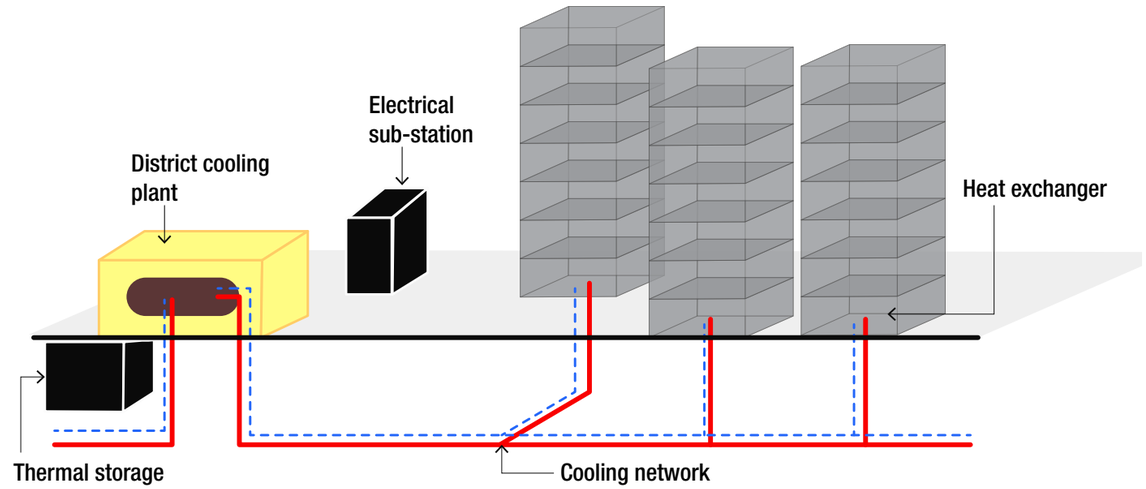


Figure 8.32- Schematic of district cooling plant with thermal storage (above)
Source: Authpr

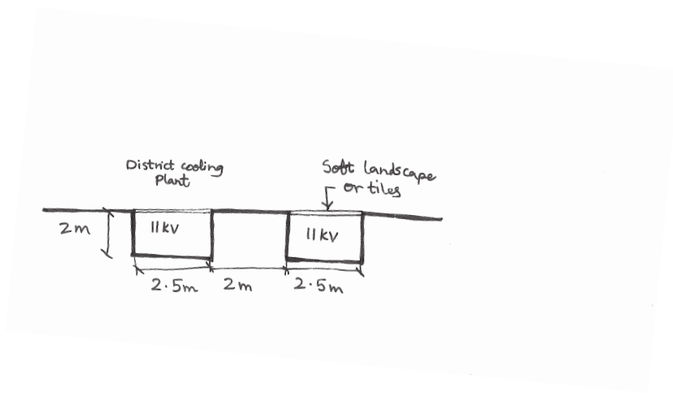


Figure 8.33- Connection between electrical sub-station and district plant as per Dubai regulations (left centre)
Source: Author

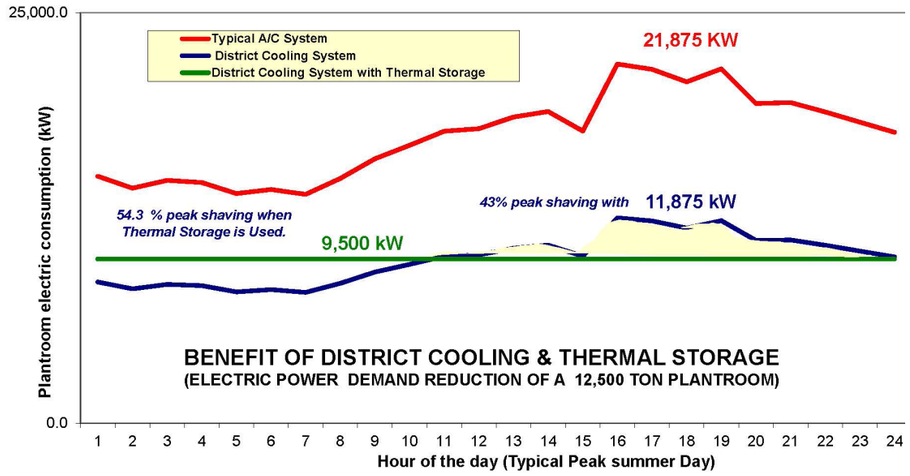


Figure 8.34 - Impact of thermal storage on demand of district cooling plan (left bottom)
Source: Berbari, 2016

BUILDING FORM

GEOTHERMAL COOLING SYSTEM AND VRF's

Geothermal energy can be used in buildings for cooling or heating. For cooling systems, water is circulated through underground piper where heat is dispersed. The water can then be used in the air conditioning system (fig 8.36). This saves the energy that is needed to cool water and helps to increase the efficiency of air conditioning systems. Using geothermal energy system for cooling is a relatively newer concept especially in the middle east but is receiving increased attention in the last 2 years.

Rising AC demand brought on by new construction projects is raising the question of adopting more sustainable cooling systems such as district cooling networks, geothermal energy and VRF's (variable refrigerant flow) (CW, 2017). The commercial AC sector in Dubai is forecast to grow by 3-7% over the next few years (Nambiar, 2017). The gulf region has a lower water table (between 2-7m) which makes it easier to install geothermal cooling systems. Smaller applications such as individual homes can install shallow geothermal systems for heat rejection without hitting the water table. Larger building that have a higher demand will require specialized drilling which can increase the installation cost. Salem et. al (2012) discuss the economic feasibility of using Ground Couple Heat Pumps (GCHP) for buildings in Dubai using the headquarters of Dubai Silicon Oasis (DSO) as a case study. They found that although the installation cost of GCHP's are high, the pay back time is about 8-9 years. The maintenance of air conditioning systems is a minimal and efficiency is much higher when GCHP's are used.

VRF technology has a high potential in the UAE but does not have a very widespread use (Nambiar, 2017). VRF's use refrigerants a cooling medium and are be connected to several ductless AC units in a building. The biggest advantage of installing a VRF systems is that it can operate at the required capacity and rate as needed by the building occupants. For example, if six out of ten rooms/offices are occupied in a building, the system would be able to operate at 60% of the capacity to cool the rooms that are being used (fig 8.37). There would be a 40% energy savings as compared to a conventional AC system which needs to be either on or off. The first VRF system is being installed by Diamond Developers in Dubai Sustainable City in Dubai.

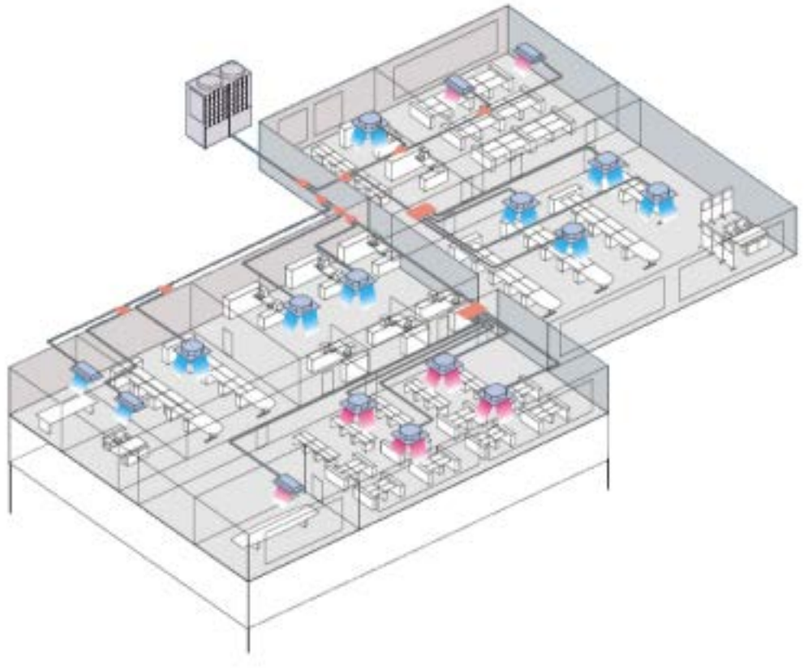


Figure 8.37 - VRF system in a building
Source: http://mitsubishi-heavy-ind.com/

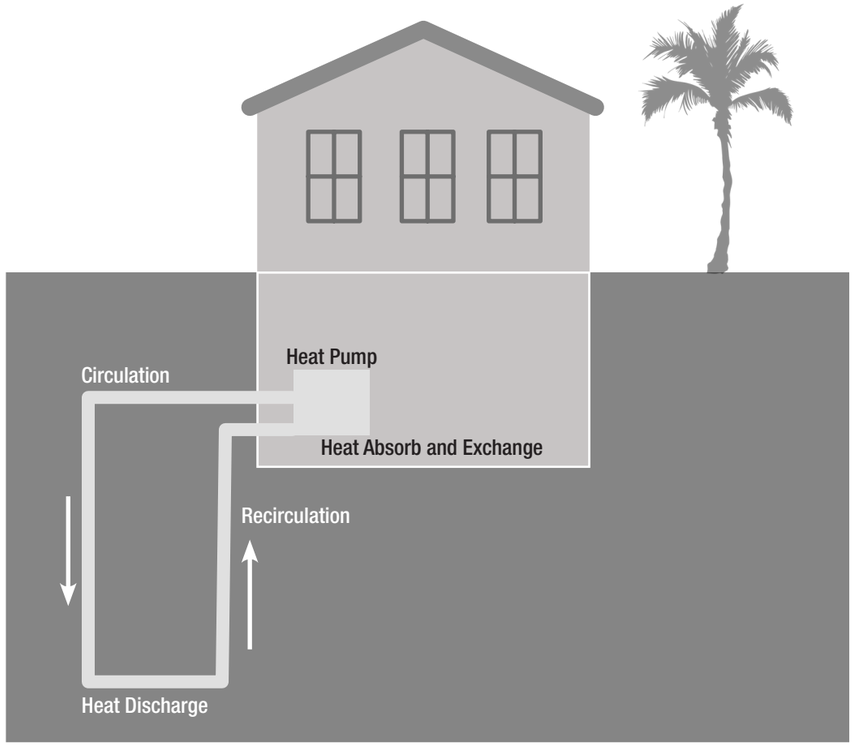
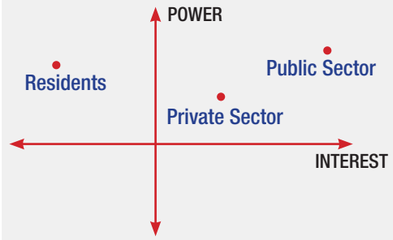
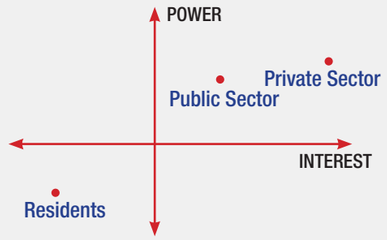
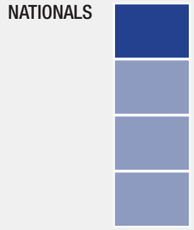
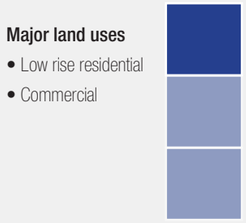
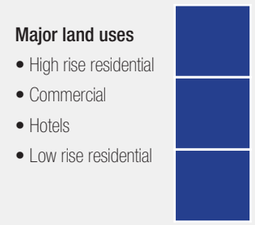
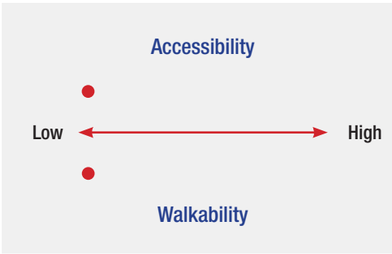
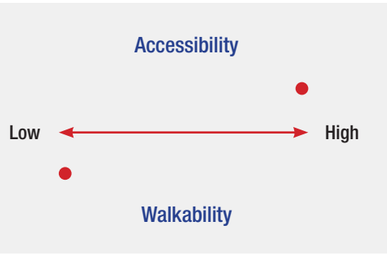
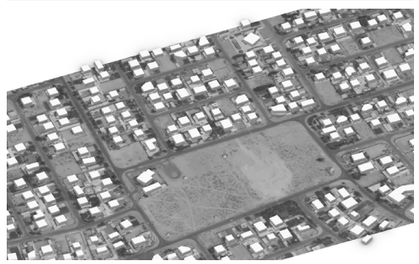
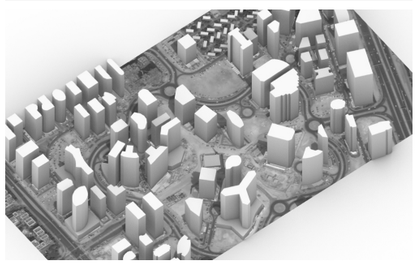


Figure 8.35 - Geothermal Cooling System
Source: Author

Figure 8.36 - A commercial-scale ground source heat pump system.
Source: Craig Miller Productions, NREL

SUMMARY TABLE

	MIZHAR	TECOM
URBAN DECISION MAKING The differences in urban decision making in both the neighbourhoods have influenced the position of the public sector, the private sector and residents. The public sector has a higher influence in Mizhar while in TECOM there is a bigger balance between the public and private sectors. Residents can potentially have a stronger say in Mizhar than in TECOM.		
ENERGY TARIFF Nationals pay a fourth for electricity and water as compared to expats. Tariffs are decided based on the nationality of the tenant. Mizhar is a neighbourhood with predominantly national housing while TECOM has a higher percentage of expats.		
ENERGY DEMAND The energy demand for the neighbourhoods were estimated based on the number of solar panels needed to meet electricity supply. The calculations considered gross floor areas of different land uses, average daily electricity consumption of the land uses and capacity of MBR park. Mizhar has approximately a third of the energy demand as compared to TECOM.		
ACCESSIBILITY AND WALKABILITY Both neighbourhoods have poor walkability as is the case with many other areas in the city. However, TECOM is located is well connected and easily accessible by the metro, tram and bus while Mizhar has a poor bus network.		
BUILDING MORPHOLOGY Mizhar has mostly low rise residential villas with a few commercial buildings and schools. TECOM has predominantly medium-to-high rise residential and commercial buildings. The FSI (or compactness of building form) in Mizhar is much lower than TECOM indicating that travel related energy use and emissions are much higher in Mizhar as compared to TECOM.		

URBAN MICROCLIMATE DESIGN

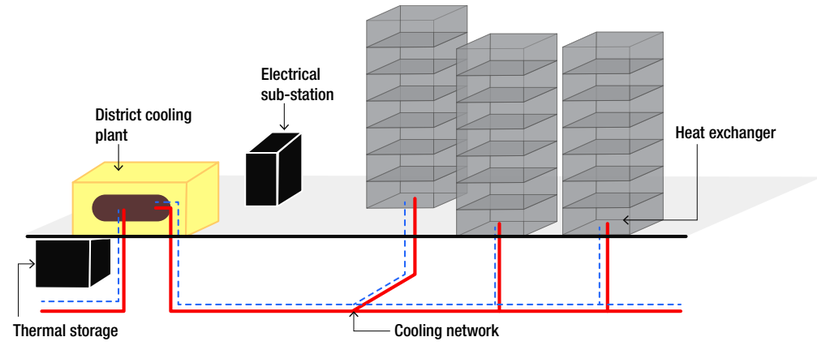
Building Form
Building form needs to consider shadow density and pay extra attention to transitional spaces between indoors and outdoors to reduce thermal shock caused by high temperature differences (almost 30 C) in summer. Passive cooling techniques and light colored materials with an appropriate U value.

Street Canyon
Street canyon should consider the width-to-height ratio of streets and should be oriented to allow for proper wind flow. Shading along the pedestrian part of the street should be mandatory.

Vegetation
A study by Wong et.al (2010) found that between the three parameters - vegetation, building footprint and building height, vegetation has the biggest impact on improving local microclimate. In Dubai, using vegetation extensively as a measure to improve the local microclimate should be carefully considered since humidity levels are high and water stressed conditions make it expensive to maintain lush green vegetation. The use of native plan species for landscaping should be popularized instead.

DISTRICT ENERGY SYSTEMS

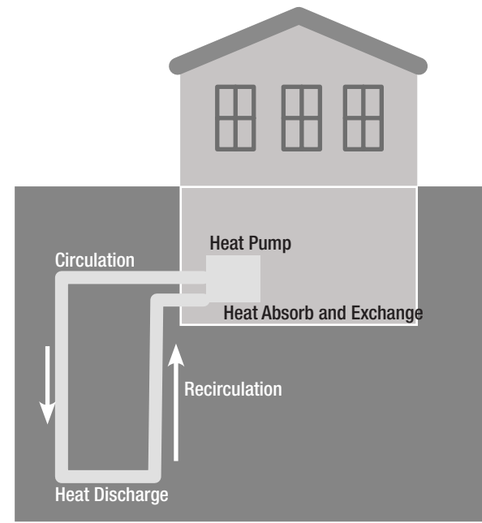
The implementation of district cooling systems for medium-high rise neighbourhoods has gained momentum in past few years in Dubai. TECOM has 3 district cooling plants that distribute chilled water to the air conditioning systems of buildings within the neighbourhood. Using thermal storage, locating district cooling plants next to electrical sub-stations and using treated sewage effluence in the plants helps to improve efficiency and reduce the cost of maintenance.



GEOTHERMAL COOLING AND VRF's

Rising AC demand brought on by new construction projects is raising the question of adopting more sustainable cooling systems such as district cooling networks, geothermal energy and VRF's (variable refrigerant flow) (CW, 2017). The commercial AC sector in Dubai is forecast to grow by 3-7% over the next few years (Nambiar, 2017). The gulf region has a lower water table (between 2-7m) which makes it easier to install geothermal cooling systems. Smaller applications such as individual homes can install shallow geothermal systems for heat rejection without hitting the water table. Larger building that have a higher demand will require specialized drilling which can increase the installation cost.

VRF technology has a high potential in the UAE but does not have a very widespread use. VRF's use refrigerants a cooling medium and are be connected to several ductless AC units in a building. The biggest advantage of installing a VRF systems is that it can operate at the required capacity and rate as needed by the building occupants.



Chapter 9

Recommendations

Dubai faces many challenges to bring about the necessary changes to transition to a more clean, efficient and sustainable energy system. The role of planning in the energy transition is demonstrated at the neighbourhood level in Dubai through an urban retrofit plan. This plan is intended to create conditions that can promote a collective investment in public goods by different stakeholders and create a demand for innovation in climate and cultural appropriate urban design. The components of this chapter are as follows:

Challenges and considerations for the Emirate of Dubai

Planning processes and the extreme desert climate are major issues that must be addressed to challenge norms that don't energy efficiency and plan for long term benefits. Further, considerations for building design, streets and public spaces are also highlighted.

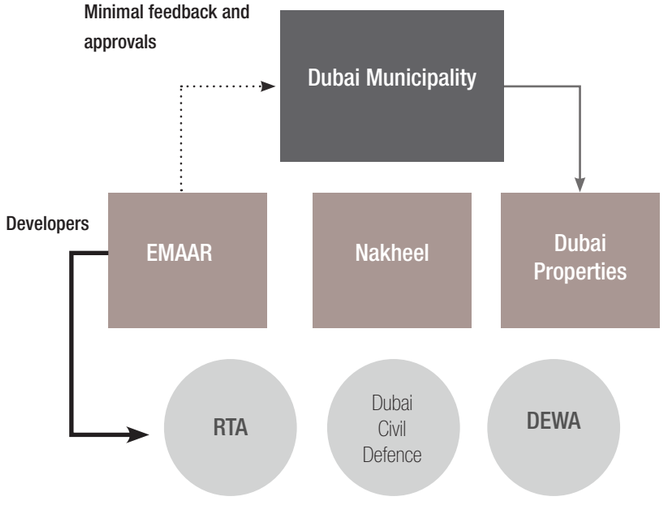
Neighbourhood Urban Retrofit Plans

The plans for Mizhar and TECOM propose policies that should be implemented by the different government entities. Design guidelines on how to achieve the policies show the potential of transitional spaces in both neighbourhoods. The conclusions highlight the common challenges and differences between Mizhar and TECOM.

Main Research Findings

The intention of this research and design project is to begin a discussion about the role of spatial planning in the energy transition in cities. This chapter concludes with an illustration of the main research findings which puts forward a tool that can be used by cities to develop an energy informed urban development strategy.

