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Energy Efficient Urban Configurations for Residential Projects in Cairo

A Thesis submitted in the Partial Fulfillment for the Requirement of the Degree of Master of Science in Integrated Urbanism and Sustainable Design

by

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31/07/2013

Disclaimer

This dissertation is submitted to Ain Shams University, Faculty of Engineering and University of Stuttgart, Faculty of Architecture and Urban Planning for the degree of Integrated Urbanism and Sustainable Design.
The work included in this thesis was carried out by the author in the Year 2013

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

The scarcity of energy sources in Egypt is one of the most challenging issues for urban development. To meet the escalating demand on housing, hundreds of residential projects are being constructed all over Cairo. Simultaneously, buildings are responsible of a big share of energy consumption and as such, working for a more energy efficient built environment is very crucial. Many substantial approaches to implement energy efficiency principle on the built environment are available, but this research focuses specifically on the fundamental role of urban design in energy conservation.

The research draws out twelve main design principles that outline energy efficient urban configurations in residential projects in Cairo. The twelve design principles have been extracted from diverse literature sources focusing on the design principles of eco-districts and climatic urban design principles adapted from the urban configurations of the old Arabic Medina.

Those principles are then used to assess and evaluate the urban configurations of two recent residential projects in Greater Cairo. Through analysing the case studies the research traces the main deficiencies that impede the development of energy efficient urban configurations of recent practices in Greater Cairo. Furthermore, the research draws attention to current urban planning regulations and their relation to energy efficiency. The results depict that the urban design of the selected case studies do not fulfil most of the energy efficiency design principles, hence consuming a lot of energy and wasting resources. This emphasises the necessity to develop ongoing design practices and update current urban planning regulations to optimize energy efficient urban configurations in the urban environment.

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1. Introduction and Methodology

1.1 Introduction

Reducing energy consumption is becoming one of the main approaches to mitigate climate change and reduce C02 emissions besides its positive implications on reducing pollution, improving health and economy. At present time, cities are responsible for a large share of energy consumption. Numerous studies have investigated and offered different approaches to reduce the consumption of fossil fuel and electricity (generated by combusting fossil fuels) while focusing on technological solutions as their main instruments. Other approaches concentrated on providing alternatives to 'fossil-fuel-based' energy supply. In addition to policies and strategies related to the households' occupants' behaviours have been put forward, the architectural design and enhancement of building technology, construction and used material make significant contributions to conserve energy and natural resources within the built environment (Marshall, 2008).

This research focuses on the potential role of urban design in reducing energy consumption as an approach among the many approaches and policies to reduce energy consumption within the built environment. Proper urban design and planning could provide strategies for saving energy through establishing energy-efficient urban forms. The concept of sustainable development has given a major stimulus to the question of the contribution that certain urban forms might make to reduce energy consumption and pollution levels (Breheny, 1992). An efficient urban form influences transportation, greening, buildings; land uses and offers opportunities to reduce energy consumption. Yet there are many challenges facing and limiting the capabilities of establishing such an urban form. These challenges vary from technical to political, such as the lack of knowledge on the relationship between urban form and sustainability, the investors' lack of interest and the weak enforcement of urban planning regulations.

Like many other places in the world, Egypt is dramatically facing problems with energy shortage and consumption. In the last few years, Egypt has faced a severe fuel shortage in power plants which led to long hours of blackout in several governorates and shortage of gasoline in many gas stations (Ahram, 2012). In Egypt, buildings in general are responsible for 60.18% of the total electricity consumption in all sectors. Energy demand has reached about 69.2 Billion kWh with an annual increase of 7%, where the industry takes about 43%, residential and the commercial buildings' share is 42.6%, governmental buildings and services consume about 16.7% while agriculture uses only 4% (Elsayed & Michel, 2006).

The government has adopted a new programme for building new settlements in the vast unoccupied desert to withdraw the massive urbanisation processes occurring in Cairo due to the high demand on housing (Shalaby, 2000). Those settlements are well known as satellite cities and are responsible for most of the developments and urban expansion around Cairo. It is widely agreed that the spatial strategies adopted by the Egyptian government in the current new settlements are neither environmentally, socially nor economically sustainable (Shalaby, 2000) (Ghonimi, et al., 2001) (Alzamly, et al., 2010). The layout of these settlements ignores the traditional planning principles for the desert environment, which have been established in the area over many centuries (Shalaby, 2000) (Alzamly, et al., 2010). Ignoring those principles, particularly those related to the urban form, is one of the reasons for sustainability problems. It goes without saying, that this includes its consequences on thermal comfort, microclimate, energy consumption and energy efficiency (Abdullah, 2013) (Alqadi, 2013) (Shalaby, 2000). Due to the demand and pressure on housing, it is expected that the satellite cities around Cairo will be further extended during the coming years. Those cities need to be developed according to more sustainable and energy efficient urban patterns. Simultaneously, the urban design could significantly affect and reduce the energy consumption in those particular areas. This research investigated the principles of an energy efficient urban design in the newly constructed urban expansions of Cairo.

1.2 Research Objectives and Aims

The research aims to study the theoretical background for energy efficient urban design and configuration in residential projects in Greater Cairo by looking into different design principles and approaches that try to achieve energy efficient urban forms. Such a topic with its related issues starting from energy flows in the residential neighbourhood, solar radiation, design parameters, as well as design guidelines derived from them, have been explored pursuing the following aims:

a) To investigate how can urban design and planning support the concept of energy efficiency.
b) To review the theoretical background for energy efficient urban configurations, and to explore the design principles and concepts that shape energy efficient urban forms.
c) To outline to which extent the residential projects in Greater Cairo are successful in meeting the principles of an energy efficient urban configuration.
d) To highlight on the urban planning regulations set by government and their relation to energy efficiency.
e) To draw out the main deficiencies of the urban configurations in recent residential projects in Cairo.

1.3 Research Justification

In terms of energy, there is an inherent trade-off between building design, urban form, transportation, transport choices and the potential of harnessing local renewable energy flows (Schulz, et al., 2013). This is why energy efficiency requires integrated actions that include national, regional, sub regional policies, as well as adequate urban and building design. The actions and decisions taken on all of these levels are in need of integration with other variables such as industry, technological solutions, landscaping, transportation and infrastructure (Fuchs, et al., 2008) (Peker, 1998) (Owens, 1986). For example, the positive energy performance of a particular building can turn negative if the building is situated in a low-density suburban setting with a high automobile dependence (Schulz, et al., 2013). This emphasizes the significance of integration between all levels and fields of activities and actions towards a more energy efficient built environment. Regarding residential projects, buildings are the main component and the most important consumer of energy within the built environment. Modern architecture and new construction trends have achieved a lot in terms of energy efficiency and reducing energy consumption within buildings thanks to insulation materials, industry and appropriate architectural design. Energy flows in residential projects cannot remain restricted to a single building, in the medium term; the boundaries of the audits must be expanded and widened to groups of buildings, even whole districts or neighbourhoods (Fuchs, et al., 2008).

1.4 Research Methodology

1.4.1 Research Focus

Urban design tools can offer opportunities to reduce energy consumption in residential projects (Rosenfeld, et al., 1995) and can maximize the benefits in terms of energy saving, minimize climate change effects, as well as improve pedestrian comfort (Fuchs, et al., 2008). There are many levels of action and design to achieve and enhance energy efficiency in the built environment. Those levels include the design of single buildings with its sophisticated and complex components, or the design of groups of buildings on the neighbourhood scale, or the design of the whole city as an energy system. On another scale, it can even include the policies and strategies set on the national level for a whole country or a region.

Among those levels of action and design, the research aims to focus on the energy efficiency configurations strikethrough at the scale of urban design. Hence the main focus in terms of the level of action and design, in other words, the spatial focus, is on the energy efficiency design principles when applied to the neighbourhood and district scale. Fig no 1 shows the focus of the research within other spatial levels of action aiming to energy efficiency in the built environment.

Spatial and physical levels of actions and activities towards energy efficiency						
Cross cutting variables	Buildings	Neighbourhood District	Individual settlement	Sub-regional	Regional	National
Landscape						
Transportation						
Infrastructure						
Regulation						
Land use planning						
Site Selection						
built form						

Table 1 Planning Issues and Level of Actions for Energy efficiency
Levels of intervention on the spatial structure to achieve energy efficient built environment, Source: adapted form (Fuchs, et al., 2008) (Peker, 1998) (Siong, 2006) (Owens, 1986)

The main focus of the research is on the characteristics and physical design principles underlying the energy efficient urban configurations on the urban scale as a level of action. Among those principles are compactness, mixed use, green areas distribution, transportation mode, and street orientation. etc. (Mehaffy, et al., 2009).

1.4.2 Geographical Scope

The satellite cities around Cairo are the main spatial focus of the research, as it is widely known that those satellite cities are the main feature of formal urbanisation around Cairo. According to (NUCA, 2008), which is the New Urban Community Authority in Egypt, Greater Cairo (GC) has eight satellite cities: 10th Ramadan, 15th May, 6th October, New Cairo, El Shorouk, Badr, Elobour and Zayed.

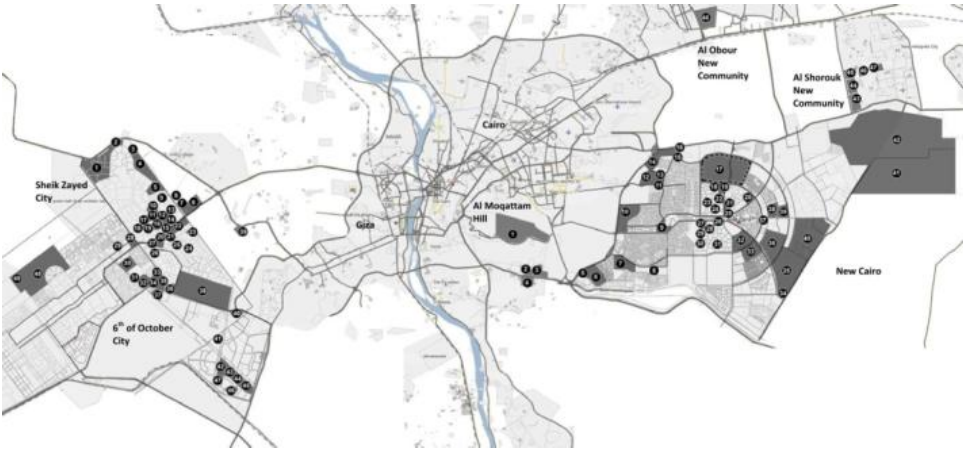


Figure 1: Greater Cairo and its surrounding new satellite cities
Source: (Yousry, 2009)

The focus is on the satellite cities due to the following factors:

a) Satellite cities are expected to have millions of inhabitants in the coming decades (NUCA, 2008).
b) Satellite cities are the locations where the largest parts of the new residential districts are being created and where most developments in urban planning practices are going on in Egypt.
c) Satellite cities have been planned to receive middle class population (NUCA, 2008), and have recently hosted several compounds (gated communities for high-income households). Those gated communities offer middle-class houses, and high-end distinctive and luxurious villas and apartments. This is in stark contrast with conventional new-town ‘master-planning’ principles (Yousry, 2009).

The middle class and high income households are most likely to consume more energy than low-income households (Ncube, et al., 2012) (Alam, et al., 1998) (Jamasb & Meier, 2010).

1.4.3 Urban Planning Regulations of Residential Projects in Cairo

In terms of urban design regulations, there are some requirements to comply with and permits to be granted to establish a residential project in Greater Cairo. For most of the residential projects, the permits are required and managed by the Ministry of Housing and Urban Communities (MHUD), the New Urban Community Authority (NUCA, 2008) and the New Cities Departments (Abdullah, 2013) (Nosair, 2013). In special cases, some other additional permits are required by different governmental bodies such as the Egyptian Environmental Affairs (MSEA), Executive Organization of Water and Sanitation Projects, the Ministry of Defence, and Operations Department of Armed Forces (Nosair, 2013) (Alqadi, 2013).

Since these bodies pose some requirements and regulations for new residential projects, it would be valuable to have a look at those requirements to explore the extent of their relevancy to the principles of energy efficient urban configuration.

1.4.4 Literature Review

To outline the principles of the energy efficient urban configuration, the thesis explored some of the literature concerned with energy efficient urban forms and the climatic design principles in hot arid zones on the urban neighbourhood level with the attempt to draw out some lessons from the old Arabic Medina and from the results achieved in contemporary practices within similar settings.

The literature review has been desk researches, by investigating works done by researches and agencies such as the findings reached by (Owens, 1986) in Energy, Planning and Urban Form and the design principles of climatic urban design done by (Givoni, 1998) in his studies on 'Climate Considerations in Building and Urban Design', and other scholars findings on the theoretical ground of energy efficiency such as (Breheny, 1992) in 'The Contradictions of the Compact City', and also the contribution of the design manuals such as (Fuchs, et al., 2008) 'Energy Manual: Sustainable Architecture' and (Hindrichs & Daniels, 2007) in 'Plusminus 20/40 Latitude', 'Sustainable Building Design in Tropical and Subtropical Regions'. Other studies and researches have been mentioned within the research.

In the Egyptian context, there are several studies that investigated the sustainability aspects of the urban design for new cities such as (Shalaby, 2000) and (Alqadi, 2013) findings on 'Compact Urban Form and (Fahmy, Stephen, & Ali, 2009) studies on the climatic urban design in Egypt. It is also worth mentioning that there is no Egyptian code or manuals for energy efficiency in building design nor urban design (Abdullah, 2013) (Alqadi, 2013) (Nosair, 2013). Therefore it is important for the study to reviews efforts done by different organizations in Egypt that aim towards a more sustainable and energy efficient built environment such as (MSEA) Egyptian Environmental Affairs Agency, (EEAA) Egyptian Environmental Affairs Agency, Housing and Building National Research Centre (HBRC) and Egyptian Group for Energy in Buildings & Environmental Design Research (EEER).

1.4.5 Aim of Case Studies

Evidence from multiple cases can be considered better founded and leads to a more robust overall study can. The main argument in favour of using the case studies is to get some guidance and ideas about the actual energy efficiency of the urban configurations of the residential projects in Greater Cairo.

In chapter three, criteria to select case studies among the residential projects in Cairo have been discussed. The criteria included: area, density, urban form, energy concepts ... etc. Selecting case studies with similar characteristics in terms of the targeted social group help focus the research on the issues of energy efficiency.

The discussion of the selected cases have been set against the design principles of energy efficiency (the principles that were extracted from the literature review which include compactness, sustainable transport, density, mixed land uses, passive solar design etc.). This led to draw the main deficiencies and advantages of the urban configurations in the selected cases in terms of energy efficiency.

1.4.6 Conclusions and Recommendations

Throughout the case studies' analysis, the research tries to draw the overall conclusions, which eventually lead to the formulation of some recommendations for the urban design of residential projects to make the projects work towards more energy efficiency.

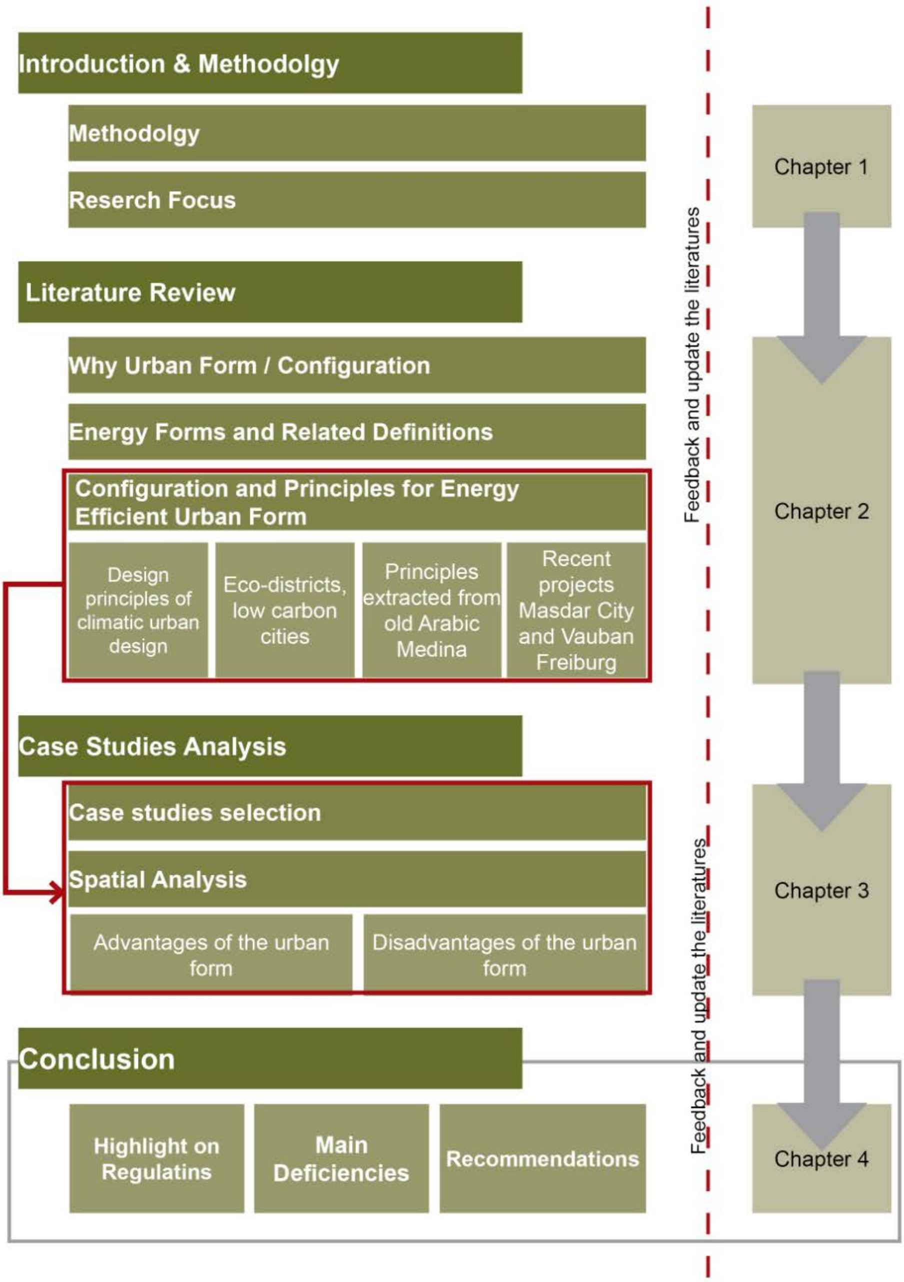


Figure 2: Abstract of methodology and research structures
Source: adapted by author

Chapter 2 : Literature Review

2.1 Why Urban Form / Configuration?

2.2 Energy Consumption and Residential Areas

2.3 Configuration and Principles for Energy Efficient Urban Form in Residential Areas

2.4 Summary and Reflections

2. Literature Review: Urban Configurations in Relation to Energy Efficiency

In this chapter the research tries to simplify the linkages between energy consumption and residential areas. The chapter starts with the justification of the potential role of urban configurations and forms for energy efficiency. This leads to the discussion on different definitions of energy and its forms and their interrelationships with the built environment. Then the research outlines the main design principles for energy efficient urban configurations for the residential projects, with showing the complexity and interaction between those principles.

2.1 Why Urban Form / Configuration?

The research focuses on residential areas on the district and neighbourhood scale. There are a lot of complex tiers and fields of action aimed towards energy efficiency in residential areas, such as the control of household consumption, consideration of the embodied energy and flow of materials, buildings design and enhancing the efficiency of supplies in addition to other policies and strategies that focus on the efficiency of the automobile and transportation technologies in residential areas. Among the various approaches and strategies to enhance energy efficiency, the study concentrates on the principles of the energy-efficient urban design for the residential areas. Figure 3 shows an abstract diagram depicting the components of urban form and its configurations. Those configurations are closely linked to achieve energy efficiency for the design of components such as; buildings blocks, open spaces, land uses, transportation and infrastructure which simultaneously affect the energy consumption and efficiency. The diagram shows that one of the most influential factors of the urban design is urban form and its configurations.

Figure 3: Relationship of fields of action in residential areas with urban configurations
Source: (Fuchs, et al., 2008) (ADOLPHE, 2001) adapted by author

2.1.1 Energy Consumption and Residential Areas

The built environment including buildings, networked infrastructures and urban areas in general constitutes the single largest source of energy consumption in the world. According to UNEP in 2007, 30-40% of all primary energy was consumed in buildings (Rydin & Hamilton, 2011). In the last decade, an important threshold in human history was trespassed: for the first time, more than 50% of the global populations are urban dwellers (Grubler & Fisk, 2013). According to the International Energy Agency, existing buildings account for approximately 40% of the world's total primary energy consumption and 24% of the world's CO2 emissions (CUED, 2013). Some other estimates consider that almost three-quarters of global energy use takes place in an urban context (Grubler & Fisk, 2013). With the robust trends towards urbanisation, the energy and sustainability challenges posed by the future development on the demand of energy cannot be described without understanding the changes on the level of an urban settlement (Grubler & Fisk, 2013). There are numerous aspects that reveal the need for action in architecture and urban planning of settlements. Among those aspects are: climate change, the need for saving resources, safeguarding of materials and energy supplies, reducing operational costs, as well as considerations of health and comfort (Fuchs, et al., 2008). This applies in the Egyptian context as well. For example, in 2009 the residential sector consumed almost 40% of the electricity generated in Egypt and almost 18 percent of the total energy as shown in (Figure 4) (IEA, 2009). When this value is added to the total energy required for public service, commercial services and transportation in the residential areas, it emphasizes the fact that the residential areas in Egypt can be considered as one of the largest energy consumers in Egypt.

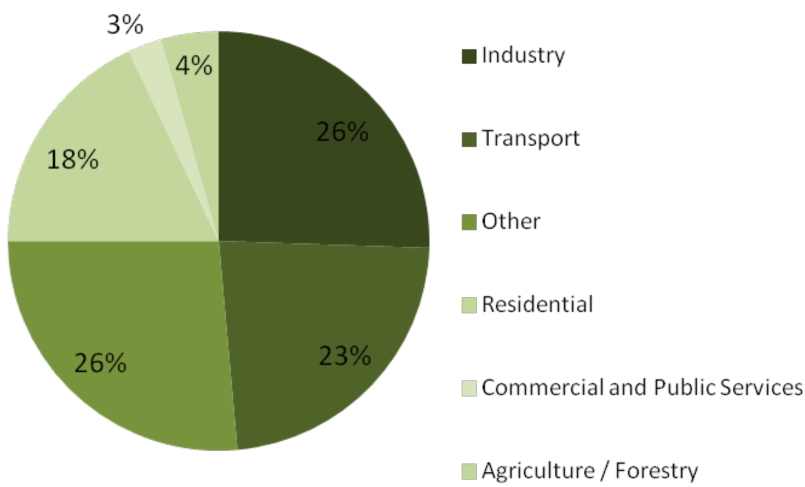


Figure 4: Energy consumption by sector in Egypt
Source: Author as adapted from (IEA, 2009)

2.1.2 Energy Forms and Related Definitions

This research uses many definitions and terminologies related to energy, therefore it is significant to set the definition of those main terminologies as discussed by (Grubler & Fisk, 2013) (Fuchs, et al., 2008). The physical definition for energy in its origin that was formulated in the 19th century is; “the power through which the potential work is transformed into real” and “the work stored in the system or the capacity of the system to do work” (Fuchs, et al., 2008). Energy appears in various forms and can be classified into mechanical, thermal or chemical energy in accordance with its physical properties (Table 2) (Fuchs, et al., 2008).

Forms of Energy	Occurs as (Example)	Technical energy conversion
Mechanical	Flowing water	Hydroelectric power plant
Thermal	Hot water	District heating
Electricity	Electricity	Heat pump
Radiation	Sunlight	Solar collector
Chemical	Natural gas	Gas fired condensing boiler
Nuclear	Nuclear fission	Nuclear power station

Table 2 Different energy forms
Source: (Fuchs, et al., 2008)

The energy of the earth derives mainly from primary energy resources: solar radiation, geothermal energy and gravitation. The energy then appears in various forms. These are supplemented by non-renewable energies, likewise stored in atomic nuclei, which are the fossil fuel forms that have been created over large periods of time by past solar radiations, and which are non-renewable within the human time scale. (Fuchs, et al., 2008) Figure 5 shows the energy sources and their primary forms on earth, by classifying them into renewable and non-renewable energy forms.

Renewable energy and non renewable energy: the intensive use of raw fossil materials over the last decades has disrupted the energy balance, as more energy is released than that which can be fed back into the earth's system, or rather be used to generate new available energy forms. This is where the definition of renewable energy begins: it is the energy continuously fed from the other three main sources of energy (solar radiation, geothermal energy and gravitation) and hence, on a human time scale, can be considered as inexhaustible. This applies also to any other forms of energy that can be derived from these sources, such as wind or water power.

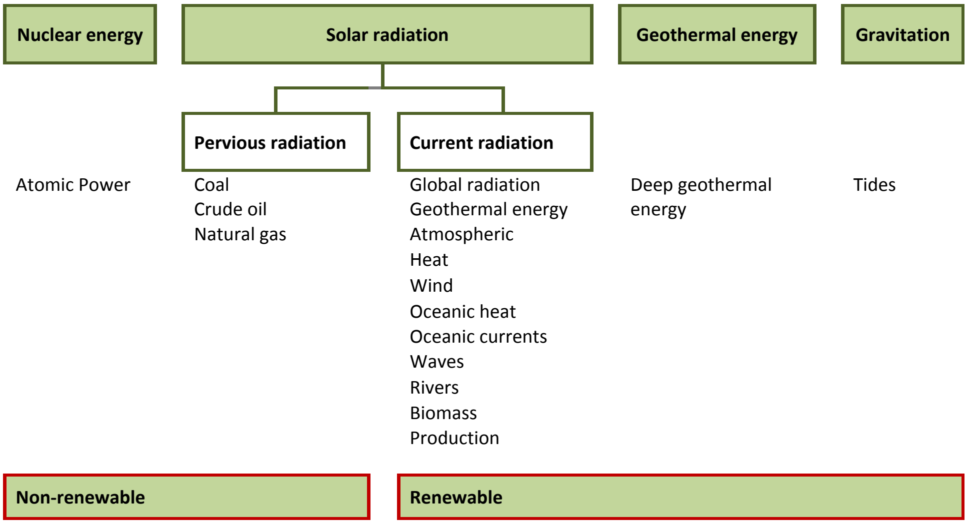


Figure 5: Renewable and non-renewable energy forms
Source: (Fuchs, et al., 2008)

a) <u>Primary energy:</u> comprises all energy forms as extracted from nature (e.g., crude oil) within a system (nation, city, and building) or imported from outside of the system's boundary (e.g., gasoline or bio-fuel to a city).

b) <u>Secondary energy:</u> the energy that is exchanged and/or transformed within the energy sector (situated between the primary and final energy) such as (refined) fuel oil that is employed for oil-fired electricity generation or natural gas fuels for district-heating purposes.

c) <u>Final energy</u>: the energy that is consumed by the end user (e.g., purchased motor fuels or electricity for households or for industry or service-sector energy consumers). Usually, it has undergone several stages of transformation, transportation and final distribution. Net energy: is the quantity of energy actually used for the energy services, e.g. street lighting.

d) <u>Embodied energy:</u> the primary energy required to produce and transport the goods and services imported and exported to and from an urban area (often referred to as indirect or gray energy in the literature), as opposed to direct energy flows (final, secondary or primary energy) used directly as fuels in an urban area.