CHALLENGES ON THE WIDER SCALE



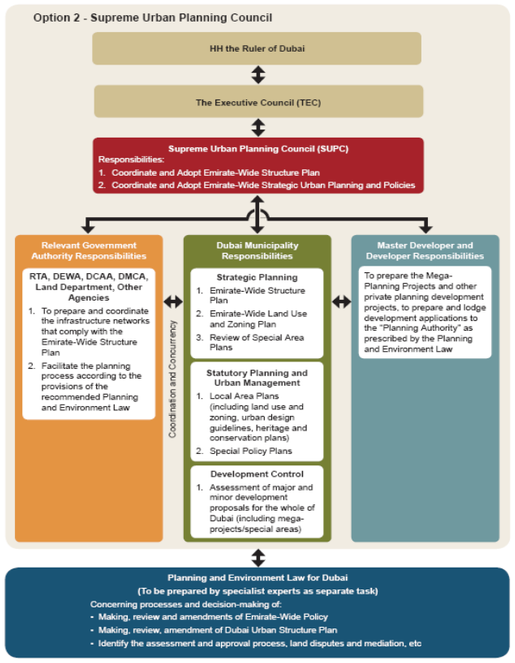


Figure 9.1 - Planning system proposed in Dubai Masterplan 2020

The Planning System

The analysis in chapter presents the influences on the planning system in Dubai. An autocratic governance system dominated by economic goals has led to a planning system with many actors that lack collaboration. The Dubai Masterplan 2020 which was published in 2009 recognizes the need for integration and proposed the creation of the Supreme Urban Planning Council (figure 9.1), who would be responsible to coordinate between the Dubai Municipality, other government bodies and developers. The need for institutional change was recognized but since the plan has been published not much has been done about this. What is interesting to note is that developers have been given a place in the 'new' planning system. They do hold considerable development rights in areas within their boundary and are recognized as an important stakeholder. This is an important advancement and should not go unnoticed. However, the economic emphasis of the Dubai Masterplan is still very high (page 40) since economic goals are still quite dominant in Dubai. The bigger question the planning system needs to consider is:

How can developers be encouraged to invest in public goods?

This is needed to be able to ensure that urban development is geared toward long term environmental, economic and social benefits in Dubai. Short term economic goals usually dominate other factors, but this model cannot be sustained and needs to shift if Dubai wants to improve resident liveability.

Extreme Climate

Dubai has a desert climate with average temperatures of 45°C during summer months (May – September) with highs of 50°C for many weeks. This means that cooling demand and its related energy use is quite high for most part of the year. Indoor temperatures are usually maintained between 18-24° C creating a difference of almost 30°C between indoor and outdoor temperature during summer. This is described as 'thermal shock' as people experience an extreme temperature when moving between places. This is because transitional spaces between buildings is not treated properly. Some solutions include air-conditioned bus stops (figure 9.2) or raised air-conditioned walkways (figure 9.3). However there are once again very energy intensive to build and maintain and are not sustainable in the long run. Bio-climatic design solutions like shaded walkways and vegetation can help lower ambient air temperatures and reduce heat gain at the ground level. But these solutions are not widespread as they cannot lower temperatures to what the 'acceptable' comfort level is today. The widespread use of air-conditioning has changed this, and it is challenge that a lot of cities with a tropical and hot climate are dealing with. But there is still a demand for public spaces even in places with extreme climate. In Dubai, public spaces for recreation are popular after sunset during summer months. Transitional spaces between buildings should be designed with the aim of pedestrian comfort and reducing thermal shock between indoor and outdoor spaces.

Figure 9.2 - Air Conditioned bus stops in Dubai
Source: http://manonthelam.com/dubai-land-of-air-conditioned-bus-stops/

Figure 9.3 - Raised pedestrian walkways proposed for Dubai Health Care City by ARUP
Source: https://www.arup.com/projects/dubai-pedways-development-strategy

CONSIDERATIONS FOR DUBAI

Building Design

Al Safat Green Building Guidelines are the latest building guidelines published by Dubai Municipality. The guidelines cover many categories that affect energy use in building design and achieving the basic level of the guidelines is mandatory for all new buildings in Dubai. However, the guidelines should be more stringent if Dubai is to achieve its goal of reducing energy demand by 30% and increasing the share of renewables.

• Tall buildings and malls are eligible to apply for an exemption from achieving the regulations. About 55% of buildings in Dubai are tall buildings and about 22% of buildings are sky-scrapers. This is a very high number and the description of what a tall building in this case is not clear (figure 9.5). Also, Dubai has one of the highest shopping mall densities in the world. There are 70 shopping malls in a city of about 2 million inhabitants (figure 9.6).

Usually, tall buildings and malls have commercial and retail uses with a higher energy demand and should not be exempted from demonstrating improved environmental performance. If this is allowed, an energy levy which is used for investing in MBR Solar park should be implemented.

• Urban microclimatic design needs to provide more extensive guidelines about urban form design and street canyons. This is a crucial aspect of neighbourhood design and can have a bigger impact on energy needed for cooling. In Dubai the energy demand in summer months is almost twice of what it is in winter. This is a significant amount and the gap between the two needs to be less drastic. This can be achieved through better building design to a very large extent.

• Although small scale renewable energy production is encouraged, it is not mandated. A maximum of 10% is required from higher rated buildings. This is a conservative target and more regulations and incentives should be provided to promote solar power.

Dubai has recently announced that 30,000 buildings will be retrofit to be more energy efficient. But there is no concrete plan on how that will be achieved. There is no design code for existing buildings and this gap needs to filled for this goal to be realized.

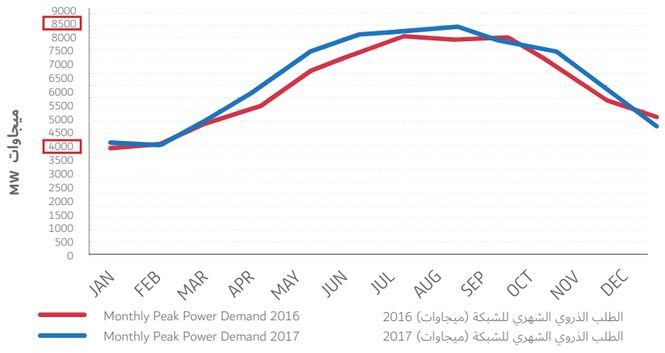


Figure 9.4 -Energy demand per month in Dubai in 2017

Source: DEWA (Dubai Electricity and Water Authority) Annual Statistics for 2017

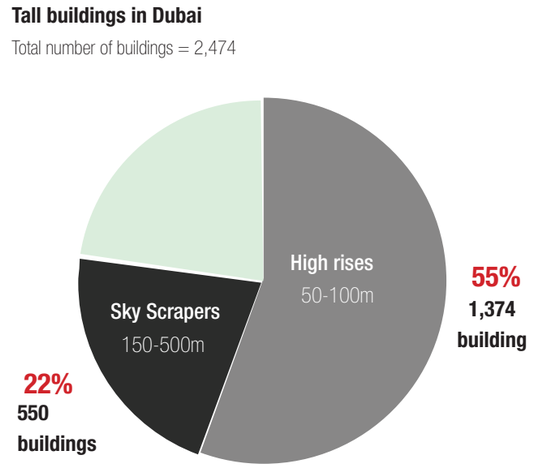


Figure 9.5 -Tall buildings in Dubai

Sources: Emporis Building Database https://www.emporis.com/city/100485/dubai-united-arab-emirates

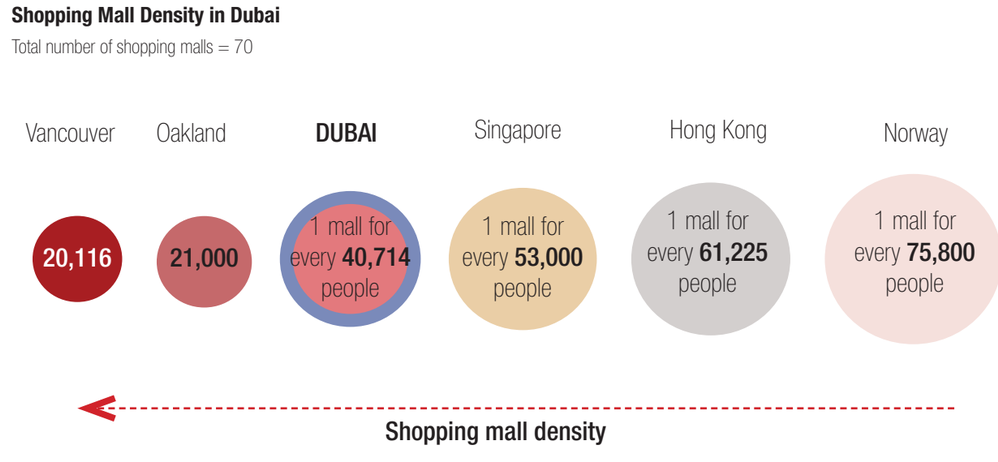


Figure 9.6 -Shopping mall density

Al Safat Green Building Regulations 2018

AL SA'FAT
Green Buildings Evaluation System

Existing Buildings

?

Streets

In a lot of areas in Dubai, the pedestrian part of the streets is not given enough importance. A lot of inner collector roads also suffer from poor walkability and connectivity. A few neighbourhoods that have a higher density such as parts of old Dubai, Dubai Marina, Jumeirah Lake Towers, DIFC etc. have a high level of pedestrian activity. Streets are not safe and attractive to pedestrians. Whenever vegetation is implemented it is usually along the sides of highways or in the round-a-about, thus not actually contributing to pedestrian comfort. Shading is also hardly ever implemented. What is interesting to note is that the Dubai Universal Design Code which is published by the Dubai Health Authority does promote street sections to include shading, cycling tracks, street furniture, vegetation or retractable ground floor facades. However, this is not implemented. There are a few examples of streets where some of these features have been considered (fig 9.7 – 9.10) but these are not a norm. To promote active travel, streets need to be designed to be attractive and safe.

Figure 9.7 - Cycling path on the street outside Sharjah National Park

Source: https://www.khaleejtimes.com/nation/sharjah/new-dh74-million-pathway-for-sharjah-residents

Figure 9.8 - Retractable ground floor on a building facade in Dubai Health Care City

Source: Google Earth

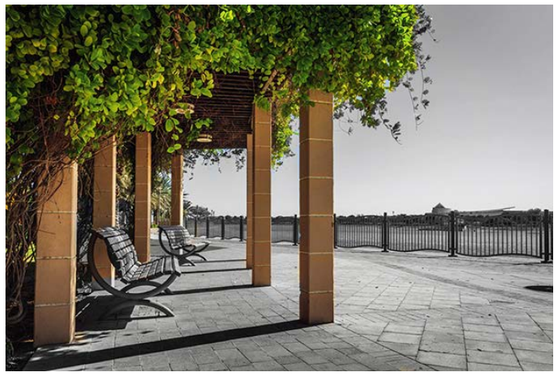
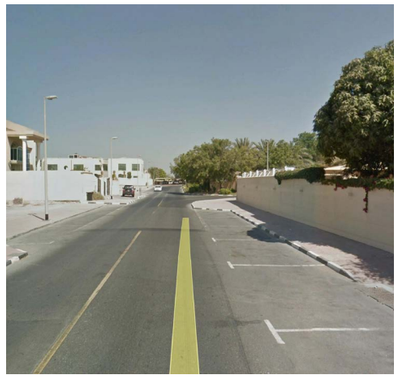


Figure 9.9 - Shading and vegetation in Al Barsha Pond Park

Source: https://morethanjustdobuy.wordpress.com/2017/12/23/al-barsha-pond-park/

Figure 9.10 - Native plant species used for vegetation on a street in Abu Dhabi

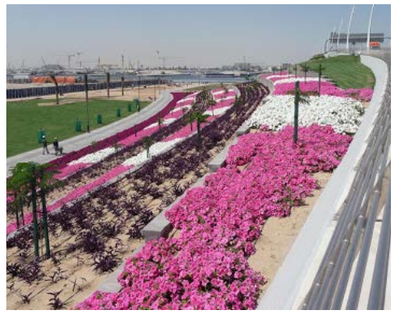
Source: https://www.thenational.ae/arts-culture/native-plants-make-a-welcome-comeback-to-abu-dhabi-



Examples of existing streets in Dubai

Street in Zakher Area, Al Ain

Source: http://www.akarlandscaping.com/portfolio/nahyan-bin-zayed-al-awwal-road-nadi-ra-to-horse-ra/



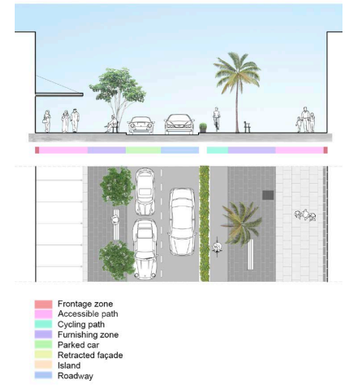
Landscaping along Al Garhoud Bridge, Dubai

Source: http://imresolt.blogspot.nl/2009/05/rta-completes-90-of-landscaping-for-al.html

Dubai Festival City

Source: http://www.cracknell.com/project/dubai-festival-city-

Examples of roads with landscaping



An example of a street section from the Dubai Health Authority Design Standards

Public Spaces

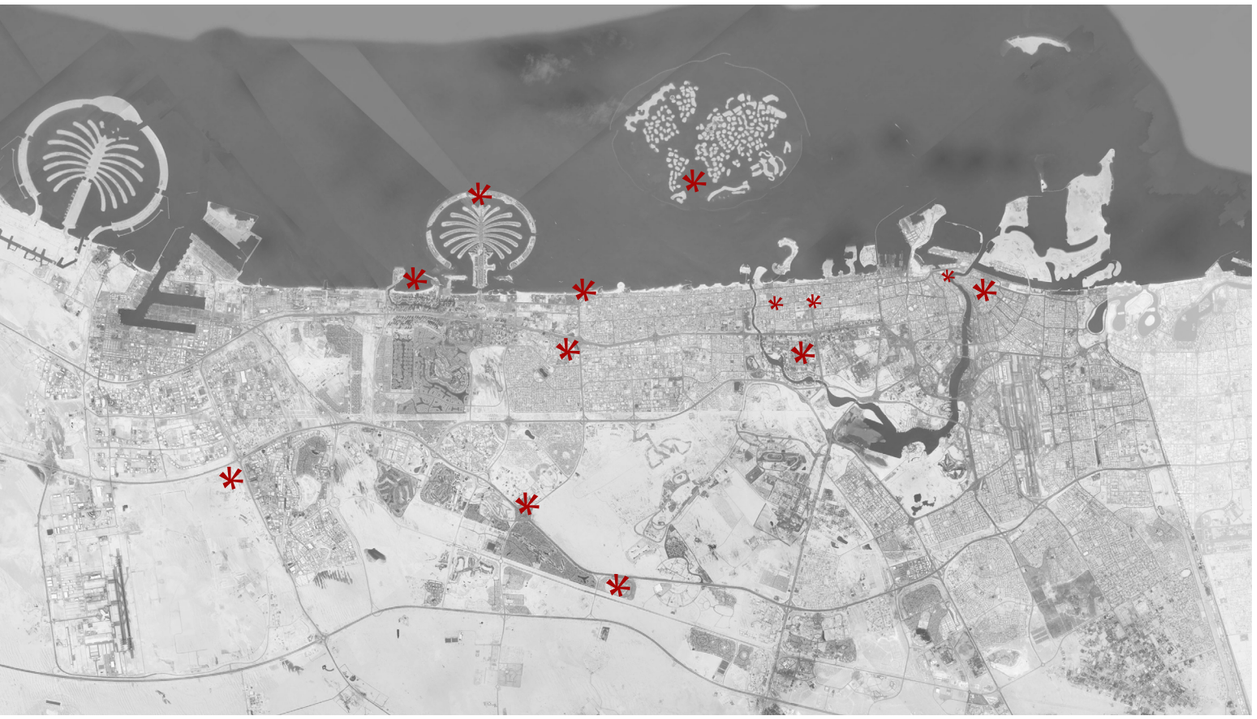
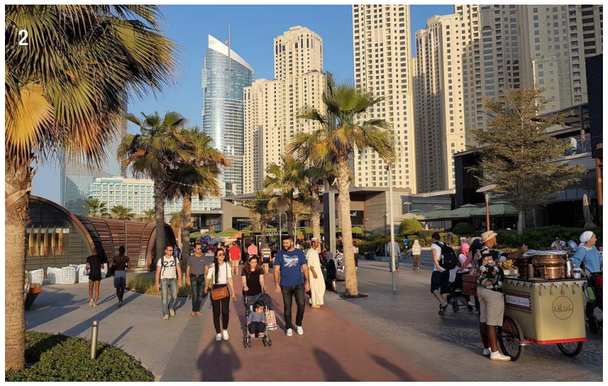


Figure 9.11 - Map showing landmarks in Dubai

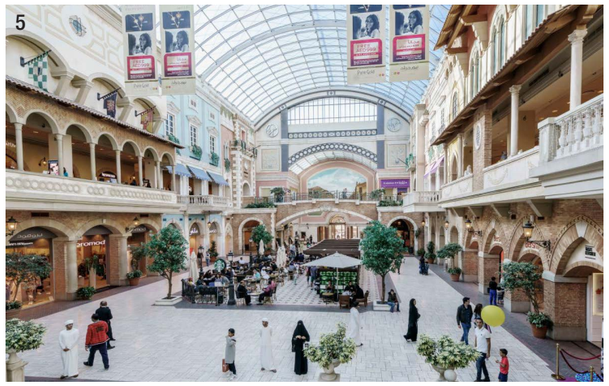
Sociologist John Urry (2013) describes Dubai as a paradise of seductive attraction to consume and buy to excess. The development of tourism, real estate and the transport sector have made Dubai a hub for holidays, conferences and property development. Dubai became one of the fastest growing cities in the world, with a place for a luxurious lifestyle. An excess of energy made this possible and changed the way in which people experience 'places'. Places are themed, branded or collected and experienced through being consumed rather than belonged to or lived within. Some of these include landmark buildings, beaches, clubs, conferences, food, hotels, entertainment venues etc. Figure 9.11 shows the location of some of these and the images on the left show what the urban character of these spaces are like.

Contrary to the 'planned' public spaces are the more 'accidental' public spaces. 'accidental' public spaces. These spaces are ones that become a part of the daily life of people and add to the sense of belonging in the city. Unlike landmark spaces they don't have a price tag attached to the amount of time spent over there. These spaces serve as venues for weekly traditions such as a game of wrestling or 'kushti' as known by the locals, or as playgrounds for children or as a gathering place for after working hours. Usually these places are transformed from vacant parking lots or undeveloped plots of land. Patches of grass outside metro stations also serve this purpose. This shows that there is a lack of recreational or social spaces in the city and should be addressed. Some examples of such activities are presented on the next page.