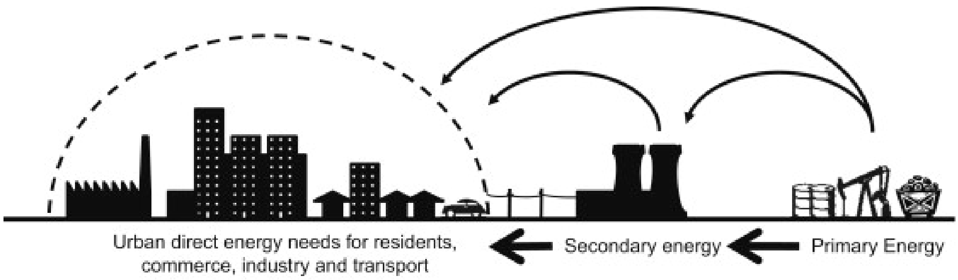


Figure 6: Energy from the primary to final energy
Source: (Baynesa, et al., 2011)

It is acknowledged that about two thirds of the primary energy obtained from nature is being lost through conversion and/or transmission, which means that the current utilization systems provides users with only one-third of the energy extracted from the nature. This is why preventing losses will represent the most important source of energy saving in the future (Fuchs, et al., 2008).

2.1.3 Significance of Embodied Energy within Residential Areas

Residential areas are constructed from a variety of components and networks such as streets, buildings, green areas, infrastructure; and each component consumes materials and energy in an explicit and complex way. As explained above, embodied energy is the total amount of energy consumed during the production, renovation, replacement and demolition phase, whereas operational energy is the energy required to operate residential areas, for purposes such as lighting, operating other building appliances, especially for heating and cooling, transportation and other processes and activities of daily operation (Dixit, et al., 2012). The embodied energy consumed in the residential or urban areas is not limited to construction only but also includes the embodied energy consumed by households such as the residential operational energy, household transportation, the flow of materials and energy embodied in household goods, and transportation to the area and commuting within the area itself (Baynesa, et al., 2011). And all of these considerations for both operational and embodied energy must be made while assessing efficiency and consumption within a certain urban system (Dixit, et al., 2012). There are some methods to understand and consider the significance of embodied energy. Among those methods are the life-cycle models and the concept of the so-called urban metabolism.

2.1.4 Urban Metabolism

The concept of the urban metabolism was originally developed by Wolman (1965) to understand the flow of energy and materials to urban areas and how urban systems continuously consume natural resources, energy and materials followed by waste production and emission through different dynamics and activities. The concept may be defined as “the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste” (Kennedy, et al., 2011)

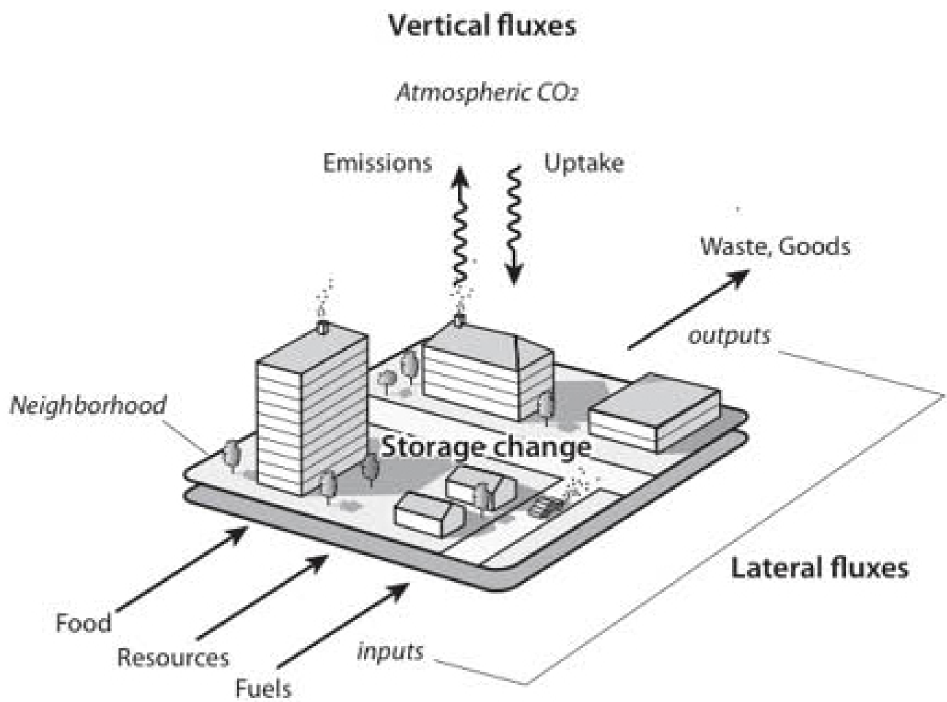


Figure 7: An abstract for the urban metabolism model
Source: (Kelletta, et al., 2013)

2.1.5 Life-Cycle Assessment

The material used for building purposes consumes much energy throughout its life-cycle stages of raw material extraction, transport, manufacture, assembly, installation, as well as its disassembly, demolition, and disposal (Manish K. Dixit, 2012). This needs to be added to the direct energy consumed in onsite and offsite operations, such as construction, prefabrication, assembly, transportation, and administration (Matthias Fuchs, 2008). Figure 8 shows an abstract for the life cycle assessment of materials (Dixit, et al., 2012) and (Pullen, 1996).

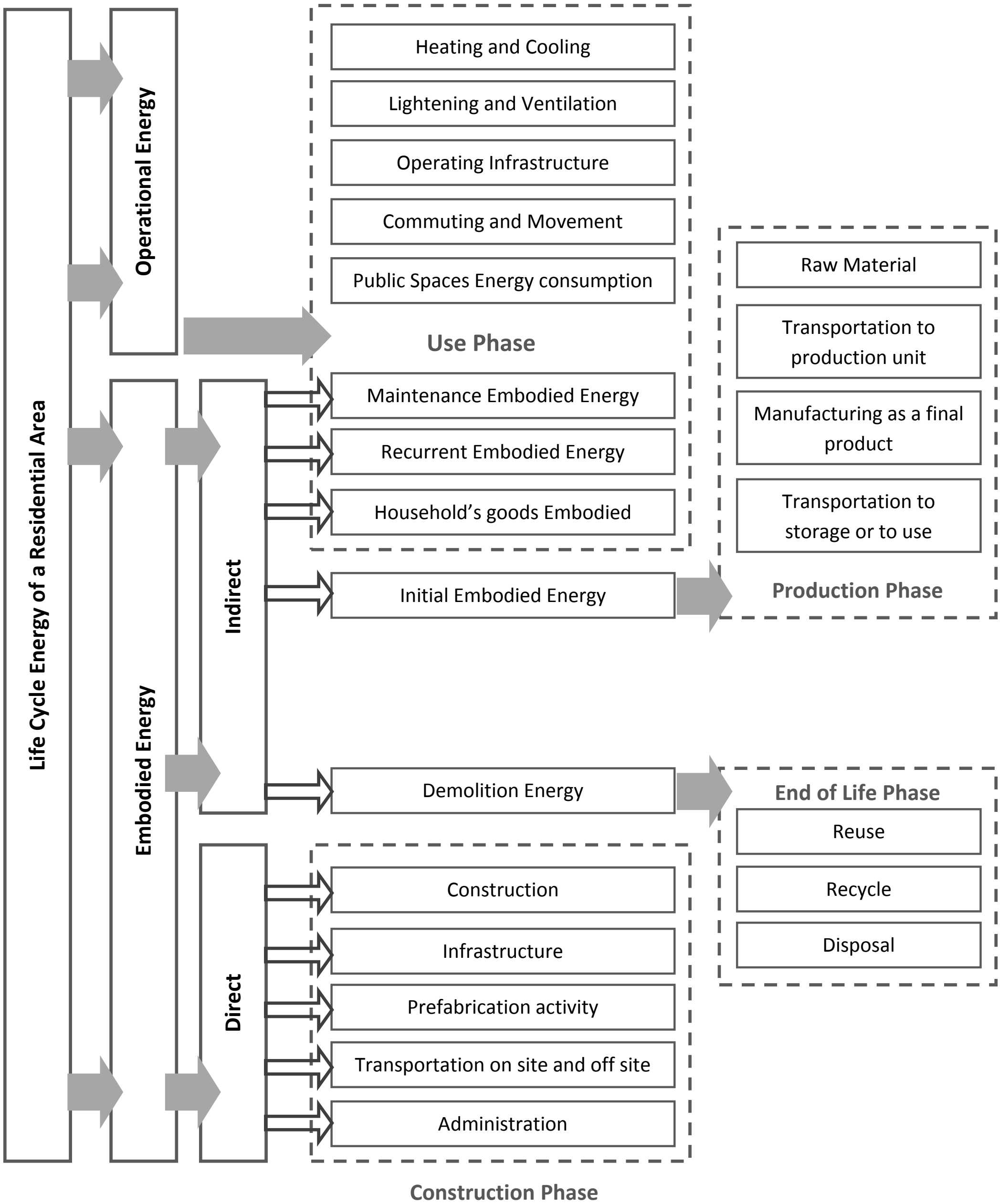


Figure 8: Abstract for Embodied energy model for the life cycle of a residential area as adapted from (Dixit, et al., 2012) and (Pullen, 1996)

2.1.6 Energy Efficiency Definition

Energy efficiency is a generic term that varies from one context to another; in the context of urban planning and design, we basically aim at achieving defined objectives as comprehensively as possible. 'Effectiveness' means achieving stated objectives regardless how much effort is required to achieve the goals. 'Efficiency', on the other hand, is a way or behaviour that leads to achieving the goals while keeping efforts to a minimum (Fuchs, et al., 2008). If we extend this understanding of efficiency to residential areas that consume a lot of energy and materials from nature to obtain their services (e.g., lighting, air conditioning, commuting), then efficiency here may indicate the realisation of goals and obtaining needed services by exerting a minimum amount of energy and material.

It is certainly difficult to mainstream a definition for energy efficiency in residential areas. Yet, a reasonable definition of energy efficiency could be formulated, such as: the conversion of energy use into a mode that enables the desired energy services (e.g. transportation from A to B) to be provided more efficiently for the same effect. In general, energy efficiency refers to less energy usage to produce the same amount of needed services or useful outputs. (Patterson, 1996). Normally, increasing energy efficiency goes hand in hand with reducing environmental damages, using fewer natural resources, producing lesser waste, and consequently causing less atmosphere pollution. This is in turn accompanied by numerous economical benefits such as, lowering costs of operating residential areas, which provide long-term strategic competitive advantages (Fuchs, et al., 2008).

Figure 9: Energy Efficiency Definition
Source (Fuchs, et al., 2008).Adapted by author

To sum up, we may argue that energy efficiency in residential area means achieving goals and objectives, including residents' needs such as daily uses, commuting, thermal comfort and others, while using the minimal amount of energy and material, thus generating low emissions and producing little waste. This may be extended to creating a closed energy system, which virtually provides energy without consuming raw material, which can only be done by using renewable energy sources, owing to the fact that most of energy systems are open systems, due to the consumption of finite energy sources (Grubler & Fisk, 2013) (Fuchs, et al., 2008).

2.1.7 Significance of Urban System Boundaries and Field of Action / Design

The built environment constitutes of multiple complex systems with different boundaries such as systems of infrastructure networks, transportation networks, and other physical boundaries for neighbourhoods, districts, cities, urban areas and metropolitan areas. It is worthwhile to consider the complexity beyond the building envelope, where interactions among buildings, spaces, infrastructure and streets come into play (Frenchman, et al., 2010). This is the main aim of the present work. Defining the boundaries of an urban system is important for a comprehensive evaluation of residential energy consumption or energy efficiency of the built environment. It is quite important to define the built environment system itself and its boundaries as well.

Among the definitions of an urban system is "a conceptual boundary in a physical or functional space which includes all components that form the urban system" (Grubler & Fisk, 2013). The boundaries may be used to define different levels and areas of a system such as towns, cities, neighbourhoods, metropolitan areas and other spatial and administrative definitions for the urban systems. The system boundary demarcates various products and processes and the related energy, material inputs, wastes and emissions that are included in the embodied energy calculation of those products and processes (Dixita, Culpa, & Fernández-Solísb, May 2013).

The intricacies of urban import/export of energy for a certain system/boundary such as a building, housing units, residential areas, towns, village, neighbourhood, or any other sub-systems such as transportation and infrastructure ought to be considered. For example, defining the boundaries of a system of the built environment is needed to assess all imported embodied energy which should be added to the amounts of direct urban energy used within a certain system, whereas the exported embodied energy should be subtracted (Grubler & Fisk, 2013).