1 Burj Al Arab
2 The Beach Mall, Jumeiraah Beach Residence
3 Palm Jumeirah
4 The view from Burj Khalifa
5 Mercato Mall
6 Burj Khalifa
7 Ski Dubai at Mall of the Emirates

Sources: Luca Locatelli, Institute for the National Geographic, dubai-vela-hotel. com, feedram.club, http://textorcall.us/dubai/city/dubai-city-landscape, https://www.dutchbudha.com/uae



Accidental Public Spaces

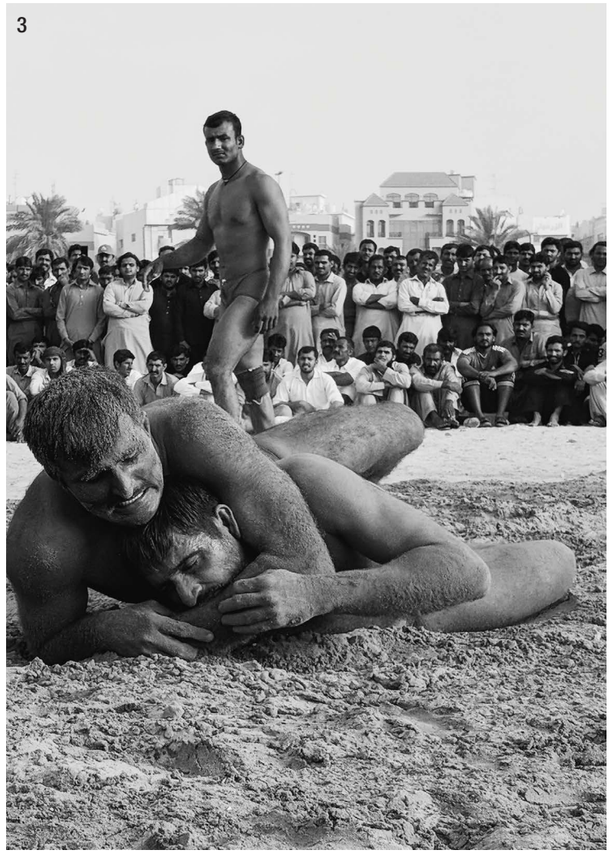
1 Children playing in a parking lot in Dubai

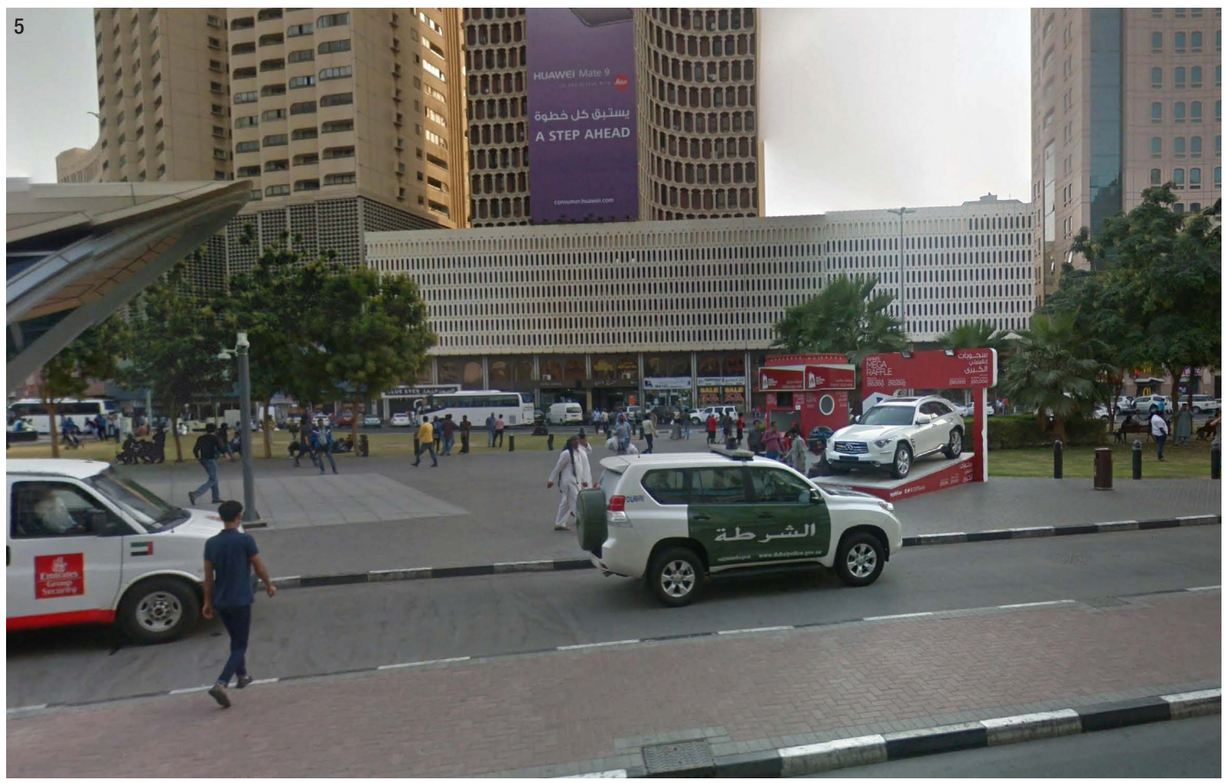
2 People playing cricket in a undeveloped plot behind Sheikh Zayed Road

3 & 4 A game of 'kushti' or wrestling held in a parking lot every Friday behing Hyatt Regency in Deira

5 A patch of green outside Baniyas Square Metro Station in Deira

Sources: https://gulfnews.com/xpress/kids-risk-life-and-limb-playing-in-parking-lots-pavements-1.1365465, http://www.agsiw.org/no-cricket-no-play-regulating-public-space-gulf-cities/, Sharvan Krishnamurthy ('Kushti Series')

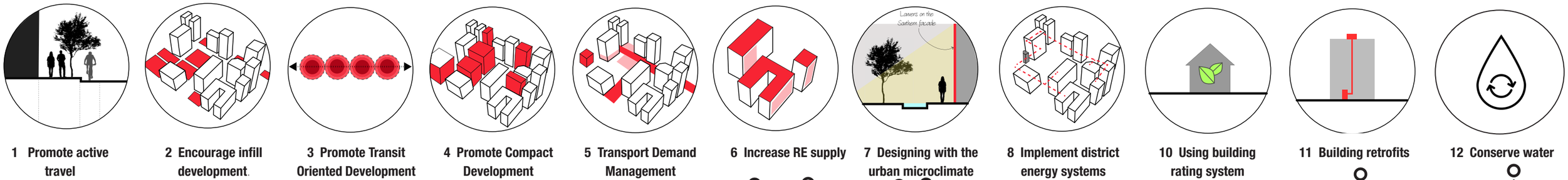




NEIGHBOURHOOD URBAN RETROFIT PLANS

The next section discusses the recommendations for the two neighbourhoods chosen in the study – Mizhar and TECOM. The challenges at the wider scale and design considerations for buildings, streets and public spaces have been accounted for in the policy and design proposals. The illustration on this page shows the relationship between the design principles derived in the theoretical framework and the policy themes chosen for the neighbourhood recommendations. The eight policy themes are transportation, infill development, public realm, renewable energy production, building design, community collaboration, water and waste. The intention behind each is explained in the following pages.

DESIGN PRINCIPLES



POLICY THEMES

MIZHAR

OBJECTIVES

1 Reduce Energy Demand

2 Increase opportunities for renewable energy production

3 Encourage resident interest to invest in a long-term return

4 Encourage a more efficient land use consumption pattern

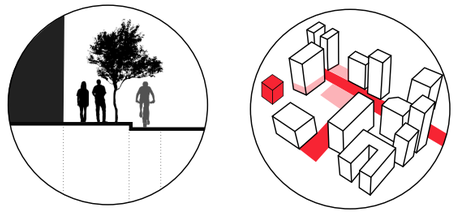
5 Create a better public realm

6 Encourage community led projects

POLICY OVERVIEW

A Transportation

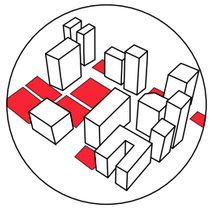
- Increase the accessibility to the metro line and number of bus stops.
- Upgrade street infrastructure to increase safety for pedestrians and cyclists.
- Decrease the amount of space taken up by roads to discourage the rise in the number of cars, increase compactness and the possibility of increased shadow density to reduce heat gain.
- Increase the importance of pedestrian pathways in the housing block by transforming existing ‘sikkas’ or utility corridors to pedestrianized pathways.
- Increase incentives to switch to electric cars powered by renewable fuels of energy.



B Infill Development

- Encourage infill development to increase efficiency of land consumption and reduce the environmental and economic costs of providing transport infrastructure.

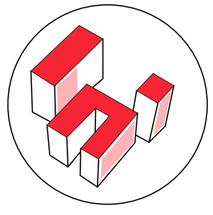
CASE 1- Freehold property market
CASE 2 - Areas around mosques
CASE 3- Encourage property extensions within street right-of-way and the creation of shared courtyards between houses.



C Renewable Energy Production

- A minimum of 60% of energy demand of individual homes should be met by renewable energy sources.

CASE 1 - Individual households
CASE 2 - Community collaboration

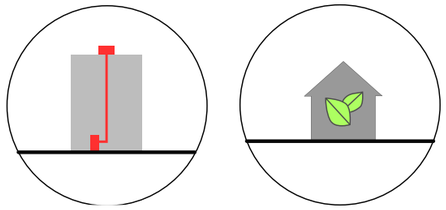


D Building Design

- All buildings should reduce their energy demand by 30%.

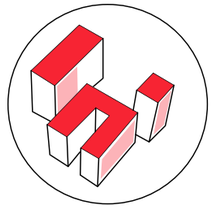
CASE 1 - New constructions should be able to demonstrate that they can achieve a 30% less energy demand than the estimated electricity load during summer.

CASE 2 - Existing buildings should invest in retrofits so that the building consumes 30% less energy than the current energy consumption.



E Community Collaboration

- Provide strong incentives to encourage community led projects that can benefit a larger part of the neighbourhood.

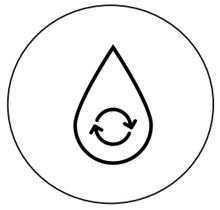


F Water

- Outdoor and indoor water use should be decreased by 30%.

CASE 1 - Outdoor landscaping should be replaced with indigenous species within a 12-month period. No new lawns should be installed. Only treated sewage effluence should be used for maintaining outdoor landscaping. Indoor water use

CASE 2 - Indoor water fixtures should be replaced by more efficient ones as per the highest guidelines of Al Safat Green Building Regulations.



A TRANSPORTATION

- **Increase the accessibility to the metro line and number of bus stops.**

The end of the red and green line of the Dubai Metro lie on the other side of the highway (311). The closest point where the proposed extension of the red line reaches is at Mirdif City Centre (fig 9.14). To increase the accessibility to the metro line the frequency of buses can be increased. More bus stops should also be implemented in the neighbourhood to cover more number of streets and the community spaces as shown in figure 9.15.

City-wide policy

Authorities who need to take the lead
Roads and Transportation Authority (RTA)

- **Upgrade street infrastructure to increase safety for pedestrians and cyclists.**

This should be accompanied by reducing the speed limits on roads and running campaigns to educate drivers about road safety. There are hardly any pavements on any of the streets and they need to be implemented to create a continuous connection for pedestrians and an attractive public realm. Improving street infrastructure will help to increase the value of the property along it.

The street right-of-way varies in width can be designed accordingly. Streets with a wider right-of-way can include a social function in the streets such as a street park. Vegetation and shading features can be added and can help to improve pedestrian comfort. Streets with a narrower right-of-way can be implemented with continuous pavements and vegetation. The different ROW's are shown in figure 9.16. The implementation of this policy is discussed with ideas about infill development.

Common policy

Authorities who need to take the lead
Roads and Transportation Authority (RTA) and Dubai Municipality (DM)

Figure 9.12 - Street type A

Figure 9.13 - Street type B

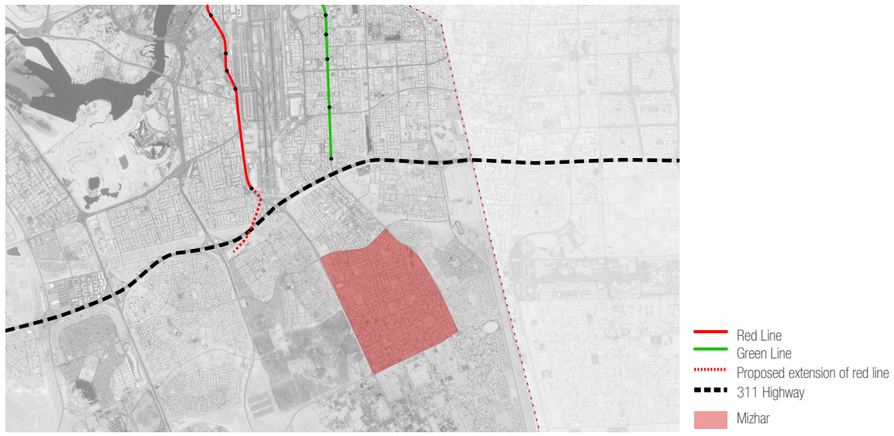


Figure 9.14 - Connectivity to public transit

Figure 9.15 - Proposed new bus stops

Figure 9.16 - Street type A and type B

- **Decrease the amount of space taken up by roads to discourage the rise in the number of cars, increase compactness and the possibility of increased shadow density to reduce heat gain. Reducing the width of the street canyon and orientation can also help with increased ventilation in the streets.**

- **Increase the importance of pedestrian pathways in the housing block by transforming existing 'sikkas' or utility corridors to pedestrianized pathways.**

  Currently these areas are underused and don't contribute to spatial quality (fig 9.19). Introducing vegetation and openings from the plots along the corridor will help to alleviate these pathways and increase the importance of pedestrian pathways. Figure 9.18 shows the location of 'sikkas' in one area of Mizhar. Design guidelines for 'sikkas' are discussed on page 123.

  Authorities who need to take the lead
  Roads and Transportation Authority (RTA)

- **Increase incentives to switch to electric cars powered by renewable fuels of energy.**

  Recently, free parking, electric charging points, registration and Salik tags are provided for electric cars. Stronger financial and infrastructural incentives need to be provided to move to cars with lower carbon footprints. Car dealerships should provide financial gains to users who choose to change their existing car to an electric car by enforcing a levy on purchasing cars that a fuelled with petrol. Preferred parking and electric charging points powered by renewables should be installed at a wider scale.

  The intention of this policy is to reduce the amount of emissions contributed by vehicular travel. Dubai has an annual car growth rate of 8.2% and radical infrastructural, financial and cultural changes are needed to shift from the car-based travel culture. Increasing the incentive for electric cars is a step to help mitigate the emissions arising from car travel.

  Common policy **City-wide policy**

  Authorities who need to take the lead
  Roads and Transportation Authority (RTA)

Skater Park

Al Karama Park

Al Barsha Pond Park

Figure 9.17 - Some examples of shading features in public spaces and pathways in Dubai

Source: http://convic.com/uaes-largest-skate-park-opens-at-kite-beach-in-dubai/ (Skater Park), http://dinodxbdino.blogspot.nl/2011/10/al-karama-park-dubai-united-arab.html (Al Karama Park) and www.MyConcierge.com (Al Barsha Pond Park)

Design guideline for 'sikkas' is discussed in detail on page 123

Figure 9.18 - Location of 'sikkas'

Figure 9.19 - Photographs of existing 'sikkas' in Mizhar (left) and another neighbourhood in Ras Al Khaimah (right)
Source: Author

B INFILL DEVELOPMENT

- **Encourage infill development to increase efficiency of land consumption and reduce the environmental and economic costs of providing transport infrastructure.**

Common policy **City-wide policy**

Within the immediate surroundings, there are open lands that are undeveloped and can be potential sites for urban development, greenspaces or renewable energy production (fig 9.21).

CASE 1- Freehold property market

Figure 9.22 shows the undeveloped plots in Mizhar. To cope with the high amount of vacancy, development can also be opened up to the freehold property market to encourage a mixed land-use and investment in urban development. The permitted uses are, retail, commercial and light industrial (only on plots bigger than 1400 sq. m). Figure 9.23 shows the streets where this can be prioritized.

Authorities who need to take the lead
Department of Economic Affairs

Value Capture
All new businesses should receive a permit only if they contribute 5% of their profits to energy initiatives in the neighbourhood. All existing businesses can have their licenses renewed once they agree to contribute 3% of their profits to energy initiatives.

CASE 2- Areas around mosques

Develop pocket parks around mosques to increase the accessibility to green spaces and amount of 'social' spaces in the neighbourhood. Streets just outside the mosque should be modified to invite pedestrians and not permit cars during the prayer times (five times a day). The existing infrastructure can also be used to increase awareness about travel choices. The parking lots outside mosques can be installed with renewable powered electric car charging points to encourage the switch to less energy intensive travel modes.

Authorities who need to take the lead
Dubai Municipality (DM) and Awaqf (Department of Islamic Affairs)

The 'social' centre of the neighbourhood
In traditional Emirati neighbourhoods, mosques generally have a social function attached to the religious function. Generally, residents would walk to the closest mosque during the 5 prayers times in the day. Figure 9.20 shows the location of mosques in a neighbourhood in UAE in the 1960's. Social interactions were a consequence of daily religious activities. In modern Emirati neighbourhoods, a mosque is provided as a part of the community facilities at a frequency of every 300-400 m with a parking space for about 10-15 cars. This suggests that walking to the mosque and the social interactions that it brings is no longer a norm that is associated with the mosque. This infrastructure can be transformed to increase the number of community spaces and increase awareness related to energy initiatives.

Figure 9.20- Mosques in a neighbourhood in UAE (old Ras Al Khaimah) in 1960's
Source: Author

Design guideline for mosques is discussed in detail on page 124

Figure 9.21- Undeveloped plots around Mizhar

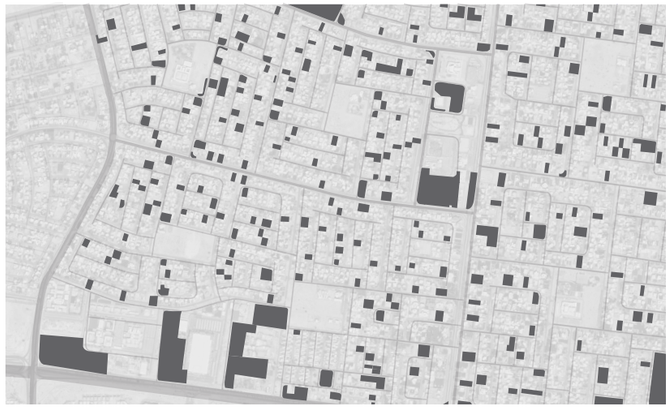


Figure 9.22- Undeveloped plots in Mizhar

Figure 9.23- Plots to be opened to the freehold market

CASE 3- Encourage property extensions within street right-of-way and the creation of shared courtyards between houses.

There is about 3-6 m between the road edge and plot boundary on most streets. Sometimes this area is much wider. This can be modified by providing the option to extend the property edge until the road edge. This area can be 'walled' into the private property or landscaped to create a 'street park'. This will help to manage the 'extra' space within the public realm to some extent.

Incentive

The property extension can be granted for free under two conditions,
(a) the additional space will not be used for lawns. Only landscaping using indigenous species is permitted.
(b) In case a boundary wall is built it cannot be a solid concrete wall. A 'mashrabiya' (permeable) inspired wall with a mesh should be built instead to improve urban architectural quality (fig 9.24). This can help with increasing potential shadow density in the street canyon as shown in figure 9.26.

This policy can be complemented by encouraging the creation of a shared courtyard between a few residences in the backyard. The creation of this semi-private courtyard helps to provide a transitional space between indoors and outdoors which is inspired from the courtyards of traditional housing styles (fig 9. 28). This area can be shaded, have permeable flooring and vegetation to make it more comfortable. Figure 9.27 shows how this area can be created.

These policies complement each other to create a private or public front yard and a semi-private backyard. By granting property extensions residents can be encouraged to feel responsible for the street and help contribute to maintain it. Design guidelines for the street and the courtyard are discussed on page 125 and 126.

Authorities who need to take the lead
Dubai Municipality (DM) and Dubai Land Department

Figure 9.24- Examples of 'mashrabiya'

Source: http://www.rumahminimalisku.net/pagar-minimalis-modern/foto-pagar-rumah-minimalis-modern/ (left) and https://www.tumblr.com/dashboard/blog/the-mylar/80101457714 (right)

Figure 9.25- Undeveloped land with the street ROW in Mizhar

Within street ROW

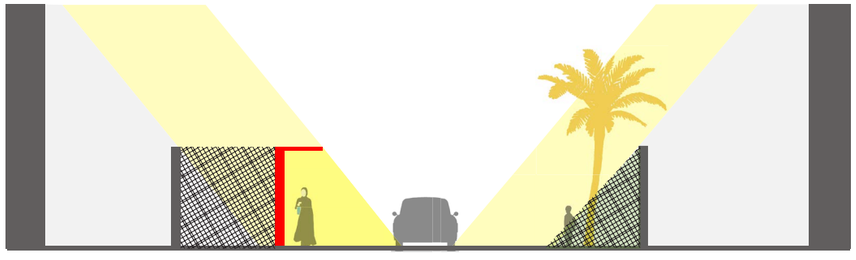


Figure 9.26- Increased shadow effect on streets

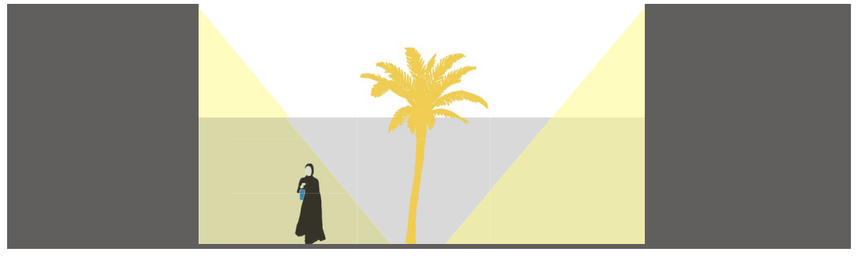
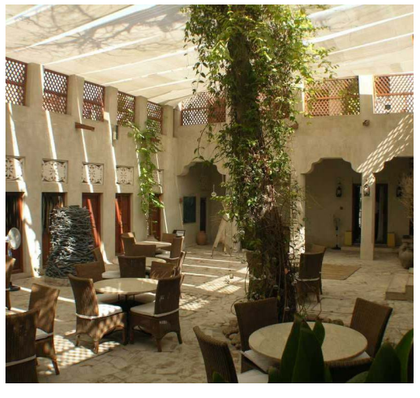


Figure 9.27- Shared courtyards between houses

Design guideline for street fronts and courtyards is discussed in detail on page 125 and 126



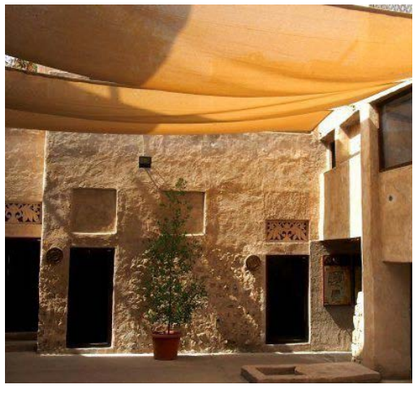


Figure 9.28- Examples of traditional courtyards

Source: www.pinstopin.com and worldtravelfamily.com

C RENEWABLE ENERGY PRODUCTION

- **A minimum of 60% of energy demand of individual homes should be met by renewable energy sources. The energy demand should be estimated by calculating the average energy demand for the summer months (from May – September) for the past two years.**

City-wide policy

Incentives

This can be deployed at two scales – individual household or through community collaboration. To incentivize residents to invest in installing solar panels to generate electricity or for water heating, a feed-in-tariff system should be introduced. The implementation of VRF's for air-conditioning and shallow geothermal cooling systems can also be encouraged. Community collaborations can be carried out amongst a group of residents in the public areas such as areas allocated for community initiatives, in parking lots or roads. Residents can jointly invest in installing solar panels and can gain financial benefits from selling any excess energy (at the market rate). Collaboration an also be encouraged between nearby areas and should not be limited to nationals only.