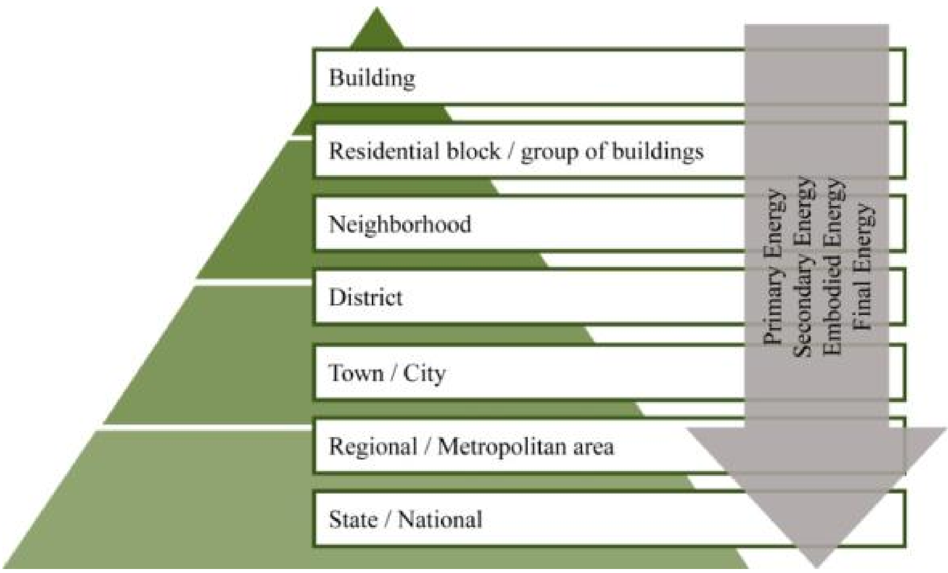


Figure 10: Abstract for potential urban system boundaries
Source: adapted by author

2.2 Principles for Energy Efficient Urban Configurations in Residential Areas

There are variables which influence the energy requirements of the spatial structure on different scales in the context of energy efficient urban design which aims to reduce energy consumption (Peker, 1998). Urban form and its configurations have implications on transportation, greening, buildings, and land uses, a fact which offers a wide range of opportunities to reduce energy consumption and Co2 emissions. This chapter aims to discuss the principles of configuration that are necessary to achieve the aforementioned energy efficient urban form while designing for residential areas.

Linguistically the word configuration means “an arrangement of parts or elements in a particular form, figure, or combination“(Oxford, 2013) or “Something (as a figure, contour, pattern, or apparatus) that results from a particular arrangement of parts or components” (Merriam-Webster, 2013). The international conference of “New Urban Configurations” held in 2012 at (TUDelft, 2013) Netherlands by the European Association for Architectural Education (EAAE, 2013) in collaboration with the International Seminar on Urban Form (IUSF, 2013), the conference defined five sub-themes for the urban configurations: “1. Innovation in building typology, 2. Infrastructure and the city, 3. Complex urban projects, 4. Green spaces: the city and the territory, 5. Delta urbanism: Living with water in the urban Deltas” (EAAE/ISUF, 2013). Accordingly urban configurations are not only limited to the arrangement of buildings but also the relation of these buildings with the built environment elements such as the buildings morphologies, green areas, landuses, circulation and mobility networks.

The recommendations for the configuration of energy-efficient urban forms ranges from the scale of the city, neighbourhoods, districts, and occasionally on a building scale, particularly where the interactions between buildings and surroundings are concerned (Givoni, 1998) (Peker, 1998), such as the orientation of groups of buildings, building shapes, housing types and other factors. Figure 11 shows an abstract representation of those principles and configurations, and demonstrates the four main sources to highlight energy efficient urban design:

a) Recent projects Masdar City[1] and Vauban Freiburg
b) Principles extracted from old Arabic Medina
c) Eco-districts - low carbon cities
d) Design principles of climatic urban design

The following principles can be considered as the main energy efficient urban design principles in the residential areas:

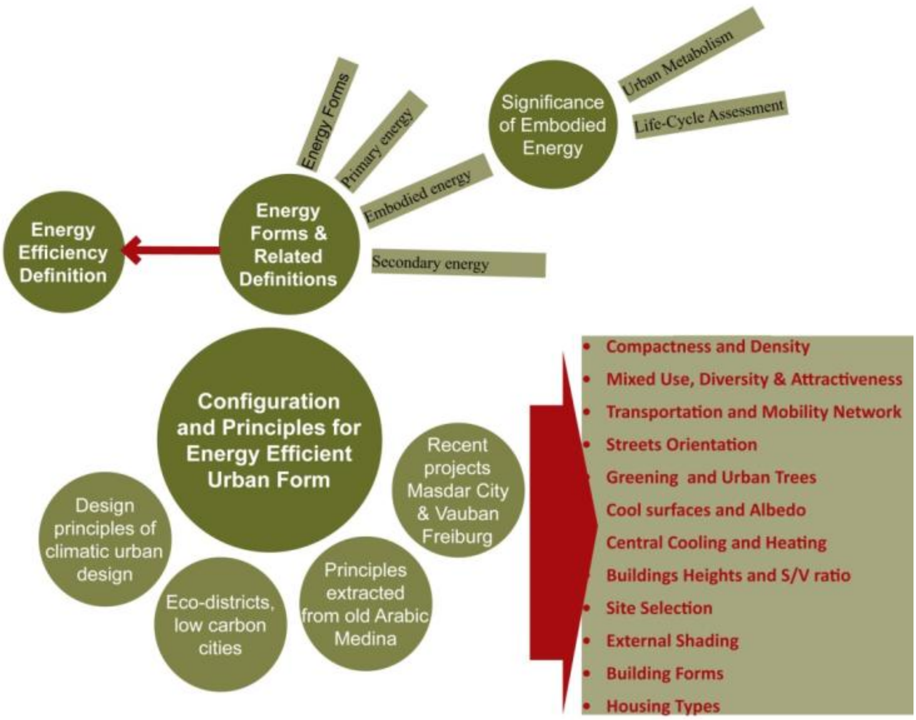


Figure 11: Main sources to draw the energy efficient urban configurations in residential areas
Source: Adapted by author

[1] It is important to mention that Masdar city is located in climatic conditions similar to Cairo (hot arid). It has not been realized yet, but the research draws out some positive lessons from its vision, principles and theoretical studies.

2.2.1 Compactness and Density

Compactness does not generally have only one definition (Tsai, 2005), but is usually referred to in the context of high-density or monocentric development (Gordon & Richardson, 1997). Compactness is also described as the degree to which development is clustered, and to which it minimizes the amount of land developed per each square mile (Galster, et al., 2001). Most areas with a high percentage of building footprint are usually widely known for their compact urban form, such Fatimid Cairo (Alqadi, 2013) (Hindrichs & Daniels, 2007).

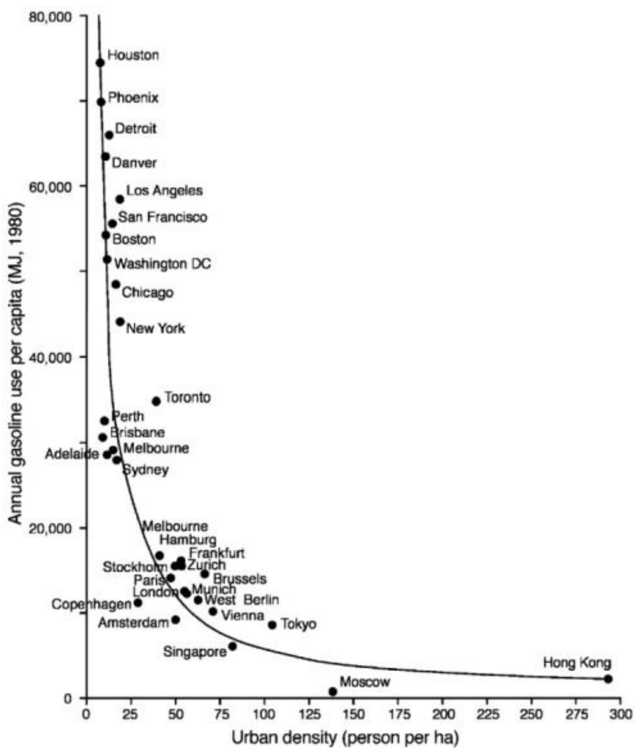


Figure 12: Per head energy consumption of various and energy consumption.
Source: (Fuchs, et al., 2008)

It is agreed that broad planning decisions regarding urban densities need to consider a range of factors, but increasing residential density in the urban form may include a significant potential for energy conservation (Norman, et al., 2006). The literature shows a clear linkage between energy consumption and density. A comparison of the per-capita energy consumption for different cities reveals this obvious relationship (Figure 12) (Fuchs, et al., 2008). The lower the density of a city or a district, the higher is the energy consumption (Burgess & Jenks, 2000) due to the transportation energy-savings possibilities (Breheny, 1995). The compact urban form impacts solar radiation, shadows, movement patterns, urban heat island effect and the efficiency of the infrastructure, which affects the energy consumption directly and indirectly.

2.1.1.1 Compactness and Solar Radiation

Proper design strategies for hot-arid zones (such as Egypt) emphasize the importance of protection against the high degree of solar radiation. The more dense and compact an urban form is in an area, the lower the exposure of spaces between buildings to solar radiation (Milošovičová, 2010). This is because the dense urban form enables buildings to shade each other and cuts overheating due to solar incidence, which eases the solar heating effect (Marshall, 2008) and thus requires less energy for cooling and heating (Givoni, 1998) (Golany, 1995) (Peker, 1998).

The compact urban form responds positively to stressful climates. The concentrated and firmly unified landuses placed in a close and tight physical relationship with each other and the structures within themselves constitute the compact city form (Golany, 1995). This alleviates the problems of stressful climates, such as intense radiation, extreme diurnal temperature fluctuation, intense dryness, cold or hot winds and dust storms. Urban design strategies suggest the use of narrow streets that allow self-shading of opposing building walls, covered footpaths, continuous arcades and shade-providing squares. (Hindrichs & Daniels, 2007). The concept of urban compactness owes much to the Arabic urban patterns such as in Fatimid Cairo. Its urban pattern is characterized by crooked narrow alleys suitable for reducing solar radiation, buildings with interior garden courtyards, and small urban spaces between buildings. A quick glimpse on the urban pattern of Fatimid Cairo shows a circulation network of streets flanked by buildings with heights suitable to supporting the outdoor thermal comfort and reducing the solar radiation penetrating them (Hindrichs & Daniels, 2007) (Sharples & Fahmy, 2008). Some characteristic features are:

a) The north-south axis which is clearly identifiable in (Figure 13). This axis and the second paralleled artery are relatively wide, those axes provide shade and privileged wind from the north, which can be felt even during summer and also provide shades to the pedestrian (Hindrichs & Daniels, 2007).

A series of local urban spaces such as arched alleys, pergolas and a colonnaded aisle provide passage to people from one sheltered space to another via a series of spaces that ensure thermal comfort (Sharples & Fahmy, 2008).

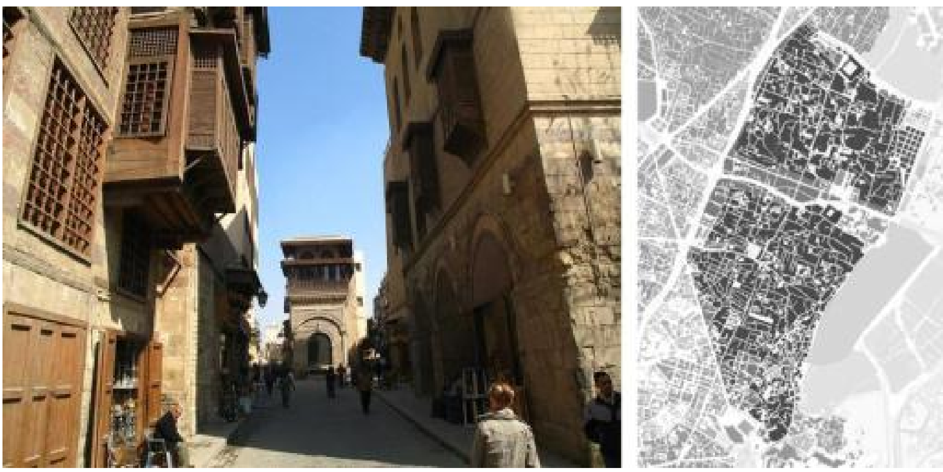


Figure 13: Compact urban pattern of Fatimid Cairo allows more protection against the sun
Source: (Masterplaan, 2009) (URPHC, 2012)

2.1.1.2 Compactness and Infrastructure

The concentration of activities is often perceived as a source of environmental problems. On the contrary, compactness does have environmental advantages as well, for example sharing of resources. The intensified use of land and the sharing of infrastructure, energy and water supply, drainage, roads and public transport all reduce the energy per capita consumed by construction (and possibly maintenance) (Steemers, 2003). The compact urban configuration establishes fast and easy accesses to daily uses, services and businesses, which saves commuting time and energy (Fuchs, et al., 2008). The high density and short distances between buildings reduces the length of all the infrastructure systems and the energy consumption is positively reduced, for example the short length of electricity network within a district reduces losses occurring via transfer (L.Ramesh, et al., 2009). Another benefit is that the shorter the length of infrastructure networks, the less embodied energy is needed for their construction (Steemers, 2003).

2.1.1.3 Compactness and Density in Relation to Urban Heat Island

From an environmental perspective, compact urban forms are usually associated with low per capita energy consumption (Breheny, 1995). But on the other hand, the compact urban forms increase the so-called urban energy-demand density~~,~~ (the amount of energy needed for a certain area). The higher energy-demand density, the larger the impacts of emissions, either as air pollutants or as waste heat release. This high energy-demand density, combined with the associated emissions, has two important implications as discussed by (Schulz, et al., 2013)

a) Energy usage involves heat losses especially high densities of urban energy usage which imply high densities of urban waste-heat releases. This, combined with the high thermal mass of buildings in densely built up urban land, gives rise to the urban heat-island effect (Schulz, et al., 2013).

b) Intensive usage of fuels in the high energy demand density of urban areas results in high levels of pollution concentration (Schulz, et al., 2013).