Pre-requisite

To help make the investment in smaller scale renewable energy initiatives, the tariffs for expats and national should be equalized. An increase in energy tariffs will instil residents to look for alternatives.

Authorities who need to take the lead

Dubai Electricity and Water Authority (DEWA) and Dubai Supreme Council of Energy

Technology feasibility

From the analysis in chapter 8 (page 74) is it possible for Mizhar to be powered entirely by renewable sources of power to a very large extent. According to research by Masdar University (Research Centre for Renewable Energy Mapping Assessment), solar energy is the renewable energy source with the highest potential in the UAE. Solar panels are becoming increasingly affordable and can be installed even on a small scale. Solar powered water heaters are also advocated for in Dubai's Energy Strategy.

Apart from renewable energy production, efficiency of cooling systems can be increased by encouraging the installation of VRF's or geothermal cooling systems. These technologies are gaining momentum in UAE and should be incentivised.

Individual Households

Figure 9.29-Roof solar panels
Source: https://greentumble.com/do-solar-panels-cause-roof-leaks/

Figure 9.30- Solar powered water heaters
Source: https://inhabitat.com/eskom-installs-solar-powered-heaters-on-south-african-roofs/

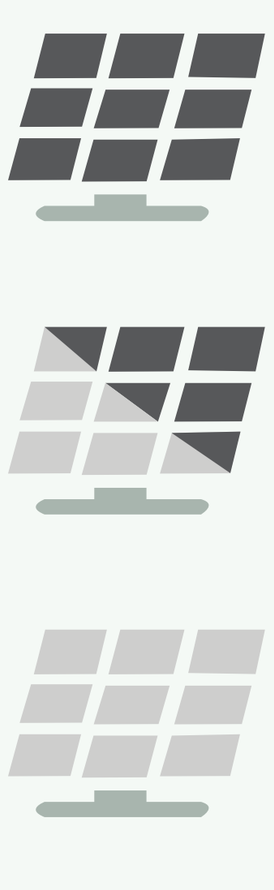
Figure 9.31- Rooftop green roof and solar panels (DEWA HQ, Dubai)
Source:www.constructionweekonline.com/

Community Collaboration

Figure 9.32- Solar powered electric car charing point
Source:https://inhabitat.com/6-solar-roads-shaking-up-infrastructure-around-the-worl

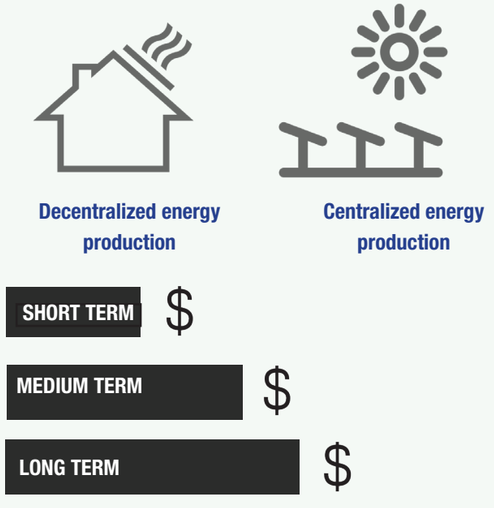
Figure 9.33- Solar panels on roads
Source:https://inhabitat.com/6-solar-roads-shaking-up-infrastructure-around-the-world/

Figure 9.34- Small scale solar panel farm
Source: https://arstechnica.com/gadgets/2011/08/how-one-michigan-undergrad-built-a-150kw-solar-farm/



A flexible investment scheme for solar power

When investment of solar power moves from the government to the community and finally the individual, the benefits increase as well. When the community or individuals are encouraged to invest in RE power and are allowed to make profits from it, it encourages long term investment and community collaboration. Since the energy can only be sold locally, the economic benefits remain within the community as well. This flexibility can be provided for decentralized energy production or centralized energy production. Moreover, if the option for a short, medium or long term benefit is discussed, this can help to create a bigger market for solar panels and other related technology. Currently, the energy market in Dubai is regulated by the government and is not open for investment from individuals or the community. This needs to be re-thought to provide opportunities for long term environmental and economic benefits.



D BUILDING DESIGN

- **All buildings should reduce their energy demand by 30%.**

City-wide policy **Common policy**

Authorities who need to take the lead
Dubai Municipality (DM) and Dubai Electricity and Water Authority (DEWA)

CASE 1- New constructions

All new constructions must demonstrate that they can achieve a 30% less energy demand than the estimated electricity load during summer. All outdoor landscaping should only use indegenous species with a low water demand.

Guidelines for design of new buildings

New buildings need to consider factors that influence heat gain within the local urban microclimate. These include, surface to volume ratio, street canyon, materials, vegetation, orientation and roads.

CASE 2- Existing Buildings

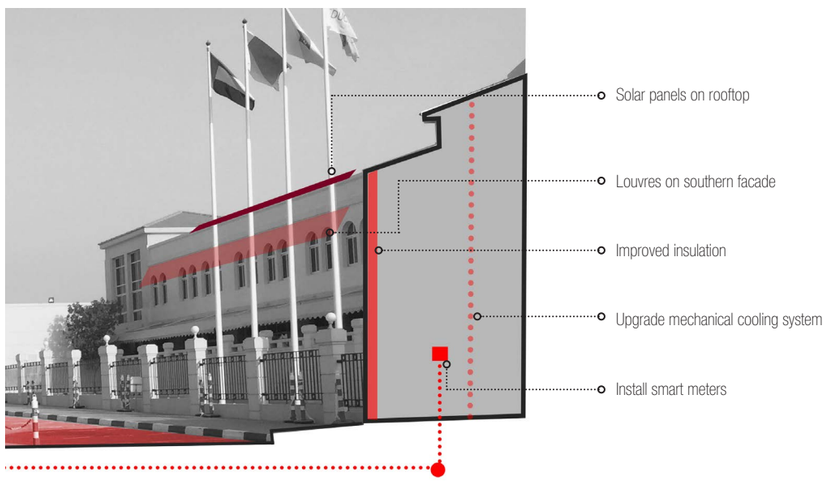
Invest in retrofits so that the building consumes 30% less energy than the average energy consumption. Energy consumption is the average energy consumption during summer (from May – September) in the past 12 months.

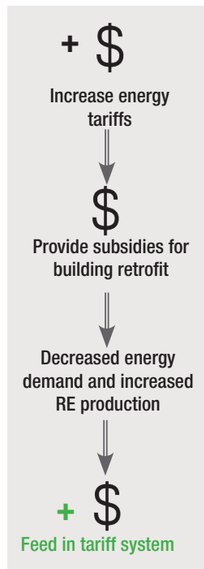
Incentives

Provide subsidies for building retrofits such as installation of solar panels, upgrading HVAC system, insulation, installing smart meters, changing water fixtures and lighting fixtures, adding louvres on the southern façade, investing in geothermal cooling systems and VRF's.

Pre-requisite

To encourage resident to invest in retrofits, the tariffs for expats and national should be equalized. An increase in energy tariffs will instil residents to look for alternatives. The increased revenue can be used for providing subsidies for building retrofits.





E COMMUNITY COLLABORATION

- **Provide strong incentives to encourage community led projects that can benefit a larger part of the neighbourhood. Areas reserved for community facilities can be allocated for these uses. Some examples include, renewable electricity production, urban farming (fig 9.35), weekly market (9.36), pocket parks, community centre or waste composting facility.**

City-wide policy

Incentives

Land to carry out the intervention and financial support for initial set up should be provided. Any profits made by the initiative can be split amongst the investors after the initial financial support is paid back.

Authorities who need to take the lead
Community Development Authority Dubai

Figure 9.35 - A farm in the UAE

Source: https://www.farmlandgrab.org/post/view/2541-uae-examines-farm-future

Figure 9.36 - A weekly market in Dubai (Ripe market)

Source: Luca Locatelli, Institute for the National Geographic

F WATER

- **Outdoor and indoor water use should be decreased by 30%.**

City-wide policy **Common policy**

Authorities who need to take the lead
Dubai Electricity and Water Authority (DEWA)

CASE 1- Outdoor Water Use

Outdoor landscaping should be replaced with indigenous species (fig 9.37) within a 12-month period. No new lawns should be installed. Only treated sewage effluence should be used for maintaining outdoor landscaping.

CASE 2- Indoor Water Use

Upgrade indoor water fixtures to consume 30% less water.

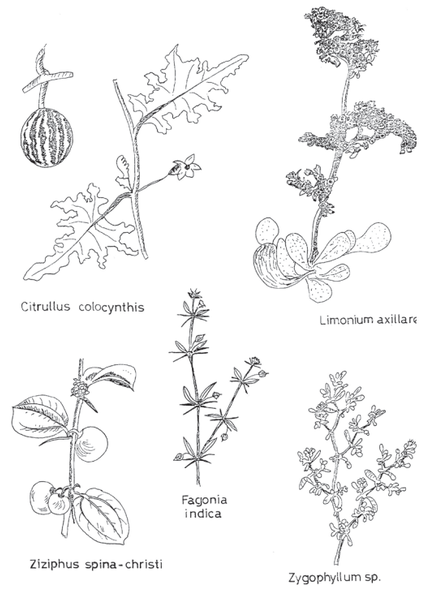
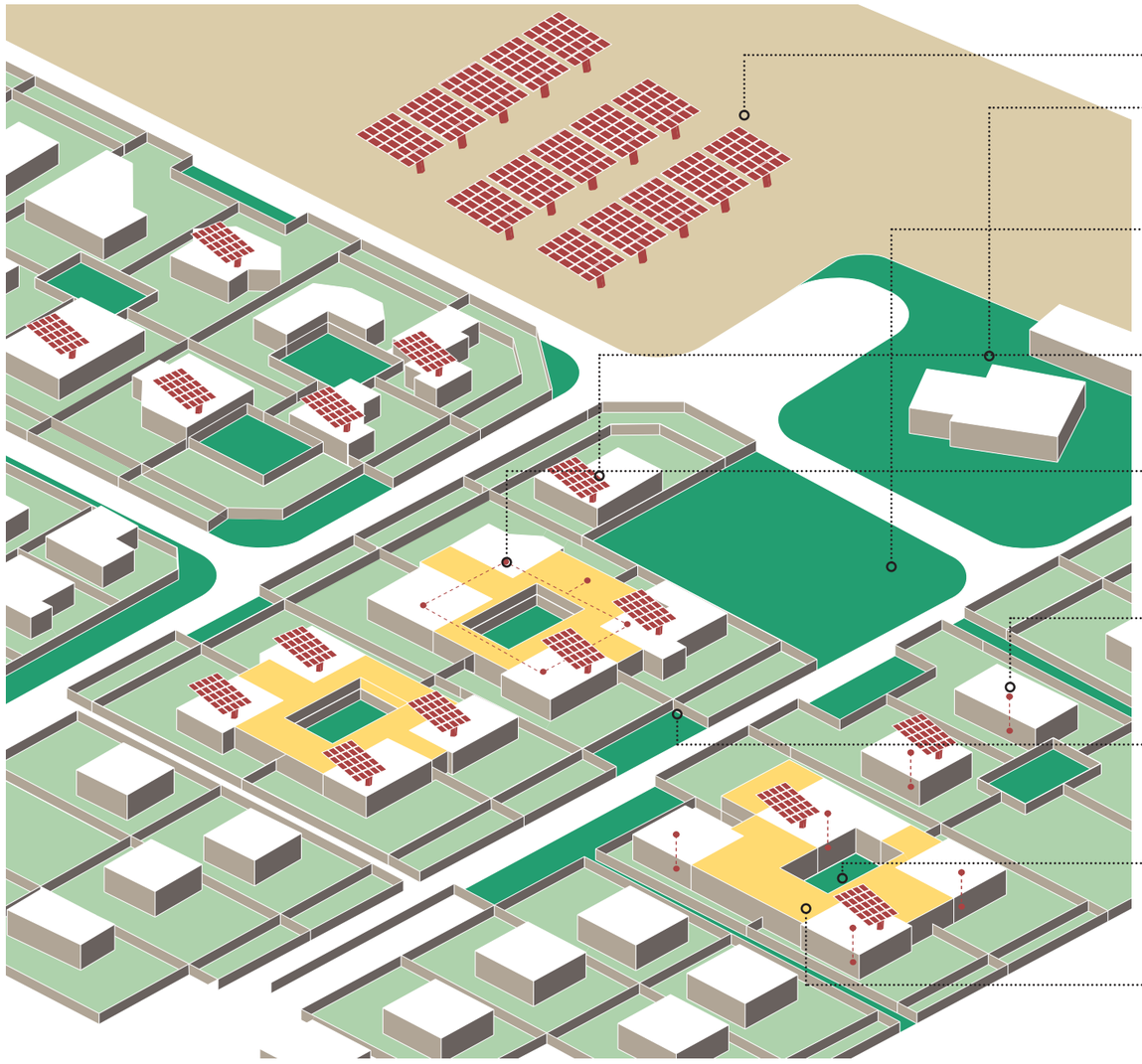


Figure 9.37 - Indegenous plant species in the UAE

Source: An extract from the work of Pat Harris, 1980
http://www.enhg.org/bulletin/b11/11_13.htm

URBAN RETROFIT DETAIL

This diagram is an illustration of how the policies discussed so far can change urban form, spatial quality and energy systems in Mizhar.



Solar Panel Farm
Community led solar panel farm in the areas reserved for community collaboration.

Mosques
Retrofit car parking around mosques to create a more attractive public area for recreational use.

Pocket parks
Implement pocket parks in undeveloped plots next to mosques to increase accessibility to open spaces within Mizhar.

Rooftop Solar Panels
Increased RE production by rooftop solar panels for every building.

VRF System
VRF (variable refrigerant flow) system for air conditioning to dramatically increase cooling efficiency and reduce energy demand. This system can also be shared between houses.

Geothermal Cooling System
Shallow geothermal cooling system can to be introduced to help meet energy demand for cooling.

Private Property Extensions
Private property can result in an increased private property boundary or in the implementation of a street park that is maintained by residents.

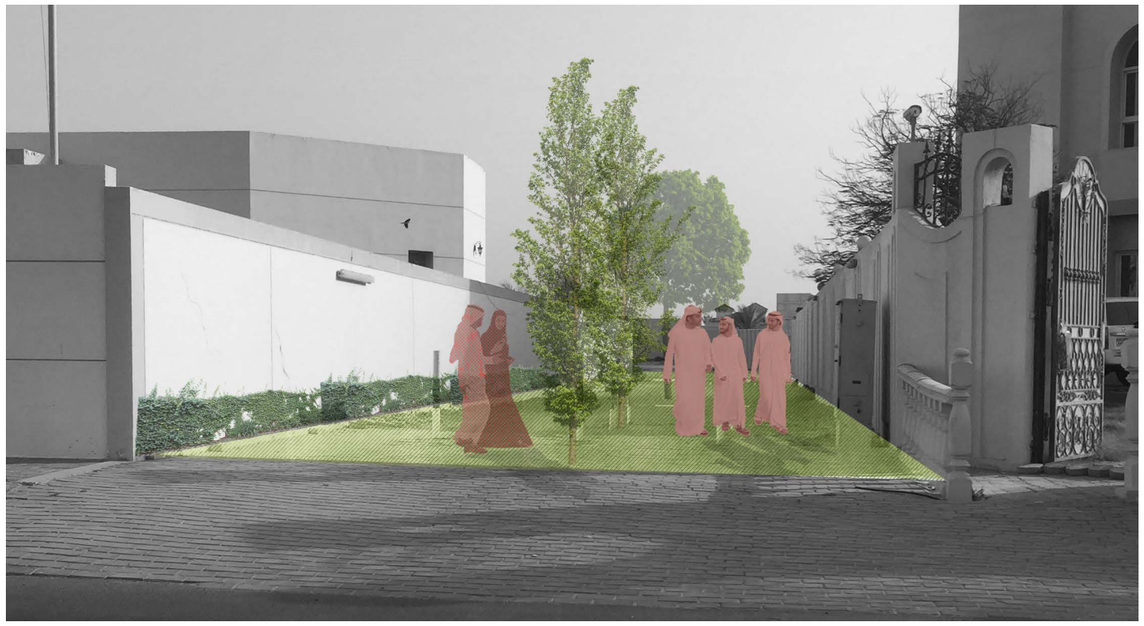
Semi-Private Courtyards
Courtyards that are shared between 3-4 residents to improve shadow density and increase the amount of social spaces in the neighbourhood.

Permitted Building Extensions
Future building extensions should be provided in these areas do intensify shadow effect in the shared courtyard.

DESIGN GUIDELINES

The design guidelines are intended to show how the policies can be achieved in Mizhar. The necessary features are described below the images.

SIKKAS



Vegetation
Vegetation on walls and within the sikka using native species that consume less water and are easy to maintain.

Flooring
Permeable flooring instead of concrete bricks.

Openings from houses
Residents can have the option to have an opening into the sikka from private property plots.

MOSQUES

Solar powered electric car charing point
Renewably powered car charging point with floor solar panels for minimum maintenance.

Flooring
Permeable flooring instead of concrete bricks.

Vegetation
Vegetation using native species that consume less water and are easy to maintain.

DESIGN GUIDELINES

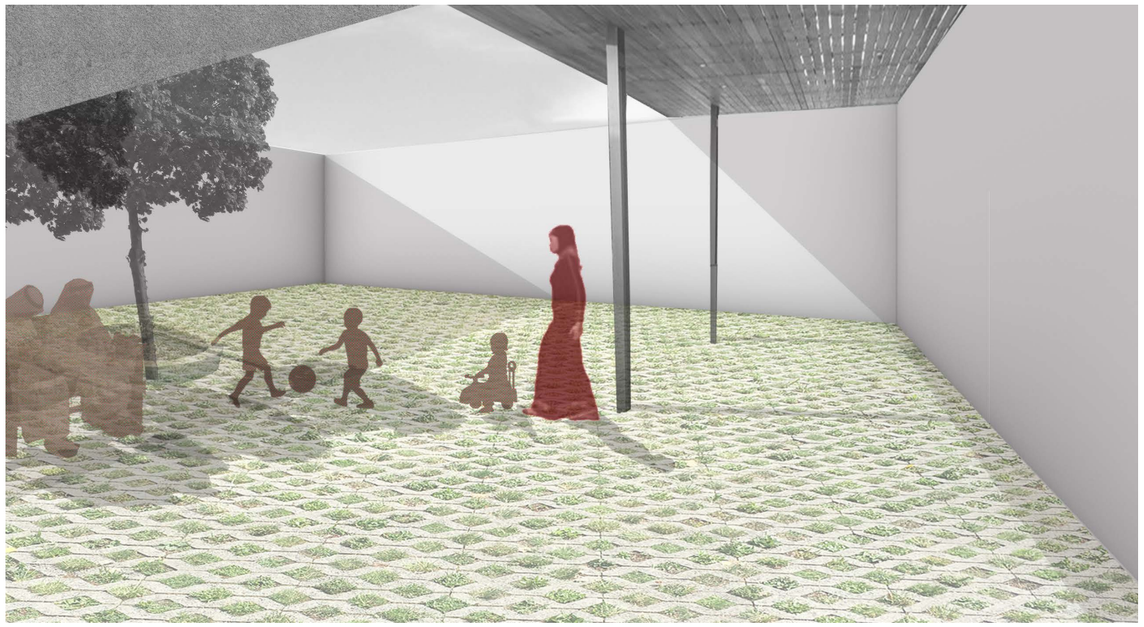
STREETS

Pedestrian Pathway
Dedicated path for pedestrians along the side of the road.

‘Street Park’
Landscaped space open to public maintained by residents. Only native species for vegetation. No concrete paving or parking is allowed. Benches, children play area, shading and other street furniture is permitted.

Permeable Boundary Wall
Boundary walls are usually built quite high (2.75-3m) for privacy. To add to spatial quality and allow for social spaces to emerge, ‘mashrabiya’ styled permeable walls should be encouraged instead of concrete brick walls.

COURTYARDS



Vegetation
Trees or large plants can be used for shading and to reduce urban heat island effect.

Flooring
Permeable flooring or low maintenance vegetation instead of concrete bricks.

Shading
Light shading devices made of wood or cloth can be used to improve urban micro-climate to make it comfortable for outdoor use.