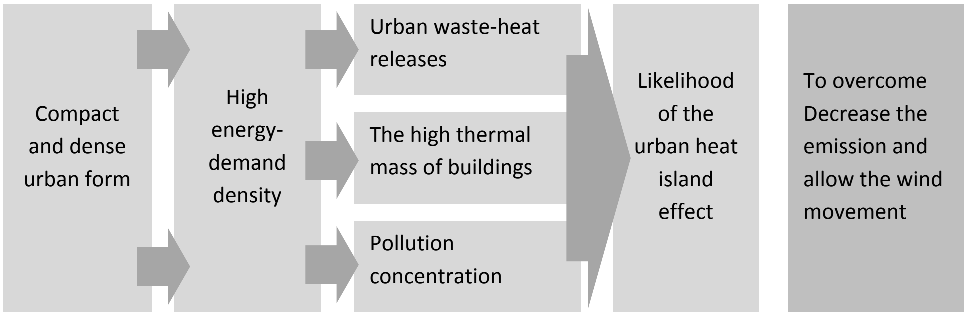


Figure 14: The possibility of the urban heat island within the compact urban form
Source: (Shaw, et al., 2007) (Schulz, et al., 2013) adapted by author

These main implications come in addition to the potential high density, exacerbating the urban heat-island effect and increasing its likelihood (Shaw, et al., 2007). The increase of the urban heat-island effect leads to an increase in energy consumed for indoor cooling (Akbari, et al., 2001) (EPA, 2013). To overcome the negative effect of high energy-demand density in the context of urban heat-island effect, zero-emission technologies are required (at the point of final use). It is recommended to use fuels that have no emissions at the final stage of usage, such as electricity, and perhaps in the long run, hydrogen, or fuels that have low emission such as natural gas (Schulz, et al., 2013), and to clear the wind movement paths (Milošovičová, 2010). This is the most common case in Cairo, as electricity is used for cooling and heating water and most of a household's use of energy depends on electricity and natural gas according to (CAPMAS). But the problem worsens due to the automobile traffic, which mainly depends on fossil fuel.

2.1.1.4 Compactness in Relation to Privacy and Liveability

In terms of social interaction and vibrancy of spaces in the compact city, there are some researchers who claim that less compact growth is welfare increasing. Due to the availability of more open spaces, green areas, privacy and other factors some people perceive that lower densities on the urban fringe increase an individual’s perceived welfare (Garcia & Riera, 2003). It goes without saying that many people want greenery, sense of safety, quiet streets, and so forth, which are provided by low-density residential suburbs. However, those qualities are not exclusive to all low-density and dispersed development. This is why we must be cautious in accepting claims that liveability is greater in one form over another. Liveability is also a matter of personal preference (Neuman, 2005). While compactness has positive implications in reducing travel distances, easy access to services, protection against solar radiation and highly improved public transport use, compactness is also correlated to be negatively associated with the liveability in urban areas. This appears in the form of smaller domestic living space, fewer open spaces, less walking and cycling and a high potential for traffic jams and pollutants. Therefore, compactness may enhance liveability, if implemented in such a way that maximizes benefits and ameliorates potential problems, thus it is a matter of tradeoffs between negative and positive impacts (Burton, 2000).

2.1.1.5 Compactness and Sustainability

In a paper written by (Neuman, 2005),’The Compact City Fallacy’, he discussed the notion of compactness in relationship to sustainability. (Neuman, 2005) He argued on compactness mainly against the traditional stems of sustainability; which are place-specific, health and the presence of interrelationships among system components.

In terms of being place-specific, all good designs are context specific, as argued by their leading contemporary proponents, such as some governmental authorities in England, Netherlands and other countries in Europe. Others argue that good designs are not generic and are widely reproduced designs which are usually often insensitive to context, whether social, environmental, economic, or political. Another problematic aspect of compactness is placing a premium on a single operational measure: population density or built-up area density. City measures are complex and operational measures are more complex than considering one measure, the analysis of the compactness should at least address differences in land use patterns, physical design, social characteristics, and ecological conditions among places with the same overall density. This needs further analysis and assessment.

He argued that the compact and dense cities are determined as unhealthy and that the origins of modern planning were derived from eliminating city crowding in the nineteenth century. Furthermore, dense urban centres have disadvantages on health due the pollution and increased energy and materials per square meters in skyscrapers, but on the other hand a good compact settlement that takes in consideration density, pedestrians and public transportation addresses some of the ills in modern cities. Hence, compactness is a desirable goal for cities but ought to be under a holistic assessment to come to a decision for the degree of compactness.

Regarding the interrelationships between different systems and configurations in the residential areas, a compact city seeks to bring uses into proximity and mix uses in town centres, thus enhancing the liveability of the city. On the other side a stiff pattern of single-family homes on the edges and people who live in them must commute, often long distances to the city centres, as only a few are connected to job centres by transit, but regardless are still preferred by a lot of people. Also some scholars such as Breheny (1992) and Jenks, Williams, and Burton (1996) concluded that the data regarding the sustainability of compact cities is not conclusive. Their analysis was limited to the question of compactness and urban form. We, on the other hand, have to look beyond the compact city for answers to the sustainability, due to the complex dimensions involved in the cities other than density and compactness because cities are not merely physical forms. This means that not all compact cities are necessarily sustainable cities.

Even with the advantages of the compactness, it needs more investigations and analyses on other factors that form those cities.

Compact forms do impart advantages such as lower land consumption, cheaper infrastructure and utility costs, and resource protection and reducing daily travel for shopping, work, and entertainment, in addition to other benefits such as protecting against solar radiation. However, (Neuman, 2005) concluded that "the compact city is neither a necessary nor a sufficient condition for a city to be sustainable and that the attempt to make cities more sustainable only by using urban form strategies is counterproductive. Instead, conceiving urban form as a procession outcome of urbanisation opens the door to a new and dynamic conception of urban planning that is based on a reversal of the last century's (not exclusive) focus on urban form governed by the static tools of the plan and zoning" (Neuman, 2005).

2.1.1.6 Compactness, Wind Flow and Movement Network

Another important factor to determine the reasonable level of compactness is the wind movement. To benefit from the privileged air movement it requires wind channels and free-obstacle streets, which seemingly contradict with the principles of compactness as the more compact, the less adequate wind access (A.Ramadan, 2010). Interactions between canopy layer climate elements cannot be illustrated for each one separately; but the wind flow and the amount of solar radiation received are affected by location, sky view factor and urban texture, thus in turn affects surfaces and the energy needed for cooling and ventilation (Givoni, 1998).

In arid urban areas, climates are dominated by nocturnal cooling of long wave radiation especially where a clustered compact form is capable of releasing heat from structured multipurpose green areas (Fahmy, Stephen, & Ali, 2009). When street canyons become narrower they become more isolated from the upper atmosphere. Many studies have demonstrated climatic variations attributable to the network and the fabric of a local climate. The local climate is affected by many factors such as building heights, building height to width of street which called H/W ratio, and distances between buildings. For example a classification system for a city's urban form from a climatology point of view was presented by (OKE, 1981). The canyon's wind flow is particularly affected by canyon orientation, slope and geometry. These characteristics can be represented in terms of the building form ratios. Figure 15 shows different urban forms in comparison with what is called the roughness of the urban texture.

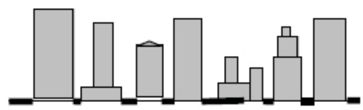
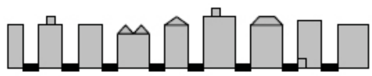
Urban Zone,	*Image*	*Rough-ness class*
1. *Intensely developed urban with detached close-set high-rise buildings with cladding, e.g. downtown towers*		8
2. *Intensely developed high density urban with 2 – 5 storey, attached or very close-set buildings often of brick or stone, e.g. old city core*		7
3. *Highly developed, medium density urban with row or detached but close-set houses, stores & apartments e.g. urban housing*		7
4. *Highly developed, low or medium density urban with large low buildings & paved parking, e.g. shopping mall, warehouses*		5
5. *Medium development, low density suburban with 1 or 2 storey houses, e.g. suburban housing*		6
6. *Mixed use with large buildings in open landscape, e.g. institutions such as hospital, university, airport*		5
7. *Semi-rural development, scattered houses in natural or agricultural area, e.g. farms, estates*		4

Figure 15: Different roughness levels in different urban zones
Source: (A.Ramadan, 2010) (OKE, 1981)

2.1.1.7 Finding the Right Balance

A good example of exploring the benefit of compactness within residential areas is a study done by (Sharples & Fahmy, 2008) which investigates the variations of performances between three locations in New Cairo with different levels of compactness. The study shows the influence of the urban form compactness on the outdoor thermal comfort as seen in (Table 3).

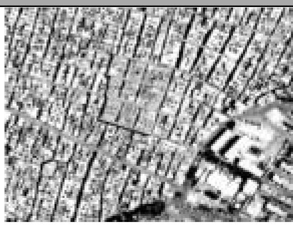
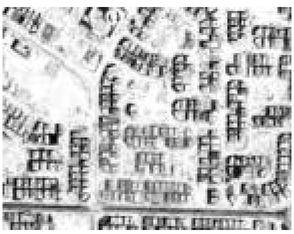
Urban form	Layout	Positive impacts	Negative impacts
Highly dense built up area High population density		better in thermal performance by day and low exposure to the solar radiation	Not the same performance same by night it hasn't sufficient wind access besides the high population density itself.
Medium dense built up area High population density		Enough wind movement and solar access for both passive cooling and health aspects	high exposure to solar vertical positions which can be enhanced by vegetation and urban trees if considered
Low dense built up area low population density		Easy and open wind movement	Highly exposed to the direct solar radiation more land consumption, sprawl and needs much more green cover, urban trees and shading elements

Table 3: Comparison between the compactness levels for three locations in Cairo
Source: (Sharples & Fahmy, 2008)

This study (Sharples & Fahmy, 2008) argues that the medium dense built up area has better outdoor thermal performance and has advantages in terms of easing the solar radiation during the day. It also has the ability to release heat during night and to allow enhance the wind movement, which in sequence reduces the energy consumed for indoor air conditioning.

To conclude the relationship between dense and compact urban forms, and energy consumption, it may be argued that the compact urban form has some positive implications and other negative ones. Figure 16 summarizes the positive and negative impacts of the compact urban form on energy consumption. In general, positive impacts are the shading and protection from solar radiation, short distances for access to services and uses, and short infrastructure. The negative impacts are mainly due to the effect of the urban heat island and the pollution. Therefore, some tradeoffs between both positive and negative impacts of compact urban form would be very beneficial. Using the advantages of the old Arabic pattern, which employ spatial networks with reasonable orientations and allows for the wind flow to access urban spaces for cooling purposes and tries to use as much as possible multiple energy forms that have no emission at the end point of use, appears to be beneficial.

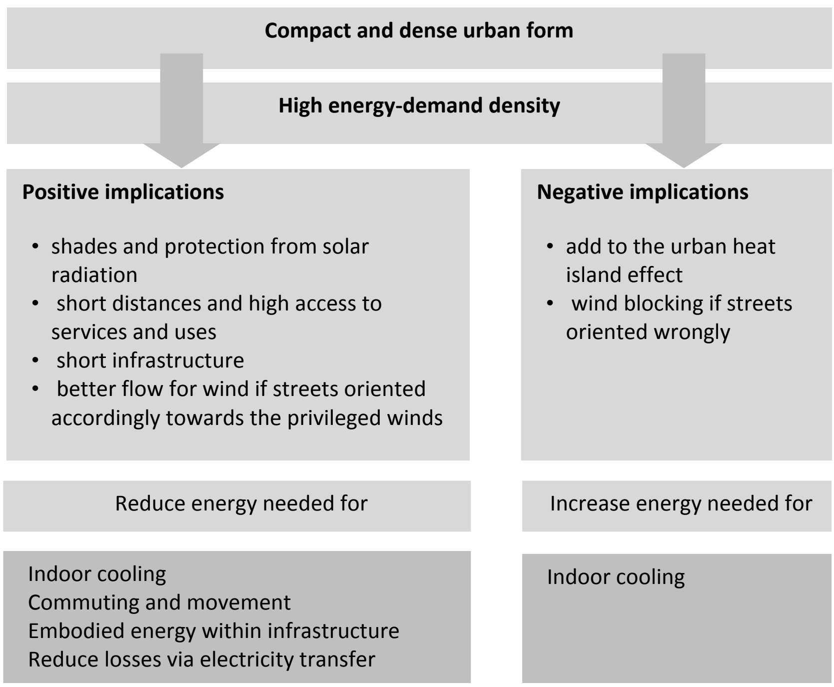


Figure 16: Abstract for the positive & negative impacts of compactness on energy efficiency
Source: adapted by author from previously mentioned literature

2.2.2 Mixed Land Use, Diversity and Attractiveness

Land use patterns and diversity of land uses have a major impact upon energy consumption and energy-efficient development (Owens, 1986). Land-use mix is the composition of uses within a given area, mixed-use developments are those with a variety of offices, shops, restaurants, banks, businesses, even light workshops and other activities intermingled amongst one another (Pivo & Frank, 2006). The integration and provision of services—which mixed use areas provide—is crucial to the sustainable development of urban structures. If a demand cannot be met locally, people will travel to another urban space in order to meet their demand (Alqadi, 2013) (Peker, 1998). Reducing the travel and the commuting distances always has a positive effect on energy consumption because traffic can be avoided, so a stronger coupling between needs and users will be very beneficial in order to reduce the energy consumption (Peker, 1998) (Fuchs, et al., 2008)

The attractiveness of urban spaces and residential areas is also significant for the satisfaction of residents, as urban areas function better than non-urban ones due to the interaction of building functions, open spaces and the interactions with neighbouring spaces. Thus, attractiveness can be achieved via certain necessary assets such as accessibility, provision of private, semi-public and public spaces, and bringing together different requirement and interests in order to cover overriding needs in an integrative way, and to preserve local qualities and provide high quality of life (Shaw & Ibrahim, 2009) (Fuchs, et al., 2008).

One of the good examples that show how the mixed land uses and the attractiveness of the urban spaces are crucial to energy conservations is Masdar City. The vision of the city formulated seven overriding characteristics defining Masdar City: optimally oriented, integration, low rise, high density, vibrant urban realm, pedestrian friendly, high quality of life, convenient public transportation, and traditional Arabian city design (Figure 17) (Masdar City, 2010). It is obvious that four characteristics out of seven are related to the principles of mixed uses and attractiveness of the city.

Figure 17: Masdar city goals and overriding characteristics
Source: (Masdar City, 2010) adapted by author

Table 4, shows a brief description of those four characteristics. Masdar City considered the attractiveness, the provision of mixed land uses, the vibrant public realm and the high quality of life as important factors for the sustainability of the city.

To conclude the influence of attractiveness and mixed use on the energy consumption of a certain area, we can state that when a district or an area is attractive enough and self-sufficient with its daily activities, people are less likely to drive and more likely to walk to destinations (if a proper pedestrian networks is provided) (Peker, 1998) (Fuchs, et al., 2008). This should be reflected in lower vehicular trip generation rates and higher non-motorized (e.g. walking, bicycling) modal splits in mixed-use settings (Cervero, 1995) which directly reduce the energy consumption.

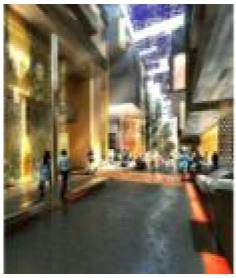
		 	
High Quality of Life	**Integrated**	**Vibrant urban Realm**	**Pedestrian Friendly**
To provide highest quality of life with the lowest environmental impact.	There are no separate zones for industry or culture. The university, business and leisure are embedded in the heart of the community	Public spaces are as important as the buildings in Masdar City, with a variety of tactics used to activate this space.	On the pedestrian level of the street, buildings to be closer together providing shading and cooler street

Table 4: Masdar city characteristics and attractiveness
Source: (Masdar City, 2010) adapted by author

2.2.3 Transportation and Circulation Network

In Egypt, the transportation sector accounts for 26% of the total energy consumption in Egypt according to statistics of the (IEA, 2009) (Salem & Huzayyin, 2009). In addition to that, the oil's share of the energy consumption lies mostly in the transportation sector (EIA, 2009). There is no accurate data on how much energy the satellite cities around Cairo consume for transportation, but observations and analysis show that most of these satellite cities are car-oriented as there is no proper and efficient public transportation system (Shaw & Ibrahim, 2009) (Alqadi, 2013).

To provide a proper mobility network within a district, the scale, area and volume of traffic are the most dominant factors that define the appropriate transportation mode. Public transport systems require relatively high population densities to offer an attractive and economically viable alternative to private automobiles (Schulz, et al., 2013). It is widely agreed that public transportation systems are much more energy-efficient than private cars. For example, in a 50 cities worldwide study issued by the UITP European commission (UITP, 2006) (UITP is the International Network for Public Transport Authorities), evidence was reached that cities with high densities and a high share of public transport are the most energy efficient. The study also claimed that public transport consumes three times less primary energy than the private car traffic in normal hours and has an advantage of 10:1 over the private car in peak hours (UITP, 2006). It is worth mentioning, that the public transportation is more energy efficient at certain levels of ridership. For instance the public transportation system with low percentage of ridership is not more energy efficient than private cars, so it is important to assure that the ridership level (or number of commuters) is enough to operate an energy efficient public transportation system (O'Toole, 2010) . Hence, one of the key studies to reduce energy consumption is the feasibility of different public transportation systems to define which one is preferred for a certain residential project, because improving transportation networks could reduce carbon emissions more than replacing all gasoline cars with corn ethanol for instance (Marshall, 2008).

In order to achieve sustainable and energy-efficient circulation networks at the scale of the district, there are some principles which can be extracted from the literature and from experiences with the eco-cites and low-carbon cities such as Masdar City in Abu Dhabi and Vauban City in Freiburg. The two examples—as eco-districts tried to achieve a sustainable mobility network by providing clean vehicles, public transportation with high-quality service, soft transportation such as walking and biking (Review, 2013), in addition to well-designed streets layouts, car parking and pedestrian networks, which in a way reduced the energy consumed via providing more sustainable ways for circulation and mobility within the district.

2.2.3.1 Integrated Circulation Networks

In Masdar City, the mobility network is complex and consists of many tiers. Regardless of the high technology used in the electrical cars proposed in the City, the mobility network itself constitutes mainly of three integrated levels of transportation (Mogge, 2009). Figure 18 shows those three levels; the yellow line represents the regional rail line of Abu Dhabi, the lowest (red) network is the Personal Rapid Transit system (PRT) system, which extends to the external car parks. The green grid represents the pedestrian paths, which are strongly connected with the PRT stations (Mogge, 2009).

Such a comprehensive and integrated mobility network was introduced in Masdar City as a key factor to save energy, reduce pollutants and reduce CO_2 emissions within the city, which consequently reduces the urban heat-island effect as well (Mogge, 2009). Furthermore, the efficient mobility network is not only limited to the hierarchy of transportation means, but it also ensures the accessibility and connectivity with the services and activities. Figure 19 shows the relationship between mobility network and access to services in Masdar City.

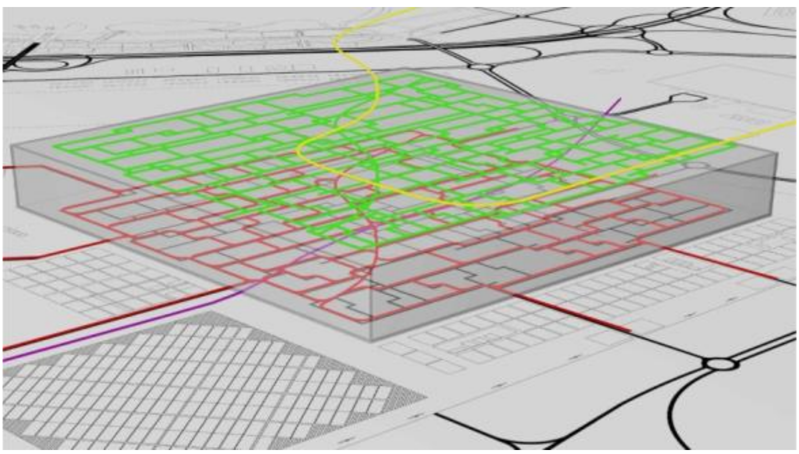


Figure 18: MASDAR Mobility integrated System Layers
Source: (Mogge, 2009).

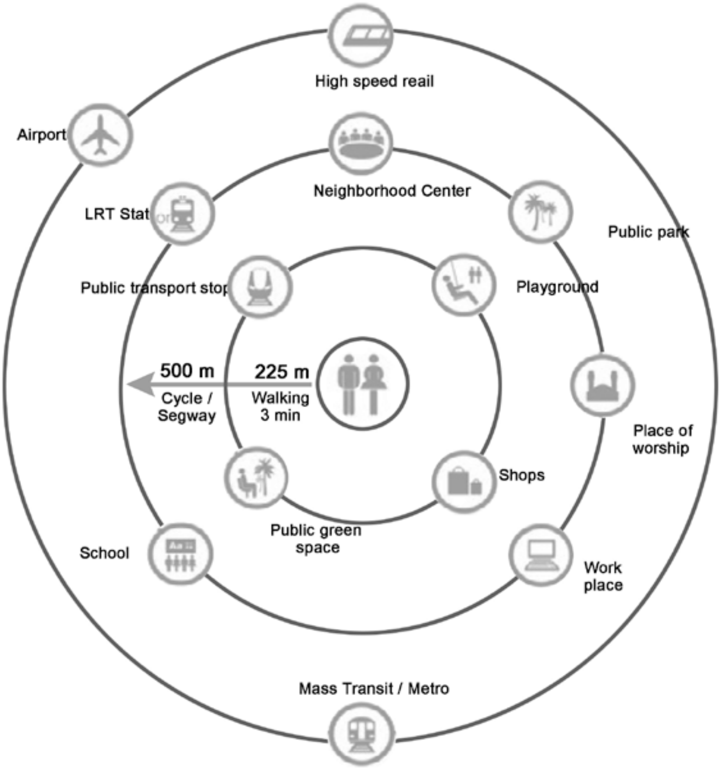


Figure 19: MASDAR City, Mobility network and access to services
Source: (Masdar City, 2010)

2.2.3.2 Access and Connection with the City Transportation Network

From a general point of view, connecting residential areas with public transportation networks—if any—could reduce the use of private cars. For example Freiburg's tram system was extended to Vauban in 2006 to encourage the usage of public transportation instead of private cars usage. In addition two bus routes connect Vauban to the city centre and the main railway station (Figure 20) (Field, 2010). Such an idea is applicable in the Egyptian context, particularly for the residential areas in the suburban and in satellite cities; it is commonly known that owning a private car is crucial to living in one of Cairo's satellite cities due to the weak access to public transportation means (Abdullah, 2013) (Alqadi, 2013). In Masdar city, the same principles regarding ease of access to the wider public transportation were implemented. Abu Dhabi's light rail and Metro lines will pass through the centre of Masdar city to support the city's objective that no destination in the city is more than 250m-300m distance from public transport and to reduce private car trips to the city by to connecting Masdar City with the public transportation of Abu Dhabi (Masdar City, 2011).

Figure 20: Freiburg's tram system extended to Vauban in 2006
Source: (Field, 2010)

2.2.3.3 Streets Design

For efficient mobility within districts and neighbourhoods, there are some basic requirements for the street design, such as the provision of cycle lanes and proper pedestrian paths, which could effectively reduce the fuel used by cars. Promoting safe walking and cycling is essential to assure the success in a cutback of car movement within the districts (Dijkstra & Pucher, 2003). However, in addition to the casual requirements needed for the street design, the high temperature in Cairo, particularly in summer, is a major constraint when encouraging people to walk and cycle at the district level. Even if a transit-oriented system is used, the walkable distance in the summer is estimated to be 200-300 meter in hot-arid zones (Masdar City, 2011). For that reason, designing convenient and comfortable paths is critical for encouraging people to walk in Cairo. Strategies such as shading elements, trees and light pavements -high albedo- that reflects the solar incidence back into space would cool surfaces and air (Akbari, et al., 2001). Those strategies would be beneficial for promoting walkability in hot climates. There are also some other considerations for street design, such as the amount of land that the roads and streets occupy (which have implications on the usage of land as a resource), the increase of surfaces exposed to solar radiation, and the added embodied energy needed for construction of parking areas'. In the light of this, a reduction of space would be required and the avoidance of any poorly used traffic infrastructure would be sensible (Fuchs, et al., 2008). For example, in Vauban an ecological traffic and mobility concept has been implemented and the principles of 'car-free' transportation have been promoted. The parking areas were located on the periphery of the site, which accompanied the promotion of the public transportation and a car-sharing system (Field, 2010) (Milutinovic, 2013). The pedestrian network in Vauban consists mainly of a boulevard for pedestrians and cyclists which run along the north side of Vaubanallee, with a network of non-motorized traffic routes on the northern side of the site (Field, 2010). Surfaces freed by reducing car lanes' spaces were used for the benefit of additional greenway paths, which make walking and cycling even more direct and convenient (Field, 2010). Applying the same principles in Cairo—in the case of a hot arid climate—would entail narrowing the streets and providing them with appropriate trees for providing shading to boost their outdoor thermal comfort, which in sequence would encourage walking and cycling through the districts. Narrow streets could be shaded during the hot summer days by using coverings made from light material (Fahmy, Stephen, & Ali, 2009). Figure 21 shows the streets of Vauban District which prioritize walking and playing as main usages of the streets; "play streets" where the primary use is walking and playing, and motor vehicles are permitted but within walking speed

Figure 21: A “play street” – Vauban District
Source: (Field, 2010)

2.2.3.4 Street width

Street proportions or street widths have many implications on the amount of solar radiation that hits the walls of the buildings and reaches the street surfaces, affecting the climate near the ground and the surrounding buildings. (Givoni, 1998). Usually streets proportion is defined by the H/W ratio, when H is the height of the buildings and W is the width of the streets, as shown in (Figure 22) (Milošovičová, 2010).

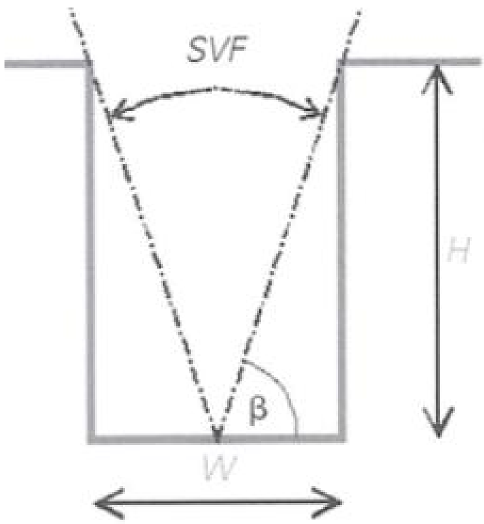


Figure 22: H/W ration and Sky view Factor
Source: . (Givoni, 1998)

To understand the influence of the H/W ratio and sky view factor in relation to solar radiation, the following table 5 shows a comparison between two streets with different H/W ratio of 1 and of 4 (Givoni, 1998) Those effects combined with more shading than what the high H/W provides, would imply that a higher H/W ratio result in lower heating of the urban streets and gives more shades which in sequences support the pedestrian paths with shades and ease the solar radiation effect of heating. A high H/W ratio is more suitable in a hot climate such as in Cairo particularly when pedestrian areas and walkability need to be encouraged.