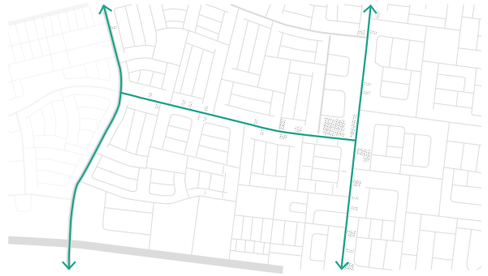
MIZHAR URBAN RETROFIT PLAN

This plan illustrates the impact of the policies within the neighbourhood that would change urban form and land use. Transportation related policies, infill development and community collaboration are mapped.

- Increase public transport accessibility by increasing the number of bus stops
- Upgrade street infrastructure to increase safety for pedestrians and cyclists
- Transforming existing ‘sikkas’ or utility corridors to pedestrianized pathways
- Encourage property extensions within the street right-of-way
- Encourage shared courtyard between houses
- Prioritize housing development
- Plots for the freehold market
- Existing mosques
- Develop pocket parks or open public space
- Areas for community led projects that can benefit a larger part of the neighbourhood

IMPLEMENTATION PLANS

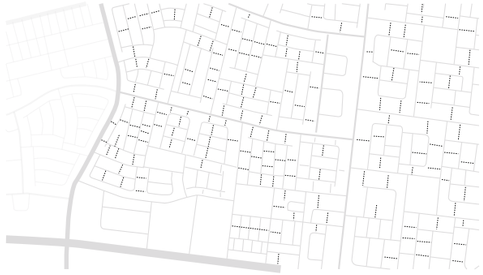
These plans show the policies that can be implemented at the same time. They complement each other through having shared incentives, economic or spatial connections. Some priority areas have been highlighted.



- Upgrade street infrastructure to increase safety for pedestrians and cyclists.
- Plots for the freehold market

- Develop pocket parks or open public space
- Existing mosques

- Encourage property extensions within the street right-of-way
- Encourage the creation of a shared courtyard between houses.
- Prioritize housing development



- Transform existing ‘sikkas’ to pedestrianized pathways.

- Increase public transport accessibility by increasing the number of bus stops.
- Areas for community led projects that can benefit a larger part of the neighbourhood

Priority Areas

This plan shows areas that should be prioritized. These are inner streets in the neighbourhood clusters close to the daily mosques. The feasibility and acceptance of the proposals can be tested by engaging with residents before wide-scale implementation.

TECOM

OBJECTIVES

1 Reduce Energy Demand

2 Increase opportunities for renewable energy production

3 Commit developers, building owners and apartment owners to invest in a long-term return

4 Encourage a more efficient land use consumption pattern

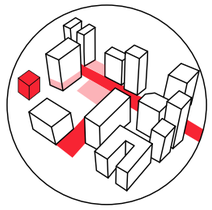
5 Create a better public realm

6 Reduce dependency on cars for travel

POLICY OVERVIEW

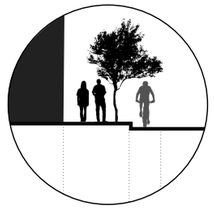
A Transportation

- Reduce the amount of car parking and transform existing on-surface parking lots to reduce heat gain and be utilized for an additional use.
- Decrease the amount of space taken up by roads to discourage the rise in the number of cars, increase compactness and the possibility of increased shadow density on streets to reduce heat gain.
- Increase the reliance on public transport.



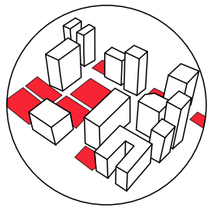
B Public Realm

- Increase pedestrian accessibility by improving street infrastructure.
- Implement public open spaces.
- Use vegetation in public areas and streets to improve the local urban micro climate.



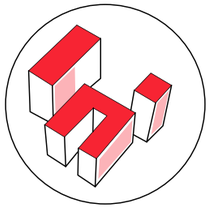
C Infill Development

- Encourage infill development to increase efficiency of land consumption and reduce the environmental and economic costs of providing infrastructure to support development elsewhere.



D Renewable Energy Production

- Encourage the installation of solar panels in buildings and on undeveloped sites.

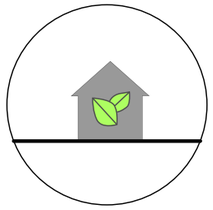


E Building Design

- All buildings should reduce their energy demand by 30%.

  CASE 1 - New constructions should be able to demonstrate that they can achieve a 30% less energy demand than the estimated electricity load during summer.

  CASE 2 - Existing buildings should invest in retrofits so that the building consumes 30% less energy than the current energy consumption.

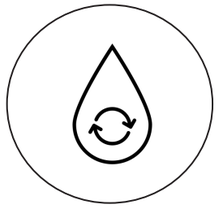


F Water

- Outdoor and indoor water use should be decreased by 30%.

  CASE 1 - Outdoor landscaping should be replaced with indigenous species within a 12-month period. No new lawns should be installed. Only treated sewage effluence should be used for maintaining outdoor landscaping. Indoor water use

  CASE 2 - Indoor water fixtures should be replaced by more efficient ones as per the highest guidelines of Al Safat Green Building Regulations.



G Waste

- All buildings must have a separate collection point for recyclables in accordance with the requirement in Al Safat Building Guidelines for apartment buildings. A waste collection company should be employed to manage the collection and disposal of recyclables.

A TRANSPORTATION

- **Transform existing on-surface parking lots so that they can be utilized for multiple purposes.**

  There are many on surface parking lots within TECOM (fig 9.39). Most buildings have underground parking as well. The amount of car parking can be reduced by providing incentives to lower the number of daily commuters in TECOM A, which includes several offices.

  Pre-requisite
  Increase the parking fee for on-surface parking lots. A part of the on-surface parking lots should be reserved only for visitors and should only be available for a short amount of time. Parking spots within buildings is given (or sold) to companies who have offices in those buildings. To be able to manage this better all parking within buildings should be administered by DCCA (fig 9.40).

  Incentives
  Provide shaded parking, underground parking or free on-surface parking spots for cars with more than one passenger and electric cars.

- **Decrease the amount of space taken up by roads to discourage the rise in the number of cars, increase compactness and the possibility of increased shadow density on streets to reduce heat gain.**

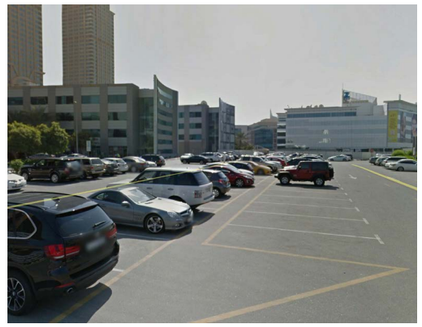
- **Increase the reliance on public transport.**

  Both TECOM A and C are well connected through a public transit system. Increasing the number of daily commuters who rely on public transport will complement the policy to help reduce the number of cars. Companies should encourage employees to use public transport and help cover the cost of public transport passes.

  Incentives
  Provide subsidized passes for the metro for employees of companies located in TECOM. Implement ride and share schemes powered by renewable charged electric cars within the area.

City-wide policy

Authorities who need to take the lead
Roads and Transportation Authority (RTA) and DCCA (Dubai Creative Clusters Authority)



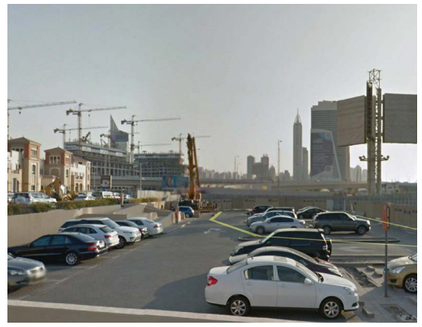


Figure 9.38 - On-surface parking lots
Source: Google Street View

Design guideline for parking lots if further explained on page 146

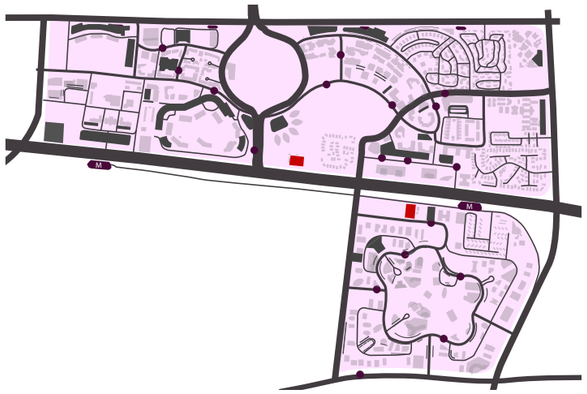
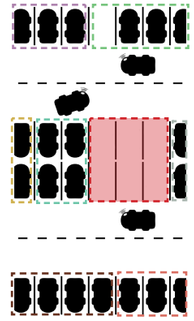


Figure 9.39 - Map showing parking lots
Source: Author

Underground parking

- Parking spots are assigned or sold to companies who rent office space in the building
- Left-over spots are sold to tenants at a later time

Managed by the DCCA



Transform parking lot
- Encourage multiple uses after working hours and on weekends
- Increase parking fee
- Reserve parking for visitors

Provide on-street parking free for electric cars and car-pools

Outdoor parking

- Managed by the Roads and Transportation Authority (RTA)
- Free after 6 pm

Provide on-street parking free for electric cars and car-pools

Management of underground parking by DCCA so that free spots can be provided for electric cars and car-pools

Figure 9.40 - Change in parking management
Source: Author

B PUBLIC REALM

- **Increase pedestrian accessibility by improving street**

Residents in TECOM C have complaints about the lack of pavements, poor lighting, lack of green spaces and trees and lack of sufficient pedestrian crossings and speed breakers (Leijen, 2011 and Teh, 2012).

Value Capture

Improve street sections by implementing continuous sidewalks and proper lighting on all inner streets. Ground floor businesses can contribute 2-5% of their profit to help with the cost of upgrading and maintaining streets.

A recreational pedestrian pathway should be installed in TECOM C as shown in fig 9.42. These have been implemented in other parts of the city and are popular among residents.(fig 9.43,9.44 and 9.45)

Authorities who need to take the lead
Roads and Transportation Authority (RTA) and DCCA (Dubai Creative Clusters Authority)

- **Implement public open spaces**

There are several open spaces that are proposed in TECOM that are not been implemented (or are just beginning to). These should be implemented and a few more need to be provided as well.

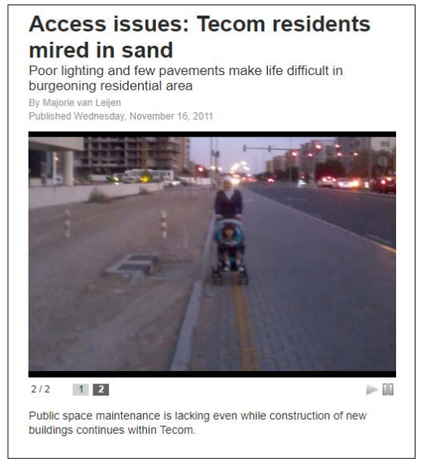
Authorities who need to take the lead
Roads and Transportation Authority (RTA) and DCCA (Dubai Creative Clusters Authority)

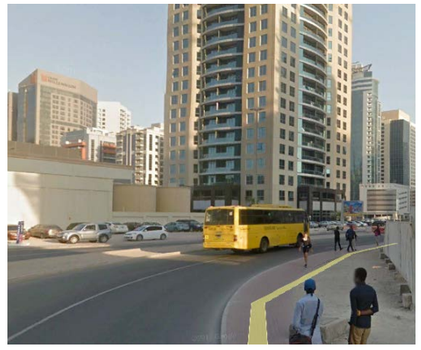
- **Use vegetation in public areas and streets to improve the local urban microclimate.**

Between the three parameters - vegetation, building footprint and building height – vegetation has the biggest influence on improving the local micro climate (Wong et. al, 2010). Native species with a low water demand should be used for outdoor vegetation.

City-wide policy

Authorities who need to take the lead
DCCA (Dubai Creative Clusters Authority)





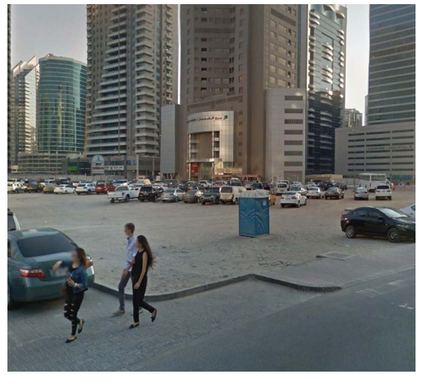


Figure 9.41 - Pedestrian pathways around TECOM
Source: Author

Figure 9.42 - Implement recreational pathway

Design guideline for parking lots is explained on page 146

Figure 9.43 -Pathway around Za'abeel Park Dubai (top right and left)
Source: http://www.tracs.net/idf5k/photos/2011/4-zabeel.jpg and http://dinodxbdino.blogspot.nl/2012/12/zabeel-park-dubai-united-arab-emirates.html

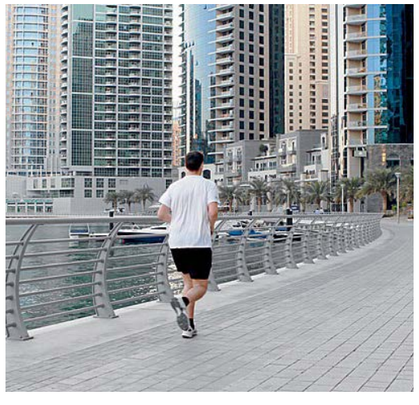


Figure 9.44 - Pathway at Dubai Marrina (bottom left)
Source: http://www.timeoutdubai.com/gallery/29343-5-to-try-dubai-running-routes?image=3

Figure 9.45 - Pathway along beach
Source: https://www.emirates247.com/news/government/latest-dubai-attraction-jumeirah-corniche-to-be-redeveloped-2013-10-27-1.525764

C INFILL DEVELOPMENT

- **Encourage infill development to increase efficiency of land consumption and reduce the environmental and economic costs of providing infrastructure to support development elsewhere.**

Encourage infill development for sites that are currently undeveloped. Infill development can also help with increasing compactness and shadow density on streets and reducing heat gain. Underused sites can be temporarily transformed to small scale solar parks to introduce renewable energy production or converted to urban parks (figure 9.46 and 9.47) Sites with halted construction can also be treated the same way.

City-wide policy **Common Policy**

Authorities who need to take the lead
Dubai Supreme Council of Energy and DCCA (Dubai Creative Clusters Authority)

Figure 9.46- Solar panels in road buffer used as a covering for bicycle paths

Source: http://solarbusinesshub.com/2015/04/10/bike-path-on-koreas-highway-

Figure 9.47- Urban park in a high-density neighbourhood

Source: Simon Roberts, 2016, Institute of the National Geographic

D RENEWABLE ENERGY PRODUCTION

- **Mandate the installation of solar panels on building rooftops (and facades where applicable).**

City-wide policy

Authorities who need to take the lead
Dubai Supreme Council of Energy, Dubai Municipality (DM) and DCCA (Dubai Creative Clusters Authority)

Figure 9.48- Rooftop green roof and solar panels (DEWA HQ, Dubai)

Source:www.constructionweekonline.com/

E BUILDING DESIGN

- **All buildings should reduce their energy demand by 30%.**

City-wide policy **Common policy**

Authorities who need to take the lead
Dubai Creative Clusters Authority (DCCA) and Dubai Electricity and Water Authority (DEWA)

CASE 1- New constructions

All new constructions must demonstrate that they can achieve a 30% less energy demand than the estimated electricity load during summer.

Guidelines for design of new buildings

New buildings need to consider factors that influence heat gain and influence the local urban micro climate. These include building orientation (fig 9.50), facade treatment (fig 9.49, 9.51,9.52 and 9.53), street canyon design and materials. All buildings must be connected to the district cooling system, installed with efficient mechanical systems (such as VRF's or geothermal cooling where feasible), fixtures and use only BIVP (building integrated photo voltaic) for any glass facades.

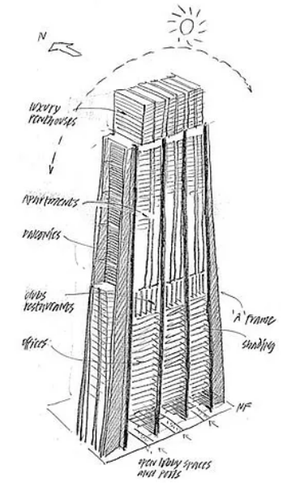


Figure 9.50- Concept sketch for Index Tower, Dubai (left)

Source: Foster and Partners

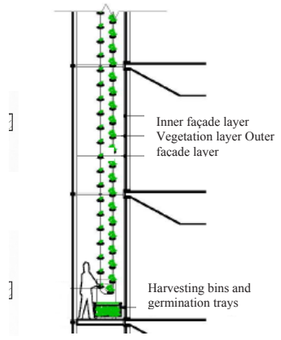


Figure 9.52- Double skin facade with vegetation

Source: Haggag, 2010

Figure 9.53- Green facade on a high rise building (left)

Source: http://www.thermosash.co.nz/c20_GreenWallSystems.aspx#&panel1-2

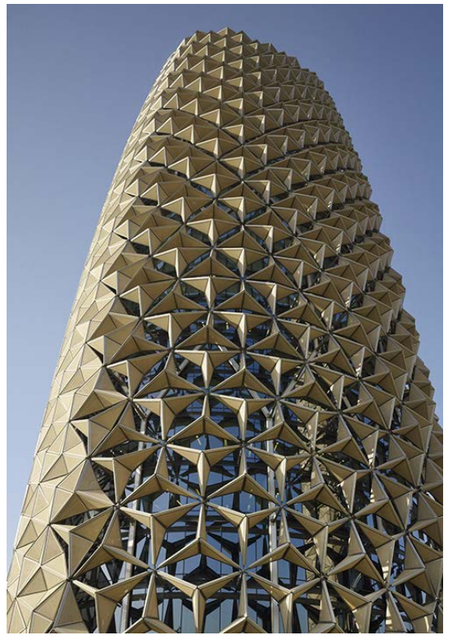


Figure 9.49- Facade cover on Al Bahar Tower, Abu Dhabi (right)

Source: https://www.e-architect.co.uk/dubai/al-bahar-towers-abu-dhabi

Figure 9.51- Green facade on Liwa International School, Al Ain

Source: https://www.thenational.ae/uae/environment/green-uae-school-is-a-living-breathing-blackboard-jungle-1.592301

CASE 2- Existing Buildings

Invest in retrofits to reduce energy demand by 30% than the average consumption. The average energy consumption is the average energy consumption during summer (from May – September) in the past 12 months. Apartment owners and building owners can contribute towards retrofits to reduce energy demand.

APARTMENT OWNERS

Apartment owners should install smart meters, upgrade appliances, replace light fixtures and water fixtures to ones with improved environmental performance as prescribed by Dubai Electricity and Water Authority (DEWA).

Pre-requisite and Incentives

Real Estate Regulatory Authority (RERA) which is a part of the Dubai Land Department should not allow apartment owners to increase their rent unless energy saving upgrades have been made to the apartment.

BUILDING OWNERS

Building retrofits include (but are not limited to):

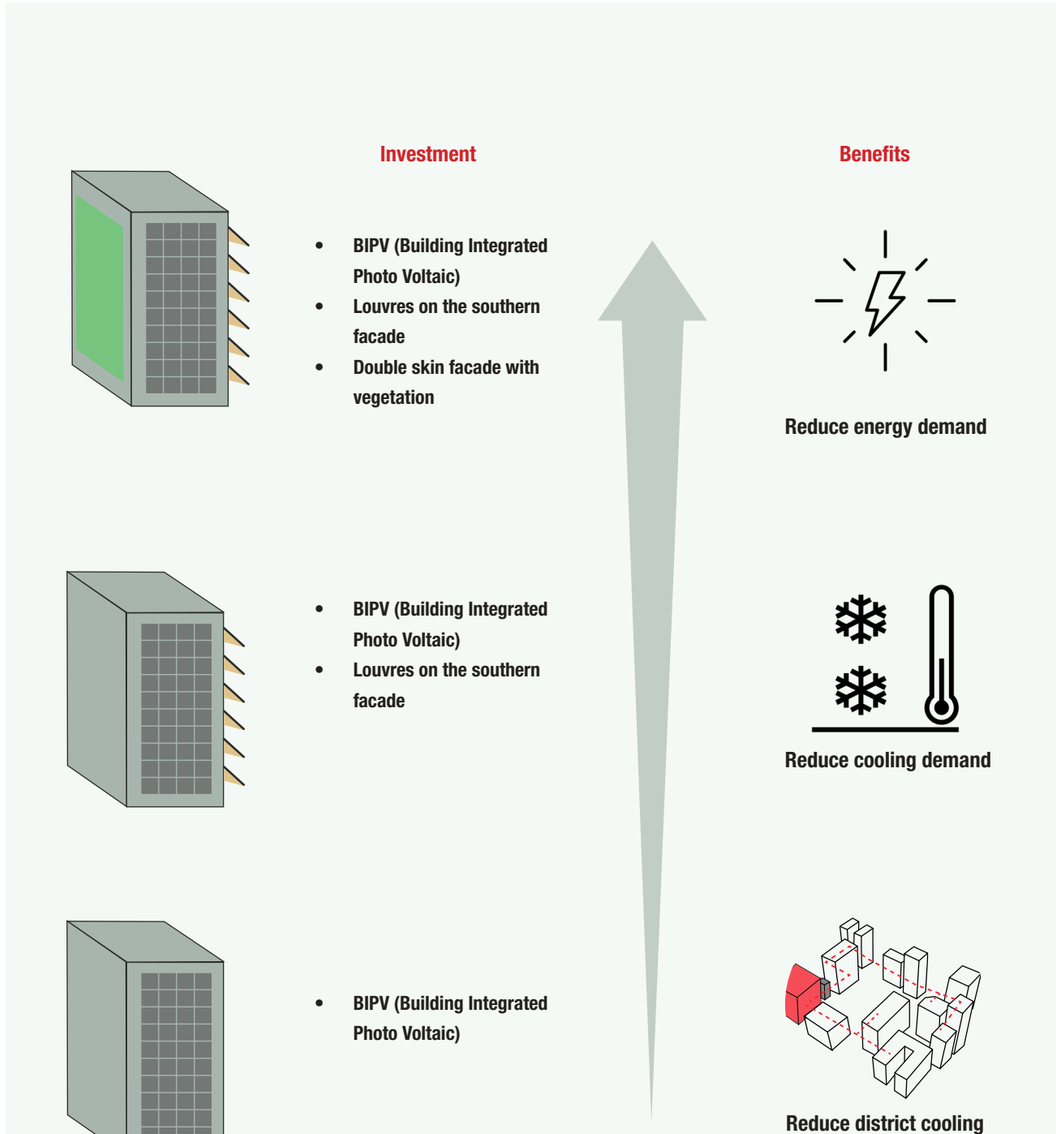
- Upgrading mechanical cooling system, install rooftop solar panels and waste recycling collection system.
- Introducing renewable energy production through BIPV (building integrated photo voltaic) on glazing and installing solar panels on roof tops.
- Installing louvres on facades to reduce heat gain, especially on the southern façade.
- Implementing a double-glazed façade on buildings that includes landscaping.

Incentives

In TECOM, the cost for district cooling is built into the rental cost of the unit. The building owner absorbs the connection charge, maintenance charge and any costs associated with the fluctuations in consumption. Building owners can be incentivised to share these costs with the tenants to save costs. The increased level of retrofit determines the amount of financial incentive a building owner is eligible to receive.

District Cooling Pricing

The pricing for district cooling in Dubai does not have strong regulations and is dealt with in different ways by different developers. Developers generally incur three different types of costs from the district cooling companies – a consumption or connection charge, a demand charge and a maintenance fee. The demand charge depends on the amount of consumption and is generally transferred to the tenant (in addition to current electricity and water bills, known as 'chiller bill'). The connection charge and maintenance charge are generally absorbed by the developer or building owner. In some areas, costs that came with implementing infrastructure were transferred to the tenant as well (Broomhall, 2012). Sometimes the district cooling charge is built into the rental charge and air conditioning or 'chiller' is provided free of cost to the end user. In this case the building owner or developer absorbs the cost associated with fluctuations in energy consumption.



E WATER

- **Outdoor and indoor water use should be decreased by 30%.**

City-wide policy **Common policy**

Authorities who need to take the lead
Dubai Electricity and Water Authority (DEWA)

CASE 1- Outdoor Water Use

Outdoor landscaping should be replaced with indigenous species such as the ghaf tree within a 12-month period. No new lawns should be installed. Only treated sewage effluence should be used for maintaining outdoor landscaping.

CASE 2- Indoor Water Use

Invest in retrofits so that the building consumes 30% less energy than the current energy consumption. Energy consumption is the average energy consumption for the summer months (from May – September) in the past 12 months.

Figure 9.54 - Ghaf trees in UAE desert

Source: http://www.voicesofyouth.org/en/posts/the-ghaf--evergreen-tree-of-the-deserts-of-abu-dhabi

G WASTE

- **All buildings must have a separate collection point for recyclables in accordance with the requirement in Al Safat Building Guidelines for apartment buildings. A waste collection company should be employed to manage the collection and disposal of recyclables.**

City-wide policy

Authorities who need to take the lead
Dubai Creative Clusters Authority (DCCA)

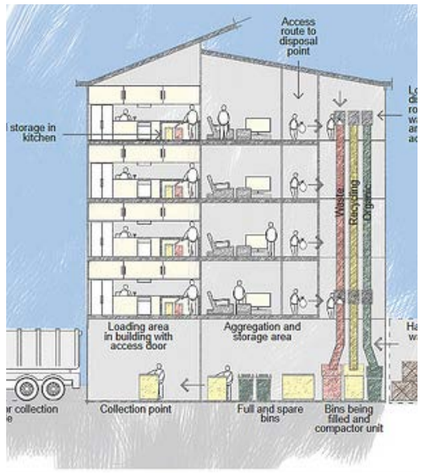


Figure 9.55- Waste management system in medium to high rise buildings

Source: http://urbanplacesandspaces.blogspot.nl/2016/03/reformulating-building-regulations-to.html

TECOM URBAN RETROFIT PLAN

This plan illustrates the impact of the policies within the neighbourhood that would change urban form and land use. Building retrofit, public realm interventions and infill development are mapped.

Apartment Retrofits
Apartment retrofits include installation of a smart meter, upgrading appliances and replacing lighting and water fixtures to ones with a higher efficiency.

Building Retrofits
These include installing BIPV, louvers, double glazing, VRF's, geothermal cooling, installing a waste collection system for recyclables or upgrading mechanical systems.

Open Green Spaces
Implement parks in areas designated for green spaces according to the master plan and allocated more areas to be converted to parks.

Rooftop Solar Panels
Increased RE production by rooftop solar panels for every building.

Infill Development
Underused plots should be prioritized for development,

Public Realm Design
The public realm along the sides of roads and in between buildings should be designed to promote pedestrian movement by creating a well paved and shaded pathways.

DESIGN GUIDELINES

The design guidelines are intended to show how the policies can be achieved in TECOM. The necessary features are described below the images.

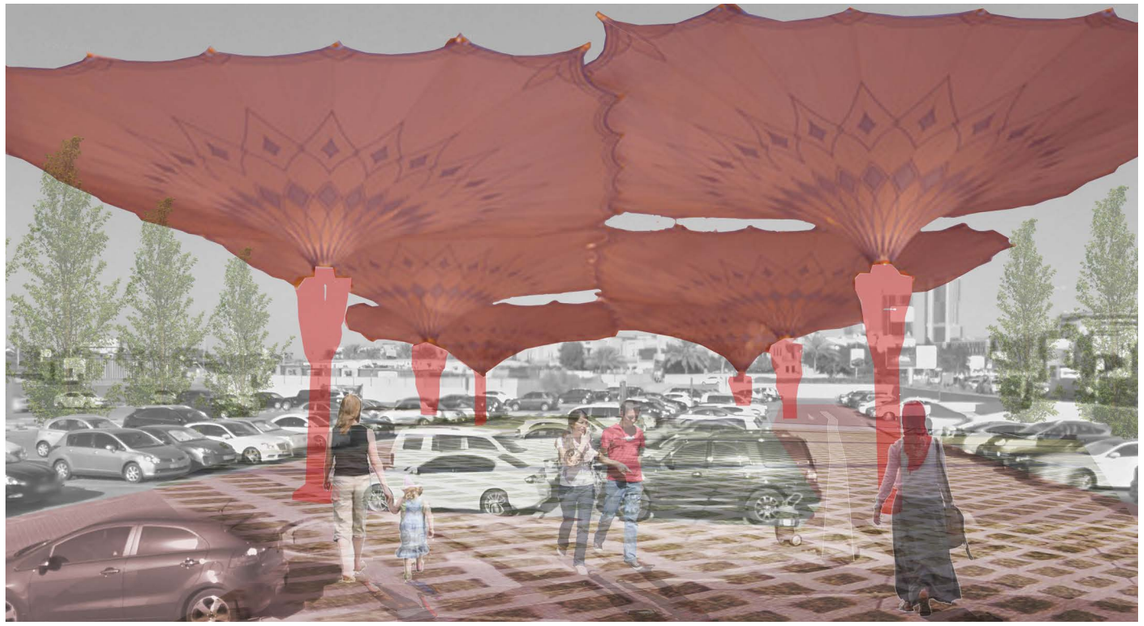
PEDESTRIAN PATHWAY

Flooring
Cleary marked and dedicated path for pedestrians along the side of the road should be implemented in all areas. A different color should be used to mark this.

Ground Floor Businesses
Ground floor businesses will benefit from the improvement of the public realm and should help to maintain the street front.

Vegetation
Trees or large plants can be used for shading and to reduce urban heat island effect.

PARKING LOTS



Vegetation
Trees or large plants can be used for shading and to reduce urban heat island effect.

Flooring
Permeable flooring or low maintenance vegetation instead of concrete bricks.

Shading
Shading devices (temporary or permanent) can be used to improve urban micro-climate to make it comfortable for outdoor use.

TECOM URBAN RETROFIT PLAN

This plan illustrates the impact of the policies within the neighbourhood that would change urban form and land use. Building retrofit, public realm interventions and infill development are mapped.

Transform existing on-surface parking lots to be used as public space after working hours and on the weekends

Introduce a parking management strategy within buildings (for underground or podium parking) to encourage the use of EV's, car-pools and increase the reliance on public transport

Implement pedestrian recreational path

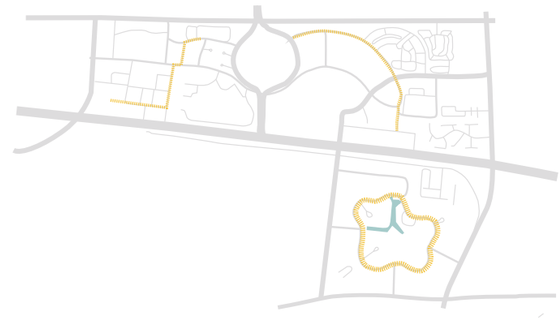
Implement public open space

Encourage infill development to increase efficiency of land consumption

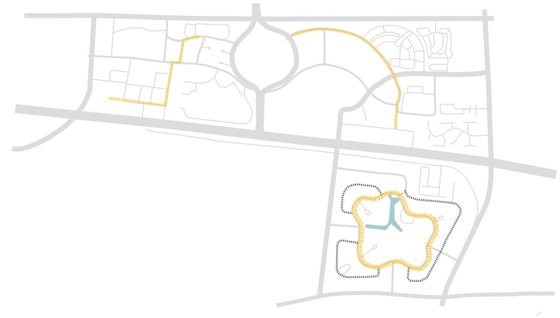
Install rooftop solar panels and encourage building retrofits

IMPLEMENTATION PLANS

These plans show the policies that can be implemented at the same time. They complement each other through having shared incentives, economic or spatial connections. Some priority areas have been highlighted.



Implement pedestrian recreational path



Implement shading and vegetation on the street canyon

Transform existing on-surface parking lots to be used as public space after working hours and on the weekends

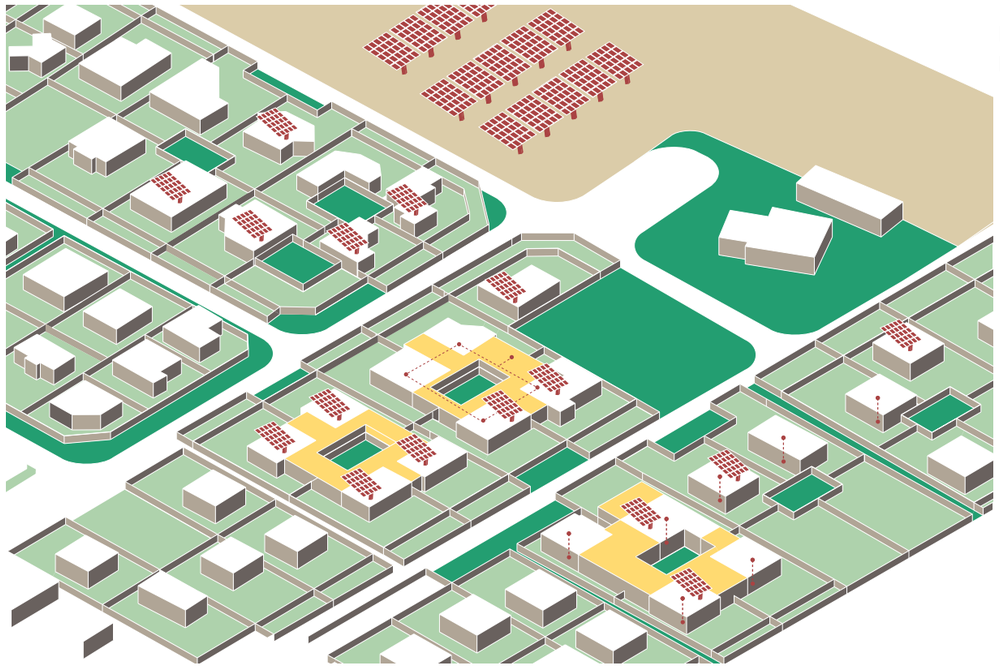
Introduce a parking management strategy within buildings (for underground or podium parking) to encourage the use of EV's, car-pools and increase the reliance on public transport

Install rooftop solar panels and encourage building retrofits

Priority Areas

CONCLUSIONS

The conclusions begin with discussing the key takeways of the urban retrofit plans for Mizhar and TECOM. The common challenges in both neighbourhoods and their differences are highlighted.



Mizhar Urban
Retrofit Plan Detail

TECOM urban
retrofit plan detail

Common challenges

Urban retrofit Plan

The recommendations in this research aim to illustrate a way in which the gap between energy strategies and urban development plans can be bridged. Exploring the ways in which this can be done in an existing context makes this an even bigger challenge. This is because the current situation also needs to be considered while thinking about a way to integrate the energy question. The plan which will be a retrofit, needs to go one step further than just making energy infrastructure related changes and should challenge development patterns that are currently not energy efficient. Further, these changes need to occur in a context that is undergoing rapid urbanization and is constantly shifting.

Extreme Climate

As discussed previously, Dubai faces the challenge of providing comfortable indoor and outdoor spaces in an extreme desert climate. Finding ways to reduce energy demand for cooling and designing appropriate transition spaces between indoors and outdoors becomes crucial. According to many studies (Lehmann et. al, 2013 and Alobaydi et.al, 2016) integrating vegetation and water bodies to allow for evaporative cooling is an effective way to reduce the urban heat island effect in hot climates like Dubai. However, this is challenge in Dubai as a lot of water is needed to maintain vegetation in a water stressed country in the middle of the desert. The design guidelines in this proposal also emphasize the importance of transition spaces and highlight that planning should create conditions that push urban designers and architects to innovate on ways in which this can be achieved.

Lack of a collaborative vision

In both Mizhar and TECOM there are several stakeholders with different interests and power to bring about any change. These factors decide what finally gets implemented in space and what doesn't. For example, in Mizhar, there is no authority who is responsible to take care of the space between the plot boundary and road edge. The Roads and Transportation Authority (RTA) builds the roads and Dubai Electricity and Water Authority (DEWA) implements underground infrastructure networks along the road. Dubai Municipality assigns plots to the owners which decides the boundary between public and private property. In the end, there is no one who takes responsibility of what happens at the edges of the ROW because no one is expected to do so. All these stakeholders are not brought together with a vision which is informed by environmental, social or aesthetic concerns.

Differences

Building morphology

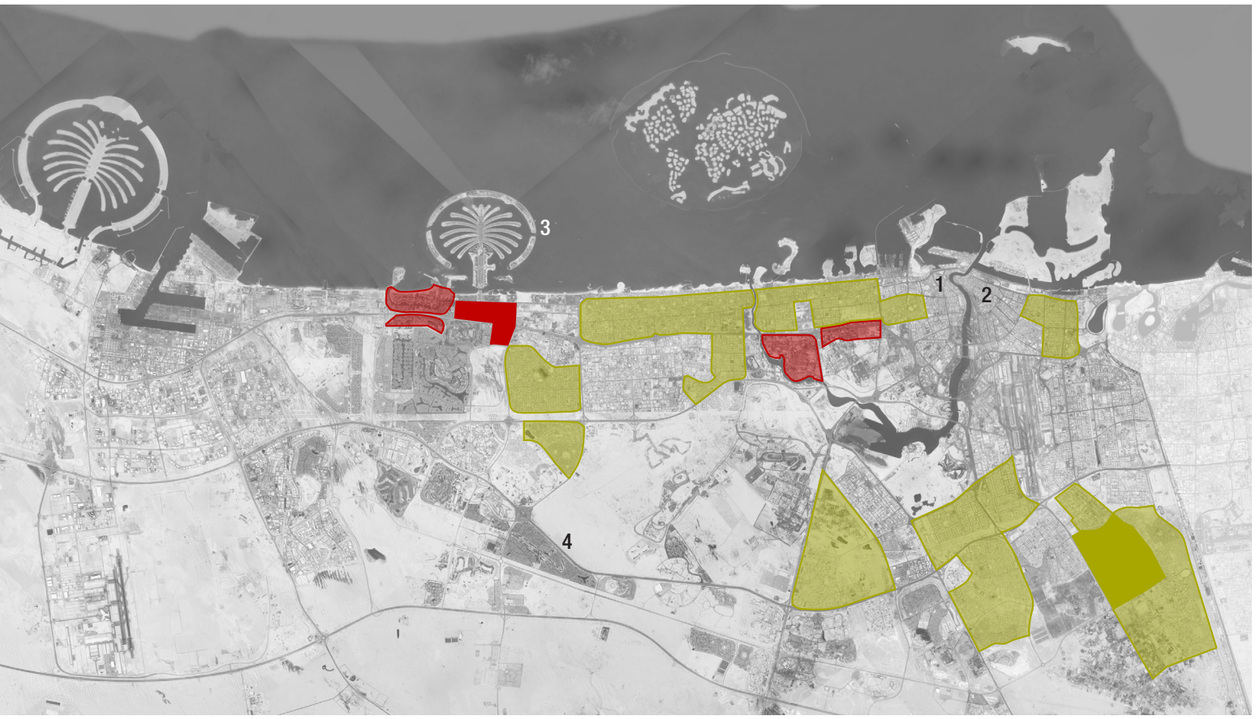
Building form, density, land use and its organization differs tremendously in both neighbourhoods. Mizhar has a low density, low rise residential use while TECOM is mostly medium-to-high rise with a mixed land use. This makes it much harder to intervene at the building level in TECOM. Retrofits in buildings would require high economic investment to achieve substantial energy savings. The biggest potential to bring about change in TECOM is the treatment of space between buildings at the ground level. Accessibility to recreational open spaces, infrastructure for pedestrians and cyclists and treating the public realm to reduce urban heat island effect can be focused on to provide long term environmental benefits. On the other hand, in Mizhar, it is possible to reduce heat gain and create more comfortable public social spaces by learning from vernacular building design principles such as the courtyard or 'sikkas'.

Implementation

In Mizhar residents are usually nationals who own individual property and residential houses. For implementation to be successful in Mizhar the different government entities along with residents need to be convinced to invest a long-term benefit in their neighbourhood. Residents in Mizhar can influence what happens in their neighbourhood to a very large extent and should be provided with enough incentives and subsidies to take initiative. In TECOM, implementation of policies to bring about a change is much more difficult since economic interests of all stakeholders is much higher than in Mizhar. In TECOM, tenants may not necessarily own the apartment and only live there for a few years. Apartment owners usually perceive TECOM as an opportunity for investment rather than living. The neighbourhood itself is built by DCCA who started out a free-zone authority with a goal to increase local businesses in the area. TECOM benefits from being located on the metro line, having (relatively) affordable housing options, district cooling system that help lower cooling costs and a vibrant mix of restaurants, bars and commercials uses. However, TECOM does have some flaws and residents in the area are complaining about a lack of public open spaces and poor pedestrian connectivity. So far not much has been done to invest in high quality public spaces or improve walkability since it is does not receive much attention amongst stakeholders. This change can only be brought about by the DCCA, who have regulatory control in TECOM. The value of investing in public goods needs to be recognized for any change to occur.

THE WIDER IMPLICATIONS

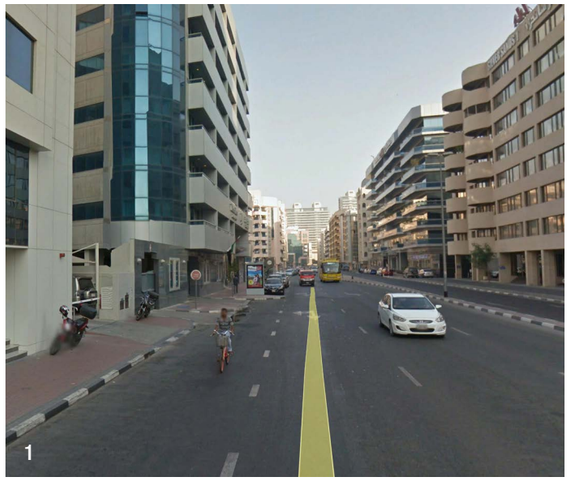
The wider implication of the proposal for the Emirate of Dubai are highlighted. Further, the main research findings and lessons for other cities to advance the energy transition are discussed.