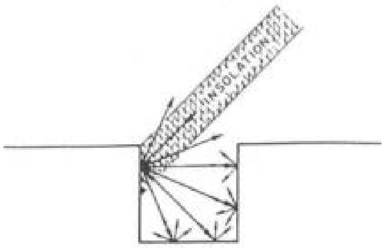
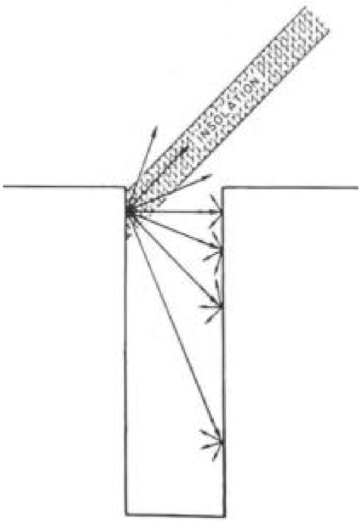
H/W Ratio	Characteristics
 H/W 1 Represents low density urban areas	Much of the reflected radiation strikes other buildings or the ground and is eventually absorbed at and near the ground level The high sky view factor allow more solar radiations to reach the pedestrian paths
 H/W 4 Represents low density urban areas	The amount of radiation reaching the ground, and heating the air near the ground, is smaller than in case of low density. Gives more shades at the ground level and to the pedestrian paths

Table 5: Comparison between different H/W ratios
Source: (Givoni, 1998). (Milošovičová, 2010) (Breheny, 1992) (A.Ramadan, 2010).

2.2.3.5 Car Parking

Car-parking areas take up a considerable amount of land within new residential areas. In some residential districts around Cairo, particularly in the satellite cities, car-parking areas sometimes represent more than 10% of the total area (Abdullah, 2013) (Alqadi, 2013) (Nosair, 2013). So, wherever possible, a compact arrangement of car-parking spaces and a reduction in the overall number of car-parking spaces would help encourage the energy-efficient forms of mobility (Fuchs, et al., 2008). In addition, this would reduce the land taken up for parking areas, considering that the land itself as a resource. The right arrangement of parking spaces can also reduce the land required. In residential districts, the use of double and triple-decker garages is one way of reducing the overall land area required for parking (Fuchs, et al., 2008).

Multi-storey car parks are also a good strategy, since stacking parking spaces vertically can reduce the land usage in urban areas. The multi-storey solution can help clear parked vehicles from public spaces, and create additional local meeting places. Add to that, the benefit of releasing some land for other facilities and activities. A problem with the multi-storey car parking is the energy required for ventilation and lighting, which can exceed the cooling requirements for the building (Fuchs, et al., 2008). Nevertheless, multi-storey car parks are still useful in the heavily built-up areas where land is extremely limited and expensive. Another vital factor for car parking is the location of the parking areas themselves. For example, both Masdar City and Vauban Freiburg—where an integrated public transportation system is provided—car-parking has been located on the periphery of the site to reduce the land used for parking and to control the go-through traffic within the district (Figure 23).

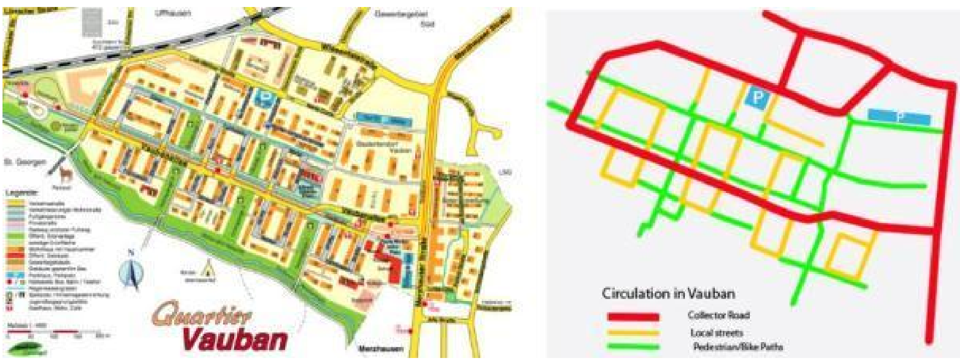


Figure 23: Vauban district layout and circulation network
Source: (Field, 2010).

In hot-arid climates, car parking areas are highly exposed to aggressive solar radiation. A common behaviour in Cairo is providing shades in the parking areas use either light materials or trees. On the other hand, the vast areas of car parks can give an opportunity for using photovoltaic panels to harvest renewable energy at the local level of a district (BELECTRIC, 2013).

Figure 24: Using photovoltaic's on the roof of a car-parking
Source: (BELECTRIC, 2013).

To sum up the topic of energy consumption and mobility within districts and neighbourhoods, the provision of an integrated mobility network that gives different choices for commuting and that encourages the cycling and walking could help to reduce the energy consumed by private cars. To implement such a principle, it is necessary to consider the conditions of the hot climate in Cairo by providing shades, cool surfaces and comfortable paths. It is also important to connect the mobility network of a district with the surrounding public transportation network.

2.2.4 Streets Orientation

In arid climates such as Cairo, there are some main passive cooling techniques such as; usual ventilation, nocturnal ventilative cooling (through cooling the masses of buildings during night), radiant cooling, evaporative (direct and indirect), cooling of outdoor spaces (Givoni, 1994) and also protection against solar radiation. All of those techniques are shared between indoor and outdoor areas, and are influenced by the street orientation as well (Givoni, 1998) (A.Ramadan, 2010). Street orientation is considered as a dominant factor to determine the "amount of shadowing and radiation, light and air movement, intensity of city ventilation and duration of relative humidity in the air" (Golany, 1995). External air flow and the amount of shadowing are extremely important criteria for outdoor comfort, and also have impacts on outdoor temperatures which influence the surfaces of the buildings and the ventilation of the buildings, hence affect the needed energy to cool the indoor spaces (Al-Sallal, et al., 2001).

Ventilation and supply of fresh air

In hot arid climates, wind and shadows are desirable on the streets and open spaces, to mitigate the effect of solar heating (Givoni, 1998). Orienting the streets with respect to the wind direction ensures the supply of fresh air within residential districts. This is important to reduce the consumption of energy needed to cool indoor areas. (Givoni, 1998). Hence, the cool air flowing from the surrounding into the districts requires defined channels to facilitate the wind movement. Such channels can be provided by streets, their appropriate orientation and open spaces to create proper wind channels (Marshall, 2008).

For example (Fathy, 1986) recommended that the optimal orientation for single buildings and blocks of row houses is along the lengthy side aligned from east to west. Nevertheless, this is somehow difficult to be applied over the entire plan of an area or group of building. The southwest-northeast orientation of the streets proved to be most convenient.

In the old Arabic Medina such as in Islamic Cairo (Figure 25), the streets used to be oriented towards southwest-northeast axis in order to benefit from the privileged winds come from the north and at the same time provide more shades during the hot-summer days. In addition, the medium building heights avoided wind blocking.

Figure 25: Street pattern of Old Cairo
Source: (Fahmi, 2002)

Figure 26 shows the preferred streets' orientation recommended by (Golany, 1995) which is the southwest-northeast orientation. This allows more wind paths and gives proper shadowing while considering the building heights and streets width.

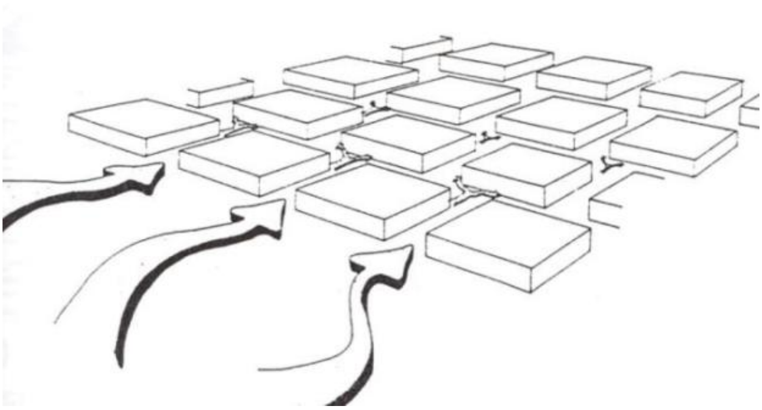


Figure 26: Preferred streets configuration in hot-arid climate
Source: (Golany, 1995)

The same principle is implemented in Masdar City, In order to enhance air movement in Masdar City, linear parks and the streets were oriented in the direction of the prevailing wind, which is 38 degrees counter-clockwise of the north axis. Buildings are limited to medium heights to maximize the benefit of the cool night breeze (Figure 27) (Masdar City, 2011). This does not exactly apply in the context of Cairo but the same logic of principle can be used.

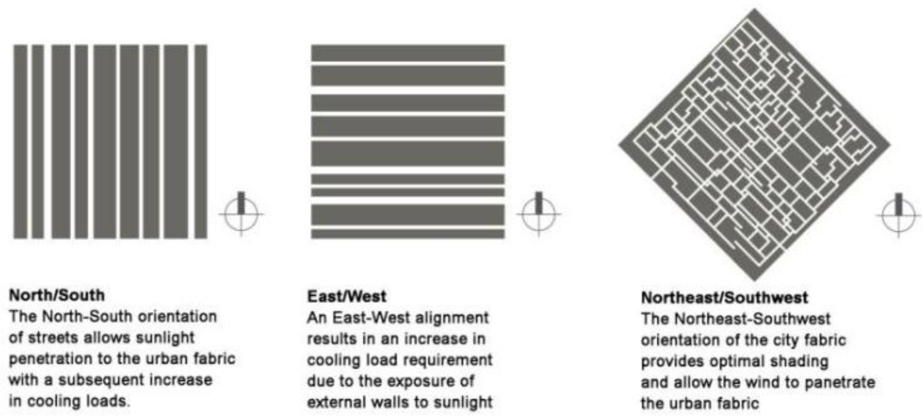


Figure 27: Streets orientation options, 3rd option was preferred - Masdar City
Source: (Masdar City, 2010)

It is important to mention that the flow of fresh air is not limited only to the provision of appropriate orientation and enabling wind channels but it is also influenced by the building heights, street widths and the so-called 'sky view factor'[2]. This is important for solar radiation and for the velocity of wind and for the creation of obstacle-free ventilation lanes (Givoni, 1998). For example, in the case of the streets that are perpendicular to the wind direction and adjacent to buildings with the same heights, the first row of buildings diverts the wind upwards. This concurrently prevents the rest of buildings and the pedestrian paths from benefitting from the cool wind

[2] The ratio of the radiation received (or emitted) by a planar surface to the radiation mitted (or received) by the entire hemispheric environment is called the sky view factor y is determined for a specific point in space, i.e., it gives a measure of the openness of the sky to radiative transport relative to a specific location (Brown, et al., 2001) (WATSON & JOHNSON, 1987)

movement (Givoni, 1998) (Milošovičová, 2010). The differentiation of the buildings heights is appropriate in the sense that it creates a vertical wind current which helps in achieving better wind distribution (Figure 28) (Givoni, 1998) (Milošovičová, 2010).

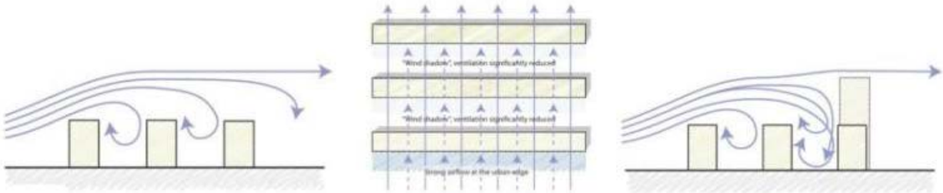


Figure 28: Air flow for groups of buildings with same & different heights (Milošovičová, 2010) as adapted from (Givoni, 1998)

To conclude, there are many factors concerning buildings and streets orientation that are essential to consider such as solar radiation, prevailing wind conditions, topography, vegetation, temperatures, humidity and geomorphology (Hindrichs & Daniels, 2007). For this reason, to achieve sustainable designs with reduced demands on mechanical energy consumption, the streets' orientation complemented with an appropriate sky view factor and well planned wind movement channels need careful consideration and analysis before any initial design phases -particularly in arid climate- begin. (Hindrichs & Daniels, 2007)

2.2.5 Greening and Urban Trees

Using trees within urban and residential areas is a quite common technique that provides shading to the buildings. The purpose is intercept sunlight before it warms a building which reduces the energy needed for indoor cooling. Planting trees and other green spaces within individual building sites may help in lowering air temperatures and cooling the ambient air, which offer significant benefits by reducing the energy needed for the building air-conditioning (GOLANY, 1996) (Berdahl & Bretz, 1997). Urban trees can help shield buildings from cold winter winds (Akbari, et al., 2001).