- Mizhar
- Areas similar to Mizhar
- TECOM
- Areas similar to TECOM

The ideas discussed in the urban retrofit plans for Mizhar and TECOM can be applicable to other neighbourhoods in Dubai. Building morphology plays a big role in determining this since these configurations impact energy demand. Although transport related energy use might vary because of the proximity to public transport or major highways, at the neighbourhood scale the problems of poor walkability and accessibility remain the same. In Dubai, the decision-making authority also influences the implementation of policies and should be considered. Figure xx shows the areas that have a similar morphology and governance to Mizhar and TECOM. The areas like Mizhar consist of housing built through the national housing scheme. The plot sizes, street ROW's and buildings are the same as Mizhar. These areas also all fall under the Dubai Municipality. TECOM on the other hand has medium – high rise buildings with a mixed land use. Areas that are similar to TECOM have a similar morphology but might have varying land uses. Except for one neighbourhood (Jumeirah Lake Towers), the rest of the areas are governed by the DCCA. Jumeirah Lake Towers falls under DMCC (Dubai Multi Commodities Centre) which is a regulatory body with similar powers as the DCCA.

There are other areas in Dubai with different morphologies that have not been considered in this project. The first one is areas in the older part of Dubai close to the creek and CBD. These areas are managed by the Dubai Municipality and are medium-high rise, high density areas with a mixed land use inhabited by expats. Mankhool, Deira and Bur Dubai are examples of these neighbourhoods (1 and 2). Other examples include gated communities with low density residential villas on the outskirts of the city. The urban form of these areas is unique and usually have poor accessibility to public transport. These areas are usually not governed by the Dubai Municipality and fall under a different regulatory authority. Some examples include the Palm Islands (3) and Arabian Ranches (4).



Main Research Findings

The wider implications of the proposed urban retrofit plans on the context of Dubai have been discussed. Can other cities learn something from this? How can this approach be transferred to a different context? What would be the main considerations?

Energy strategies in cities today adopt the goal to reduce GHG emissions. This is only one aspect of the energy transition and does not address norms that are currently not promoting energy efficiency. The comparative analysis highlights the limitations of this approach and emphasizes the importance of the spatial analysis. The theoretical framework puts forward spatial planning measures that can be adopted by cities to promote the energy transition. These measures can be broadly classified in two categories, transportation and land use planning and building form and are designed to integrate energy systems and infrastructure networks.

The way in which energy is perceived also determines its relationship with space. For example, places built on cheap energy usually reflect pattern of high energy consumption such as low-density sprawl accompanied by an energy intensive transportation system. To plan for long-term benefits that can change how places are perceived requires the examination of the governance model and local societal values. This is needed to promote a collective interest and investment in an energy efficient urban development. This research and design project shows the potential of change that is brought about by an integrated approach that considers the spatial dimension, the urban decision making model and local societal values. The energy transition in cities should consider all these dimensions to be able to plan for long term benefits that can ensure a transition to a more sustainable, clean and efficient energy system.

The illustration on the next page highlights the main conclusions of different parts of this research.

ENERGY TRANSITION IN CITIES

WHAT ARE THE GOALS OF ENERGY STRATEGIES?

1. REDUCE GHG EMISSIONS
2. INCREASE SPATIAL QUALITY
3. PROMOTE LONG-TERM ENVIRONMENTAL SUSTAINABILITY

WHAT IS THE ROLE OF SPATIAL PLANNING?

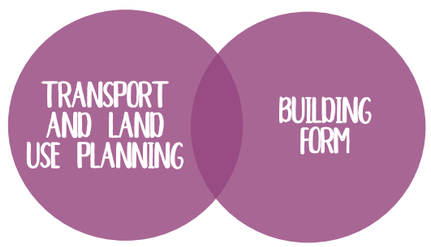
1. CHALLENGE NORMS THAT DON'T PROMOTE ENERGY EFFICIENCY
2. PROMOTE A COLLECTIVE INVESTMENT IN PUBLIC GOODS
3. PLAN FOR LONG TERM BENEFITS TO CHANGE THE PERCEPTION OF SPACE

WHY IS THE SPATIAL ANALYSIS IMPORTANT?

1. BRIDGE THE GAP BETWEEN URBAN DEVELOPMENT PLANS AND ENERGY STRATEGIES

2. ADDRESSES THE SPACES BETWEEN BUILDINGS

3. INTEGRATES TRANSPORT PLANNING AND BUILDING DESIGN



SPATIAL PLANNING MEASURES FOR THE ENERGY TRANSITION

TRANSPORATION AND LAND USE PLANNING

1. PROMOTE ACTIVE TRAVEL
2. INTEGRATE INEFFICIENT SITES
3. PROMOTE TOD AREAS
4. COMPACT DEVELOPMENT
5. TRANSPORT DEMAND MANAGEMENT

BUILDING FORM

6. MICRO CLIMATE DESIGN
7. INCREASE RE SUPPLY
8. DISTRICT ENERGY SYSTEM
9. RETROFIT BUILDINGS
10. MINIMIZE WATER USE
11. REDUCE WASTE

HOW CAN CITIES DEVELOP THIS?

SPATIAL ANALYSIS

- TRANSPORTATION AND LAND USE PLANNING
- BUILDING FORM
- ENERGY INFRASTRUCTURE

+

GOVERNANCE MODEL

- STAKEHOLDERS
- PLANNING PROCESS
- PLANNING INSTRUMENTS
- ECONOMIC FEASIBILITY

+

SOCIETAL VALUES

- LOCAL CULTURE
- BEHAVIORAL NORMS
- COMMUNITY ASPIRATIONS

Reflection

Scientific relevance

This research and planning project explores the influence of spatial planning in facilitating the process of energy transition within the context of Dubai. Energy use within the built environment is closely related to the organization of urban form and functions. Governments seek to influence urban form and the functions of cities through spatial planning. Spatial planning is a broader activity that is usually understood as the laws and policies to coordinate actions that may have an impact on the form of the city. Spatial planning can influence diverse sectors in urban areas including the energy sector. The influence of spatial planning on energy consumption and production in urban areas is uncertain to a large extent. It is very difficult to quantify the impact of spatial planning measures such as land use change or transportation demand management on energy use. A few sophisticated models that try to estimate this make basic assumptions about user behaviour and choices. This gap is also reflected in energy strategies adopted by cities today. Although these strategies are unable to quantify the impact of the proposed policies or illustrate the changes it can bring within the urban form, they set the policy direction for the future of urban energy systems. Many actions and policies require re-thinking the design of urban form and the decisions that led to it. For example, promoting active travel can reduce the number of trips made by cars. But many cities today (including Dubai) would need a radical infrastructural and cultural change to transform their transport system. The perception of space and its organization in urban areas will need to shift to achieve an energy efficient built environment. Energy strategies need to start having a stronger link with urban development plans to be able to effectively change the 'decision rules' that can lead to an improved energy performance. Through this research I want to contribute to this question and explore the parameters of planning that can impact energy use in Dubai.

Societal relevance

One of the results of the comparative analysis of the energy strategies of the four cities (Vancouver, Oslo, Hong Kong and Oakland) is that urban form modifications, technology-based solutions and user behaviour have almost an equal emphasis when addressing energy issues in the city. If residents don't feel like they have a place in the planning system or a sense of belonging to the city, they cannot be urged to make better choices and change their behaviour. The way residents choose to interact with the city is vital and without the correct incentives to behaviour, all other efforts are futile.

The political system in Dubai, demographic composition, and overriding economic orientation of policy has led to a built environment with competing developments and a planning system that is not capable of engaging with all stakeholders. Decision making in Dubai is primarily top-down as it is a part of a monarchal form of governance. What makes this condition challenging is Dubai's demographic composition. Dubai has been a migrant city for the last century. Today about 90 per cent of the population is comprised of non-citizens or expats with no political rights or voice. Most of population is transient with very little (or no) power to demand for change and is not always interested in participating in the decision-making process. The remaining 10%, who are citizens with strong rights and power, do not feel the need to challenge their leaders. Larry Beasley, who led the transfer of the 'Vancouver model' in Abu Dhabi, asked citizens if they would like to be a part of a more democratic planning process like countries in the west (2010). Almost all people responded by saying that they would rather be a part of a system that gets things done faster rather than wait for things to get off the ground. Even if urban form modifications and technology-based solutions are heavily emphasized, without resident engagement Dubai will not be able to successfully transition to a cleaner and more efficient energy system. This is a condition that needs to be recognized by the existing planning process and energy strategy.

The role of planning

My assumed role in this project is of an urban planner to inform Dubai government on how to facilitate a process for developers, urban designers and architects to work within. Fast growth and sustainable development patterns have not gone hand-in-hand in Dubai. Through my discussions with professionals at Dubai Municipality, Roads and Transportation Authority and the Dubai Creative Clusters Authority, it was clear that the planning system in Dubai lacks a framework that sets out the role of each entity and provides a platform for collaboration. Without this, working towards an environmental, economic and social benefit is not possible. Although all stakeholders recognize this, changing this system is difficult. Higher policies and objectives need to shift for other organizations to align themselves within that framework. Planning policies should create a demand for design innovation and put in processes that can help to implement it.

This project has a strong research base which will guide the redesigning of the planning process in Dubai to better balance competing interests and engage with all stakeholders. This process is informed by spatial conditions of the existing energy system. Neighbourhood morphology, socio-economic demographic and key stakeholders should be considered when devising planning tools for implementation. These factors vary for different areas in city and need to be further studied and linked to the city-wide context.

The role of spatial planning in the energy transition is a crucial one since it can challenge fundamental norms that don't promote energy efficiency. Planning processes and systems can pave the way for a collective investment in public goods that can help to promote long term environmental benefits. The results of this research illustrate the impact of spatial planning to change the relationship of space to energy. While the context of the solutions that are derived may vary from neighbourhood to neighbourhood, the central role of planning will not change. Other cities can also adopt this approach and integrate spatial analysis with the governance model and societal values to help promote the energy transition.

Transferability of the results within the region

Within the Gulf region, Dubai is considered a leader in depicting a 'successful' urban landscape. Dubai is often criticized for not having an original architectural or urban character and being a sketch board for international architectural designers heavily influenced by American ideals of urbanism. The 'Dubai model' characterized by a cluster approach to economic and spatial development is a trend in many cities in the region. For example, the Cairo 2050 masterplan had a slogan and visual that resembled the urban character of Dubai. The aims to have a 'cleaner, greener and better Cairo' raised numerous debates amongst Egyptian intellectuals. Is Cairo trying to brand itself through high-end real estate developments, preferring tourists and international companies to its own people (----)? Superlatives are a norm in architecture and urban planning in Dubai with new developments competing to be the 'biggest', 'tallest' or most 'luxurious'. This ambition is also seen in Kuwait with the announcement to build 'Burj Mubarak', proposed to be taller than the worlds current tallest building, Dubai's Burj Khalifa. One needn't even go too far away from Dubai to see its influence. Ras Al Khaimah, the northern most state in the UAE extended their coastline with the completion of Al Marjan Island (in 2003), an artificial island allocated for high end commercial and residential uses. Ras Al Khaimah has different (and more beautiful) geographic features than Dubai with its natural coastline largely undeveloped. The Emirate is sparsely populated and suffers from the impact of sprawled low-density development. The aspiration to extend their coastline by building an artificial island does not address existing urban problems inland. Still, Al Marjan Island is symbolic of 'success' and is considered to bring Ras Al Khaimah one step closer to being like Dubai.

These examples reaffirm the position of Dubai as preferred urban paradigm in the Middle East. The similar climatic and political conditions of Dubai's neighbours increased the transferability of the 'Dubai model'. In the last few years, the depletion of oil, the financial crash of 2008 and international pressure is pushing Dubai toward adopting a more integrative development pattern based on principles of sustainable development. This project emphasizes the need for coordination among different competing interests (and entities) in Dubai for a more energy efficient urban environment that reduces greenhouse gas emissions and the pressure on natural resource consumption. Perhaps this can be the next lesson Dubai passes on to its neighbours – long term environmental and economic sustainability that improves the liveability of its residents.

References

From Dubai Urban Development Framework to Dubai 2020 Urban Masterplan.

Dubai's GDP grows 16.7% in 2004. (2005). Gulf News. Retrieved from https://gulfnews.com/business/sectors/general/dubai-s-gdp-grows-16-7-in-2004-1.272606

Dubai has 30,000 construction cranes. (2006). Gulf News. Retrieved from https://gulfnews.com/business/sectors/construction/dubai-has-30-000-construction-cranes-1.241346

Highlights of the Dubai Strategic Plan 2015 (DSP). (2015).

(ADDC), A. D. D. C. (2017). Water and Electricty Tariffs in 2017

(AGECC), T. S.-G. s. A. G. o. E. a. C. C. (2010). Energy for a Sustaianble Future. Retrieved from New York, Unites States:

(CIA), C. o. I. A. (2007). United Arab Emirates and OPEC [Press release]

(DCCA), D. C. C. A. (Cartographer). (2017). Admistrative jurisdiction of different institutions in Dubai

(EC), E. C. (1999). Cycling: . Retrieved from Belgium:

(EIA), E. I. A. (2017). Country Analysis Brief: United Arab Emirates. Retrieved from http://www.iberglobal.com/files/2017/emiratos_eia.pdf

(IEA), I. E. A. (2013). Transition to sustainable buildings. Retrieved from Paris, France:

(IRENA), I. E. A. I. I. R. E. A. (2017). Perspectives for the Energy Transition - Investment needs for a low-carbon energy system. Retrieved from http://www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf

(LEED), L. i. E. a. E. D. (2014). LEED Reference Guide for Neighborhood Development. In. United States of America: U.S.G.B.C. (United States Green Building Council).

(MOCCE), M. o. C. C. a. E. (2014). Mission and Vision. Retrieved from https://www.moccae.gov.ae/en/about-ministry/mission-and-vision.aspx

(OEC), T. O. o. E. C. (2015). OEC Statistics for UAE. Retrieved from: https://atlas.media.mit.edu/en/profile/country/are/#Exports

Law No. 15 of 2015 concerning the Creative Clusters in the Emirate of Dubai, 20 C.F.R. (2014).

(RTA), R. a. T. A. (2014). RTA Strategic Plan. Retrieved from Dubai: https://www.rta.ae/wpsv5/links/RTA_Strategy_Plan.pdf

(SMCCU), S. M. C. f. C. U. (2014). Pearls and Pearl Diving. Retrieved from https://smccudubai.wordpress.com/2014/05/16/pearls-and-pearl-diving/

(UNFCC), U. N. F. C. o. C. C. (2015). The Paris Agreement. Paper presented at the Transforming our world: the 2030 agenda for sustainable development, COP 21, Paris, France.

(WCED), W. C. o. E. a. D. (1987). Our Common Future.

(WEC), W. E. C. (2013). Empowering local and regional authorities to deliver the EU climate and energy objectives. Retrieved from Brussels, Belgium: http://www.energy-cities.eu/IMG/pdf/comm_2030_web.pdf

A Faludi, S. H. (1975). The Study of Comparative Planning. Paper presented at the CES London, United Kingdom.

Adam, D. (2009). World will not meet 2C warming target, climate change experts agree. Retrieved from https://www.theguardian.com/environment/2009/apr/14/global-warming-target-2c

Agency, I. E. (2006). World Energy Outlook. Retrieved from Paris, France:

Ahmed K. Nassar, G. A. B., J. Duncan Whyatt. (2016). Dynamics and controls of urban heat sink and island phenomena in a desert city: Development of a local climate zone scheme using remotely-sensed inputs. International Journal of Applied Earth Observation and Geoinformation, 76-90.

al, N. V. e. (2018). Global Energy Prices. Retrieved April 2018 www.GlobalPetrolPrices.com and https://www.globalenergyprices.com/electricity-prices/

Alabbar, M. A. (2004). Dubai's GDP registers 6.2% growth in 2003. Albawaba. Retrieved from https://www.albawaba.com/business/dubai%E2%80%99s-gdp-registers-62-percent-growth-2003

Asad Salem, H. E. M. H. (2012). A feasibility of geothermal cooling in Middle East. Paper presented at the 3rd International Conference on Urban Sustainability, Cultural Sustainability, Green Development, Green Structures and Clean Cars (USCUDAR), Barcelona. http://www.wseas.us/e-library/conferences/2012/Barcelona/USCUDAR/USCUDAR-18.pdf

Baldwin, D. (2017). Free charking, free Salik tags for electric cars in Dubai. Gulf News. Retrieved from https://gulfnews.com/news/uae/transport/free-charging-free-salik-tags-for-electric-cars-in-dubai-1.2094971

Banister, R. H. a. D. (2007). Transport and reduced energy consumption: what role can urban planning play? Transport Studies Unit, Oxford University Centre for the Environment.

Bank, T. W. (2014). Access to electricity (% of population). Retrieved from: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=2014&start=1990&view=chart

Barnard, L. (2016). UAE residents prefer to rent than buy homes, turned off by high prices - Propertyfinder survey. The National. Retrieved from https://www.thenational.ae/business/property/uae-residents-prefer-to-rent-than-buy-homes-turned-off-by-high-prices-propertyfinder-survey-1.94693

Barton, H. (2017). City of Well Being. London, United Kingdom: Routeledge Publishers.

Behnaz Rezaie, M. A. R. (2012). District heating and cooling: Review of technology and potential enhancements. Applied Energy, 93, 2-10.

Berbari, G. (2016). Sustainable Design: District Cooling [Press release]

Bernardo, C., & Bhat, C. (2014). Non-motorized Travel as a Sustainable Travel Option. In T. Gärling, D. Ettema, & M. Friman (Eds.), Handbook of Sustainable Travel (pp. 277-291). Dordrecht: Springer Netherlands.

Breheny, M. (1995). The compact city and transport energy consumption. Transactions of the Institute of British Geographers, 20(1), 81-101.

Brian Efird, S. G., Paul Mollet, Imtenan Al-Mubarak, Sgouris Sgouridis, Itsung Tsai. (2017). The political feasiility of policy options for the UAE's energy transition.

Broomhall, E. (2012). Dubai residents fume over hike in cooling fees. Arabian Business. Retrieved from https://www.arabianbusiness.com/dubai-residents-fume-over-hike-in-cooling-fees-437848.html

Broomhall, E. (2012). Dubai residents suffer as district cooling bills jump. Arabian Business Retrieved from https://www.arabianbusiness.com/dubai-residents-suffer-as-district-cooling-bills-jump-440656.html

Broto, V. C. (2017). Energy landscapes and urban trajectories towards sustainability. Energy Policy, 108, 755-764.
Bureau, E. (2017). Hong Kong's Climate Action Plan 2030. Retrieved from Hong Kong:

Buxton, M. (2000). Energy, Transport and Urban Form in Australia. London and New York: Spon Press.

Calthorpe, P. (1993). The Next American Metropolis: Princeton Architectural Press.

Calthorpe, P. (2011). Urbanism in the Age of Climate Change: Island Press.

Carlo Ratti, N. B., Koen Streemers. (2004). Energy consumption and urban texture. Energy and Buildings. doi:10.1016/j.enbuild.2004.10.010

Cathcart-Keays, A. (2016). Two-wheel takeover: bikes outnumber cars for the first time in Copenhagen. Retrieved from https://www.theguardian.com/cities/2016/nov/30/cycling-revolution-bikes-outnumber-cars-first-time-

copenhagen-denmark

Center, D. S. (2016). Population and Vital Statistics. Retrieved from: https://www.dsc.gov.ae/en-us/Themes/Pages/Population-and-Vital-Statistics.aspx?Theme=42

Choi, S. G. a. A. S. (2014). Transport transitions in Copenhagen: Comparing the cost of cars and bicyles. Ecological Economics, 113, 106-113.

Cities, C. Cities vulnerable to climate change. Retrieved from http://www.c40.org/ending-climate-change-begins-in-the-city
Cole, R. J. (2011). World Sustaianble Building Conference, Helsinki, Finland.

Colin Booth, F. H., Jessica Lamond, David Proverbs. (2012). Solutions for climate change challenges of the built environment. London: Wiley-Blackwell.

Companies), O. O. o. t. P. E. (2017). World Oil Outlook. Retrieved from Vienna, Austria:

Corder, R. (2008). Dubai's traffic pollution among world's worst. Arabian Business. Retrieved from http://www.arabianbusiness.com/dubai-s-traffic-pollution-among-world-s-worst-52827.html

Couch, C. (2016). Urban Planning: Palgrave.

Council, W. E. (2014). Global Energy Transitions. Extraction and translation from "Energie für Deutschland 2014". Retrieved from

Countries, O. o. t. P. E. (2016). OPEC share of world crude oil reserves. Retrieved from: http://www.opec.org/opec_web/en/data_graphs/330.htm

Culture, U. G.-M. o. I. a. (2000). United Arab Emirates Yearbook 1999. United Kingdom: Trident Press Ltd.

CW. (2017). Is it time for geothermal air conditioning in GCC? Construction Week Online. Retrieved from http://www.constructionweekonline.com/article-44253-is-it-time-for-geothermal-air-conditioning-in-gcc/

Darke, D. (1998). Discovery guide to the United Arab Emirates: Immel Publishing.

Deulgaonkar, P. (2017). Dubai ranked third in the list of most green buildings in world. Arabian Business. Retrieved from http://www.arabianbusiness.com/dubai-ranked-third-in-list-of-most-green-buildings-in-world-677384.html

Development, C. f. G. (2015). Developing countries are resposible for 63% of current carbon emissions Retrieved from https://www.cgdev.org/media/developing-countries-are-responsible-63-percent-current-carbon-emissions

Dhirgham Alobaydi, M. A. B. a. B. O. (2016). The impact of urban form confirgurations on the urban heat island: The case of Baghdad, Iraq. Procedia Engineering, 145, 820-827.

Dominic Stead, V. N., Ruzan Alaverdyan, Maria Jose Festas, Adam Kowalewski, Janhja Kreitmayer McKenzie, Andre Muller, Juha Talvitie. (2008). Spatial Planning - Key instrument for development and effective governance. Retrieved from New York and Geneva:

Dourojeanni, A. (1993). Procedimientos de gestión para el desarrollo sustentable. Retrieved from Santiago de Chile:

Droege, P. (2006). Renewable City. United Kingdom: Wiley Academy.

Droege, P. (2008). Urban Energy Transition: An Introduction. The United Kingdom and the Netherlands: Elsevier.

Economist, T. (2009). Building the smart grid. Retrieved from https://www.economist.com/node/13725843

Elessawy, F. (2017). The Boom: Population and Urban Growth of Dubai City (Vol. 2).

Elsheshtawy, Y. (2010). A transient population.

Emelianoff, C. (2013). Local Energy Transition and Multilevel Climate Governance: The Contrasted Experiences of Two Pioneer Cities (Hanover, Germany and Växjö, Sweden). Urban Studies, 51(7).

Faludi, A. (2010). The Performance of Spatial Planning Planning Practice and Research, 15(4), 299-318.

Freiermuth, R. T. a. E. (2017). Travel and tourism travel impact 2017 United Arab Emirate. Retrieved from https://www.wttc.org/-/media/files/reports/economic-impact-research/countries-2017/unitedarabemirates2017.pdf

Gamble, J. (2014). How do you build a city in space? Retrieved from https://www.theguardian.com/cities/2014/may/16/how-build-city-in-space-nasa-elon-musk-spacex

Geerlings, D. S. a. H. (2003). The integration of land use planning, transport and environment in European policy and research. Transport Policy, 10, 187-196.

Government, U. (2010). UAE Vision 2021. Retrieved from Abu Dhabi: https://www.vision2021.ae/en/our-vision

Hans de Buijn, E. t. H., Roel in't Veld (2010). Process Management: Why project management fails in complex decision making processes: Springer.

Harald Rohracher, P. S. (2013). The Interplay of Urban Energy Policy and Socio-technical Transitions: The Eco-cities of Graz and Freiburg in Retrospect. Urban Studies, 51(7).

Harari, Y. N. (2016). Homo Dues: A Breif History of Tomorrow: Harvill Secker.

Harriet Bulkeley, M. B. (2010). Rethinking Sustainable Cities: Multilevel Governace and the 'Urban' Politics of Climate Change. Environmental Politics, 14(1), 42-63.

Hasbani, K. U. (2016). An inspiration for green economy transition in the Gulf.

Healey, P. (2007). Urban Complexity and Spatial Strategies. Oxon, United Kingdon: Routeledge.

ICLEI- Local Governments for Sustainability, U.-H. a. U. (2009). Sustainable Urban Energy Planning. Retrieved from Nairobi:
IPCC. (2007). Climate Change Synthesis Report. Retrieved from

IPCC. (2007). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Summary for Policymakers. Retrieved from Cambridge, United Kingdom and New York, NY, USA:

IPCC. (2014). Summary for policymakers: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group 3 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from United States:

IPCC Fifth Assessment Report, (2015).

Jabareen, Y. R. (2006). Sustainable urban forms. Journal of planning education and research, 26, 38-52.

James Milner, M. D. a. P. W. (2012). Urban energy, carbon management (low carbon cities) and co-benefits for human health. Current Opinion in Environmental Sustainability, 4(4), 398-404.

James Woodcook, D. B., Phil Edwards, Andrew M Prentice and Ian Roberts. (2007). Energy and Transport. Energy and Health.
Jan Zoellner, P. S.-R., Christin Wemheuer. (2008). Public acceptance of renewable energies: Results from case studies in Germany. Energy Policy, 36(11), 4136-4141.

Jonathan Rutherford, O. C. (2014). Urban Energy Transitions: Places, Processes and Politics of Socio-technical Change. Urban Studies, 51(7), 1353-1377.

Jones, M. J. a. C. (2010). Dimensions of the sustainable city (Vol. 2): Springer.

Kamphuis, Y. (2017). Why I won't buy a house in any major city - and neither should you Retrieved from https://www.weforum.org/agenda/2017/10/end-of-cities-urbanization-housebuying/
Katie Williams, E. B., Mike Jenks. (2000). Introduction to urban form and transport: New dimensions. London and New York: Spon Press.

Keirstead. J, J. M. a. S. A. (2012). A review of urban energy system models: Approaches, challenges and opportunities. Renewable and Sustaianble Energy reviews, 16(6), 3847-3866.

Kerr, J. (2017). More Vancouverites commuting on public transit: census. Vancouver Courier. Retrieved from http://www.

vancourier.com/news/more-vancouverites-commuting-on-public-transit-census-1.23108303

Laura Kleerekoper, M. v. E., Tadeo Baldiri Salcedo. (2012). How to make a city climate-proof, addressing the urban heat island effect Resources, Conservation and Recycling, 64, 30-38.

Lehmann, E. S. a. S. (2013). Local measures to mitigate the urban heat island effect in hot and humid climate: Comparative case study of Sana'a, Bushehr and Dubai Marina. International Journal of Development and Sustainability, 3(1), 38-54.

Lehmann, S. (2008). Sustainability on the Urban Scale: Green Urbanism - New Models for Urban Growth and Neighborhood United Kingdom and The Netherlands: Elsevier.

Leijen, M. v. (2011). Access issues: Tecom residents mired in sand. Emirates 24/7. Retrieved from https://www.emirates247.com/news/access-issues-tecom-residents-mired-in-sand-2011-11-16-1.428506

Loeiz Bourdic, S. S., Caroline Nowacki. (2012). Assessing cities: a new system of cross-scale spatial indicators. Building Research and Information, 40(5), 592-605.

Loeiz Bourdic, S. S. (2012). Building energy models and assessment systems at the district and city scales: a review. Building Research and Information, 40(4), 518-526.

M. Jamil, F. A., Y.J.Jeon. (2014). Renewable energy technologies adopted by the UAE: Prospects and challengs - A comprehensive overview. Renewable and Sustaianble Energy reviews, 55, 1181-1194.

Mamoru Taniguchi, T. I. (2005). The compact city as a means of reducing reliance on the car: A model-based analysis for a sustaianble urban layout. England: Ashgate Publishing Limited.

Mantia, C. I. (2012). From Dubai Urban Development Framework to Dubai 2020 Urban Master Plan. Retrieved from Mega, V. (2005). Sustainable Development, Energy and the City: A civilisation of visions and actions. United States of America: Springer.

Meyer, M. (1999). Demand management as an element of transportation policy: using carrots and sticks to influence travel behavior. Transportation Research Part A, 33, 575-599. Milind Naphade, G. B., Colin Harrison, Jurij Paraszczak and Robert Morris. (2011). Smarter cities and their innovative challenges.

Mills, R. (2017). This is a good time to talk about energy security. Retrieved from https://www.thenational.ae/business/this-is-a-good-time-to-talk-about-energy-security-1.50354

Municipality, D. Mission Vission Values. Retrieved from Dubai: https://login.dm.gov.ae/wps/portal/aboutdm?urile=wcm:path:/DMContentEnglish/Home/About+DM/Mission+Vision+Values&mapping=aboutdm

Municipality, D. (2012). Dubai 2020 Urban Masterplan. Retrieved from Dubai:

Nair, D. (2015). Around 20% of Dubai's prime properties stand empty. Khaleej Times. Retrieved from https://www.khaleejtimes.com/business/local/around-20-of-dubai-s-prime-properties-stand-empty

Nations, U. (2010). Energy for a Sustainable Future.

Network, A. J. M. (2017). UAE to invest $163bn in renewable-energy projects. Retrieved from http://www.aljazeera.com/news/2017/01/uae-invest-163b-renewable-energy-projects-170110160613154.html

Neuman, M. (2005). The compact city fallacy The journal of planning education and research, 25, 11-26.

Newman, P. (2009). Transitioning away from oil: A transport planning case study with emphasis on US and Australian cities. United Kingdom: Earthscan.

Newton, P. (2000). Urban Form and Environmental Performance. London and New York: Spon Press.

Nicola Dempsey, C. B., Shibu Raman, Sergio Porta, Mike Jenks, Colin Jones and Glen Bramley. (2010). Elements of Urban Form: Springer.

Nijkamp, P., & Pepping, G. (1998). A Meta-analytical Evaluation of Sustainable City Initiatives. Urban Studies, 35(9), 1481-1500. doi:10.1080/0042098984240

Ning Wu, E. A. S. (2010). Artificial Intelligence: Solutions for Urban Land Dynamics: A review. Journal of Planning Literature, 24(3), 246-265. doi:10.1177/0885412210361571

Nyuk Hien Wong, S. K. J., Nedyomukti Imam Syafi, Yixing Chen, Norwin Hajadi, Haripriya Sathyanarayanan, Yamini Vidya Manickavasagam. (2010). Evaluation of the impact of the surrounding urban morphology on building energy consumption. Solar energy, 85, 57-71.

O'Connor, P. A. (2010). Energy Transitions. The Pardee Papers, 12.

Ouf, A. M. S. (2000). Urban conservation concepts for the new millennium in the United Arab Emirates: Zayed center for heritage and history.

P.Lin, A. K., S. Kennedy, S. Sgouridis. (2011). Sensitivity of CO2 Emissions to Renewable Energy Penetration for Regions Utilizing Power and Water Cogeneration. Paper presented at the Advances in Sustaianble Manufacturing: Proceedings of the 8th Global Conference on Sustainable Manufacturing

Pacione, M. (2005). City Profile Dubai. Cities, 22(3), 255-265. Per-Ola Karlsson, C. D., Jad Moussalli. (2015). Energy Efficiency in the UAE Aiming for Sustainability. Retrieved from https://www.strategyand.pwc.com/media/file/Energy-efficiency-in-the-UAE.pdf

Peter Nijkamp, C. J. M. v. d. B., Frits J. Soeteman. (1990). Regional Sustaianble Development and Natural Resource Use. Paper presented at the The World Bank Annual Conference on Development Economics 1990, Washington D.C.

Philip Booth, M. B., Charles Fraser, Didier Paris. (2007). Spatial Planning Systems of Britian and France. Oxon, United Kingdom: Routeledge.

Piper, E. W. a. J. (2010). Spatial Planning and Climate Change: Routeledge.

Quinn, B. (2006). Transport-Oriented Developments: Lessons from California. Built Environment, 32(3), 311-322.

Reillo, A. (2014). Everything you need to know about buying a property in Dubai.

Roberta Capello, P. N. a. G. P. (1999). Sustainable Cities and Energy Policies. Germany: Springer.

Rydin, P. H. a. Y. (2012). The purpose of planning: Creating sustainable towns and cities. Social policy, 41, 228-229.

Sathish, V. (2013). Zebra crossing violations: Duai Traffic Police fine 45,000. Emirates 24/7. Retrieved from https://www.emirates247.com/news/emirates/zebra-crossing-violations-dubai-traffic-police-fine-45-000-generating-dh9m-2013-02-02-1.493445

Satterthwaite, D. (2008). Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions. Environment and Urbanization, 20(2), 539-549.

Secretariat, O. o. t. P. E. C. (2017). World Oil Outlook 2040. Retrieved from www.opec.org

Sgouris Sgouridis, A. A., Steve Griffiths, Deger Saygin, Nicholas Wagner, Dolf Gielen, Hannes Reinisch, Dane McQueen. (2015). Re-mapping the UAE's energy transition: An economy-wise assessment of renewable energy options and their policy implications. Renewable and Sustaianble Energy reviews, 55, 1166-1180.

Shahbandari, S. (2015). For every two Dubai residents, there is one car. Gulf News. Retrieved from https://gulfnews.com/news/uae/for-every-two-dubai-residents-there-is-one-car-1.1472177

Shahbandari, S. (2017). Pedestrians account for 30% of road deaths in Dubai. Gulf News. Retrieved from https://gulfnews.com/news/uae/transport/pedestrians-account-for-30-of-road-deaths-in-dubai-1.1992799

Shahriar Shafiee, E. T. (2008). When will fossil fuel reserves be diminished? Energy Policy, 37, 181-189.

Shaikh, A. H. A. (2012). Is Dubai's competitive advantage sustainable? A study of strategic planning in Dubai 1996-

2010. (PhD), Coventry University, United Kingdom.
Shaw, B. (2016). Land use in dubai. Law School International Immersion Program Papers, 23.

Shishegar, N. (2013). Street Design and Urban Microclimate: Analyzing the effects of street geometry and orientation on airflow and solar access in urban canyons. Journal of clean energy technologies, 1(1), 52-56.

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller. (2007). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from Cambridge, United Kingdom and New York, NY, USA:

Stead, D. P. a. D. (2015). Transit-Oriented Design in the Netherlands. Planning Education and Research, 35(2), 131-144.

Stern, N. (2006). What is the economies of climate change? World Economies, 7(2).

Stremke, D. O. a. S. (2017). Spatial transition analysis: Spatially explicit and evidence-based targets for sustainable energy transition at the local and regional scale. Landscape and Urban Planning, 169, 1-11.

Sunak, R. M. a. Y. (2010). Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? Sustainable cities and society, 1, 45-53.

Taleb, H. M. (2014). Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. buildings. Frontiers of Architectural Research, 3, 155-165.

Teh, R. (2012). Tecom evolves into good residential area. Gulf News. Retrieved from https://gulfnews.com/business/property/tecom-evolves-into-good-residential-area-1.1001515

Tesorero, A. (2016). Dubai metro: 7 years and 830 million riders. Khaleej Times. Retrieved from https://www.khaleejtimes.com/nation/transport/dubai-metro-7-years-and-830-million-riders

Tim Elkin, D. M., Mayer Hillman. (1991). Reviving the City: Towards Sustainable Urban Development: Friends of the Earth Trust, 1991.

Tim van Helmond, B. v. M. (2007). Urban Development in Dubai. (Master), University of Technology Eindhoven, The Netherlands.

Todorova, V. (2011). Air conditioning heats up energy bills. The National. Retrieved from https://www.thenational.ae/uae/air-conditioning-heats-up-energy-bills-1.424833

Topf, A. (2014). The World's 10 Biggest Energy Gluttons. Retrieved from https://oilprice.com/Energy/Energy-General/The-Worlds-10-Biggest-Energy-Gluttons.html

UN-Habitat, U. N. H. S. P. (2015). Urban Solutions.

UN-Habitat, U. N. H. S. P. (2016). World Cities Report - Urbanization and Development, Emerging Futures.

United Nations, D. o. E. a. S. A., Population Division. (2014). World Urbanization Prospects: The 2014 Revision Highlights

Urry, J. (2013). Societies Beyond Oil: Oil Dregs and Social Futures. Londond and New York: Zed Books Ltd.

Wegener, F. D. a. M. (2004). Compact city and urban sprawl. Built Environment, 30(4), 308-323.

Williams, K. (2000). Does intensifying cities make them more sustainable? London and New York: Spon Press.

Yeang, K. (2008). Ecodesign and the transition of the built environment. United Kingdom and the Netherlands: Elsevier.

Yvonne Rydin, C. T., Simon Guy, Patrick Austin. (2013). Mapping the Coevolution of Urban Energy Systems. Environment and Planning A, 45, 634-649.

Appendix

Notes on presentation at Roads and Transportation Authority (RTA), Dubai

Location: RTA Headquarters, Umm Ramool, Dubai

Date: December 20th, 2017

Timing: 12 – 1 pm

Members present: Ebrahim Mohamed, Ahmed Elsergany, Nidal Hanbali, Khaled Shouman, Ahmed Almulla, Ammar Aljassem, Dr. Shadi Anani

Format: A 20-minute presentation outlining my research framework followed by a discussion.

Below is a summary of the main points of the discussion:

• Implementing TOD areas: About 100 km of railway (Dubai Metro) has already been developed and another 300 km is being planned. Implementing TOD areas for current metro stations is very difficult since there is already so much development around the existing metro stations. Even acquiring vacant lands or brownfields is challenging since most land owners don't want to give up their rights on the land they own. It is very difficult to convince people to give up their property for a development in the future where they can be a shared owner. This sort of thing doesn't happen easily in Dubai. There are a few areas that are already good examples of TOD areas such as Bur Juman, Union and Deira City Center. The areas around the metro stations that are yet to be constructed can be planned in this manner.

• Developers have a very strong say in spatial planning decisions and can easily override policies and recommendations pushing for sustainability. For example, the RTA was involved in a neighborhood design and put forward recommendations to modify the public realm to support more active travel (i.e. pedestrians and cyclists). Since the recommendation involved allotting a larger than usual area for footpaths and public spaces, the developer went ahead with another masterplan that had a higher density and smaller public realm.

• Potential neighborhoods to study in the future: Al Karama and Manhkool neighborhoods are currently being studied to promote walkability and cycling. This is near Bur Juman metro station and has the potential to be a good example of a TOD area for Dubai. A comparison of this to a lower density sprawled neighborhood in terms of energy consumption will be an interesting study.

Interview with Dr. Sgouris Sgouridis, Associate Professor – Engineering Systems and Management at Masdar University, Abu Dhabi

Current research interests: Sociotechnical systems modeling for sustainable transportation systems and sustainable energy systems management.

Date: December 18th, 2017, 1pm

• Technological feasibility of goals put forward by Energy Strategy 2050
The goals in the latest energy strategy are based on models which are usually conservative. Technologically a minimum of 80% of the UAE's energy needs can easily be met by renewable energy by 2050. The goals of Energy Strategy 2050 are underwhelming if you consider UAE's energy model and systems today.

• Renewable energy potentials for the UAE
Wind, PV and CSP (concentrated solar power) are the three sources of renewable energy that can considered in the UAE. Among these wind has the least potential as it can be harvested only in the mountainous areas in the northern emirates. Economically, solar power has the cheapest cost of delivered energy today. The only disadvantage is that it cannot deliver energy at night. The debate about PV panels revolves around the feasibility of storage. CSP is a fundamentally different technology where energy is concentrated and converted to thermal energy which is then used to generate a turbine. Shams 1 in Abu Dhabi is the only CSP plant in UAE today and there are plans to build an even bigger one in Dubai.

• Cost of CSP, PV and natural gas
CSP costs higher than PV although it is becoming competitive. It is more advantageous than PV as thermal energy can be easily stored and used to generate electricity from the turbine during the night. Recent technological advancements have brought down the price of the stored energy to 8 cents per KWH (kilo-watt-hour). This is 4 times higher than the price of PV but it will be competitive in a few years. Currently, most of the electricity is generated by natural gas which costs roughly half of what CSP costs.

• Cost of natural gas
The cost of natural gas is very hard to quantify as there is no price for gas in the country and even the region. The UAE produces natural gas and imports gas from the (Dolphin) pipeline to meet its needs. At the same time almost 60% of the total gas is injected back into the oil wells for enhanced oil recovery. The UAE imports gas from the dolphin pipeline for the certain price and can choose to either utilize it within the country or export it as LNG. Exporting it as LNG earns the country about 2-3 times more than the cost of buying it through the pipeline. This creates a complex picture which makes it hard to discuss the price of gas.

• Implication of long term contracts with power plants
In Abu Dhabi power plants have long term contracts (approx. 30 years) with the government that provide them a guaranteed price for natural gas. This price is not publicly known but is presumed to be low. At the same time the government also guarantees these plants a rate of return which basically means that no matter if they purchase electricity or water from these plants, they will still be paid – at least 90% of what is owed to them. So, if the government decides that they don't need electricity or water from a certain plant in the future, they will still have to pay them at 90% of the cost. This creates a powerful disincentive to bring in renewables since electricity is already paid for. The government invests in renewables sources to meet any surplus demand that is not provided for by the existing power plants. This not the case in Dubai as the government is the proprietary owner of all the power plants.

• Reverse osmosis (RO) for desalination of water
Currently, water is desalinated through a combined thermal cycle that operates at different power to water ratios. At an optimal power to water ratio a plant would produce just as much electricity as water. But it is not always possible to operate in this manner and plants events up needed more energy to desalinate water. Using RO to desalinate water is approximately 8 times for efficient than the existing plants. There were issues earlier since the salinity of water in the gulf is higher than normal, but technological advancements have overcome that made it economically competitive with a regular combined heat plant.