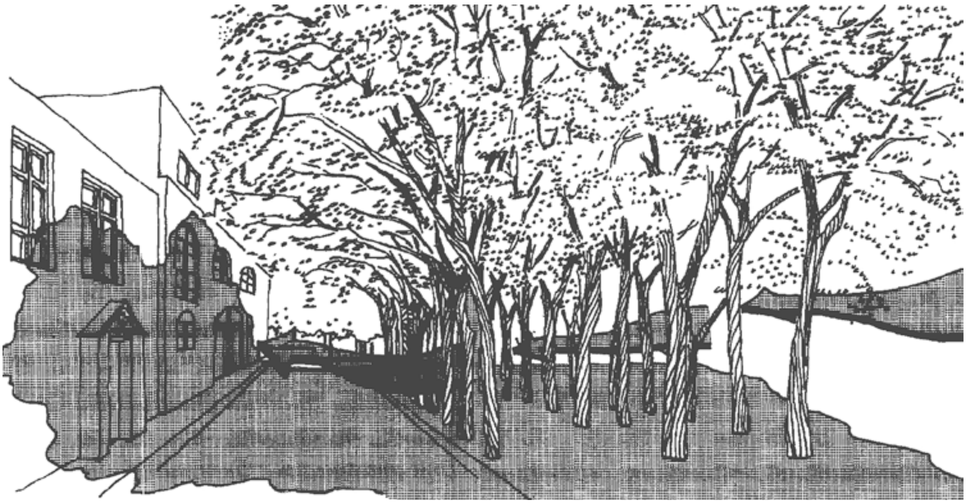


Figure 29: Vegetation belt around the residential built-up areas
Source: (GOLANY, 1996)

In one experiment done by (Parker, 1981) as discussed by (Akbari, et al., 2001), the measured energy needed for cooling a temporary building in Florida can save up to 50% of the cooling electricity in the summer after using trees and shrubs. It is understandable that the climatic conditions are different in Cairo but the same principle could be applied. For example, in a study carried out by (Fahmy, Stephen, & Ali, 2009), they indicated that urban vegetation has a prominent effect on indoor comfort levels and has to be considered in the site-assessment and in building simulations. At the same time, specific trees types should not only be selected for their urban thermal behaviour but for their indoor enhancement impact as well, e.g. adding some trees in front of a building increasingly enhances its indoor thermal comfort which thus reduces the energy required for its cooling in summer. Consequently, the type of trees should be considered because not all trees have the same thermal and microclimatic effect. This should go in parallel with the amount of water the selected type of trees need in an arid climate (Fahmy, Stephen, & Ali, 2009).

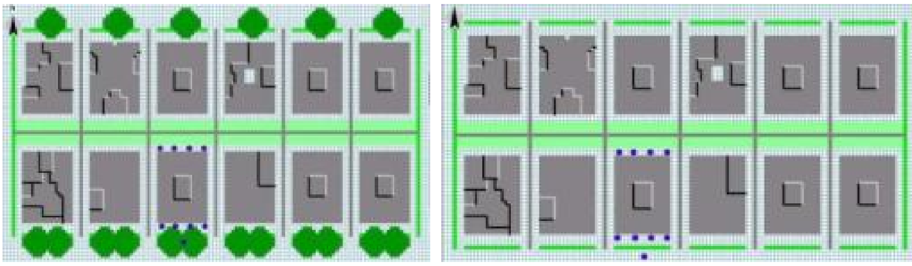


Figure 30: Location of urban Trees in residential districts
The first option with more trees along the south façade resulted in better outdoor thermal comfort and reduction in energy needed for indoor cooling
Source: (Fahmy, Stephen, & Ali, 2009)

Other factors for ensuring proper fresh air ventilation are the vegetation around residential areas. Large parks and gardens within urban areas are known to have a positive ventilation effect (Milošovičová, 2010) (Marshall, 2008). For example, the surrounding green areas in Masdar City help in cooling the fresh air (Masdar City, 2011). Moreover, the vegetation in the streets around residential areas can be used to block undesirable winds such as those coming from east-south direction during the spring time in Cairo

Figure 31: Green wind paths and trees around the city edges - Masdar City
Source: (Masdar City, 2010)

Green roofs

On the scale of a building, a dark roof is heated by the sun and this directly raises the demand on the cooling of the building in the summertime. Green roofs on the other hand, with vegetated spaces are used mainly to reduce the urban heat island effect by reducing building heat loss and increasing evapotranspiration, thus providing cooling in summer, thermal insulation in winter and an extended roof life (Shaw, et al., 2007). Even though, green-roofs are mentioned widely as a factor for reducing energy loads (Kamel, et al., 2010), other factors such as the type of trees to be planted and the amount of water required in arid in a context such as Cairo's, are vital to be considered. Additionally green roofs might be undesirable from a single building perspective.

In study done by (Kamel, et al., 2010) that investigates the effectiveness of green-roofs on reducing energy consumption for a residential building in Cairo, shows that when a green roof is implemented, its effectiveness is essentially influenced by the percentage of roof surface to the total surface of a building, i.e. the aspect ratio matter in that sense. The research shows that the most energy saving is realized when the aspect ratio of a building is 1:1.5. The study assessed hypothetically two storey residential buildings with three different aspect ratios 1:1, 1:1.5 and 1:2 while fixing the north-south ratio and expanding the west-east. For different thickness of green roofs -15, 30 and 45 centimetres- savings varied from 15-32% compared to traditional and un-isolated roofs in Cairo. The study also uncovered that reducing soil thickness of the green-roof to 15 cm results in a 15% annual savings. Moreover, the soil conductivity needs to be carefully studied due to its significant impact on the amount of energy savings.

Trees and green areas are being used to enhance the outdoor thermal comfort and reduce the ambient air temperature which helps in reducing energy consumptions used in cooling particularly in summer. Direct planting in front of the building façade has further savings effect. Such planting reduces the ambient temperature around buildings owing to the enhanced adiabatic cooling capacity, while lowering the risk of overheating in summer and thus improving the interior comfort (Fuchs, et al., 2008). Using trees around residential areas help in lowering the air temperatures as well. However, there are many considerations when applying such a concept for example; the location of the green areas, the type of the trees and the amount of water required for irrigation.

2.2.6 Cool surfaces and Albedo

The built environment has a range of surfaces such as walls, roofs, green areas, sidewalks, pavements and many more. Those surfaces are all subjected to long hours of sunshine and sun radiation which are not only a potential for energy gains, but also induce a high probability for overheating in buildings particularly in the hot arid zones. The specifications for materials used for surfaces influence its interactions with sun radiation and thermal storage hence affecting the indoor and outdoor thermal comfort which puts loads on the energy needed for cooling in the summer.

The albedo is one of most significant specifications of any surface. When sunlight hits an opaque surface, some of the energy is reflected, this fraction is called the albedo. Surfaces with low-albedo usually become much hotter than high-albedo surfaces (Akbari, et al., 2001). Usage of high-albedo urban surfaces and planting of urban trees are inexpensive measures that can reduce summertime temperatures (Akbari, et al., 2001). Most high-albedo surfaces are light coloured. Therefore on a building scale, when a dark roof is used instead, it is heated by sun and this directly raises the cooling demand of the building during the summertime. For highly absorptive (low-albedo) roofs, the difference between the surface and ambient air temperatures may be as high as 50C, while for less absorptive (high-albedo) surfaces with similar isolative properties, such as roofs covered with a white coating, the difference is only about 10C (Berdahl & Bretz, 1997). That's why cool and light surfaces can be effective in reducing cooling-energy use (Akbari, et al., 2001) which explains the custom of painting light colours on surfaces in the courtyard typologies of North African countries (Ratti, et al., 2003).

Figure 32: Light colour facades, Sidi Bou Said, Tunisia
Source: (Blogger, 2013)

Another benefit of a light-coloured roof is a potential increase in its life. The diurnal temperature fluctuation and concomitant expansion and contraction of a light-coloured roof are less than that of a dark one. Also, the degradation of materials due to absorption of the ultra violet light is a temperature-dependent process for these reasons; cooler roofs may last longer than hot roofs of the same material (Akbari, et al., 2001).

But there are some problems when such a principle is implemented; if not kept to a reasonable level, massive application in the overall albedo of numerous roofs creates glare and visual discomfort. The effect on the glare should be studied in detail before proceeding with a full-scale implementation of this measure. Another concern with the light surfaces measure, is that many types of building materials are not well adapted to painting and adapting such materials to have a higher albedo, would be more expensive than painting. Additionally, to maintain a high albedo, surfaces may need to be recoated or rewashed on a regular basis which in a way adds more to the cost (Akbari, et al., 2001).

Cool Pavements

Asphalt is the dominant material used to pave streets and roads. The low albedo of the asphalt causes a lot of consequences for example, dark asphalt surfaces increases heat from the sunlight falling upon it. The pavements in return heat the air. If urban surfaces were lighter in colour, more of the incoming light would be reflected back into space and the surfaces and air would be cooler. This tends to reduce the need for air conditioning (Akbari, et al., 2001). Although cooler pavements have energy, environmental and engineering benefits the issue is; whether there are ways to construct pavements that are feasible, economical and cooler. Savings generated by a cool pavement over its lifetime should be determined against its extra cost and the embodied energy needed for its fabrication (Akbari, et al., 2001).

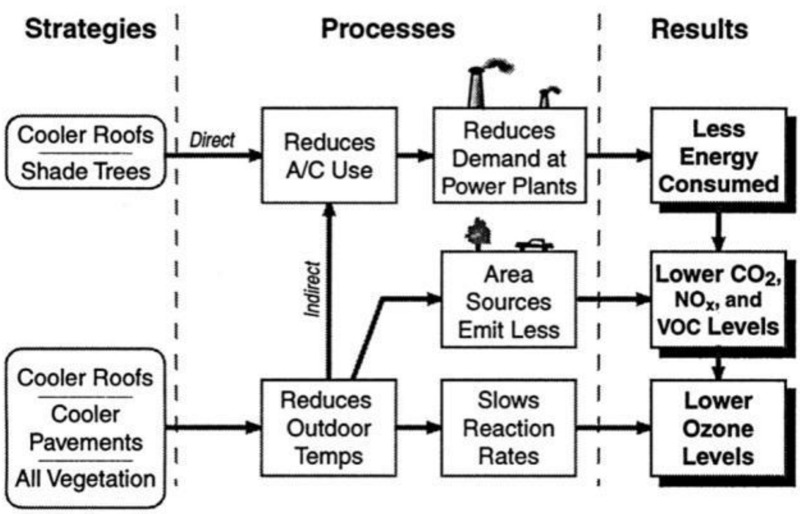


Figure 33: Methodology to analyze the impact of shade trees, cool roofs & cool pavements on energy use and air quality
Source: (Akbari, et al., 2001)

Mainstreaming such a design principle of light surfaces could efficiently reduce the energy required for cooling on district level (Akbari, et al., 2001) shows the direct and indirect effect of the albedo of the surfaces with regards to reducing outdoor temperatures thus reducing the use of air conditioners, which lead to direct and indirect less energy consumption.

2.2.7 District Central Cooling and Heating

This part is related to the technological issues of energy efficiency within districts but it is worth mentioning that while there are very limited experiences in providing district cooling systems in arid zones, there are a couple of experiences in using district cooling systems such as the one implemented in Helsinki (Figure 34), Amsterdam and Stockholm.

Such a system reduces the energy needed for cooling and reduces CO2 emissions by a considerable amount. The basic principle of the system is to use natural sources of cooling media –water or underground soil- and then pump it into different buildings within the district (Vartiainen & Salmi, 2011) (DHC, 2003) (DHC/CHP, 2003). The soil has a potential to be used for operating heat or cool pump all year around with a good degree of efficiency because the temperature underground is remains more constant throughout the year (Fuchs, et al., 2008). Of course it is very difficult to apply the same technique in the arid zones where cooling demand is extremely higher and also the technicalities and considerations involved in such a system but the principle is worth to consider while planning for residential areas.

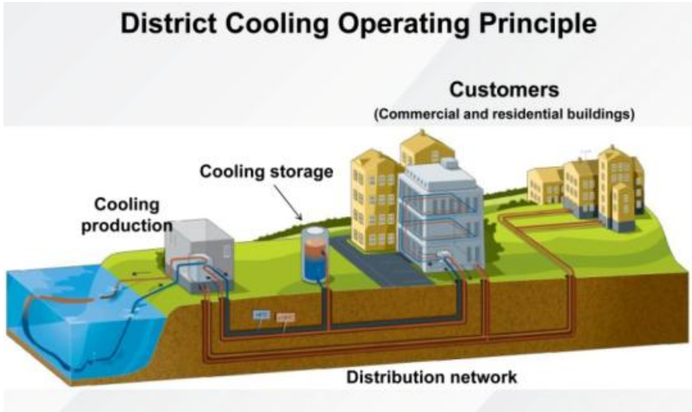


Figure 34: District cooling operating principle in Helsinki
Source: (Vartiainen & Salmi, 2011)

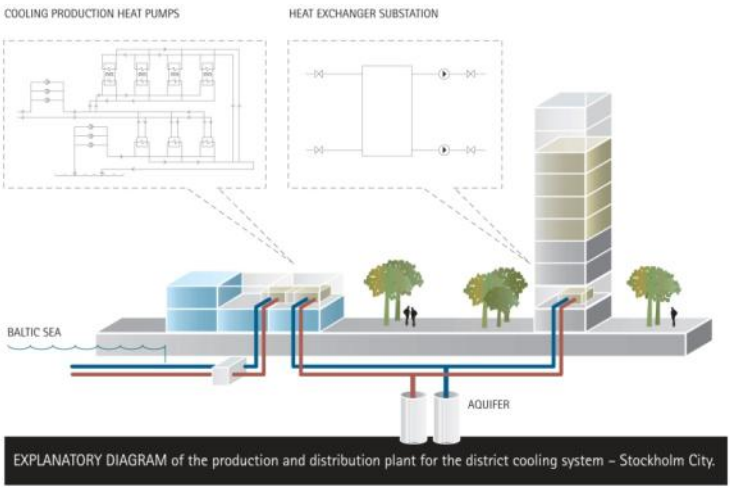


Figure 35: District cooling operating principle in Stockholm
Source: (DHC/CHP, 2003)

2.2.8 Buildings Heights and S/V Ratio

The surface to volume ratio S/V, which is an indicator of urban grain size, represents the amount of exposed skin or surfaces of a building compared to its volume such as the amount of exposed area to the wind and solar incidence (Fuchs, et al., 2008). S/V ratio affects the interaction with the surrounding context and climate through natural ventilation and solar incidence which consequently affects the energy needed for cooling in arid climate. The high S/V ratio increases the heat loss during the winter season and heat gain due to exposure to solar radiation during the summer (Ratti, et al., 2003). This interaction between surfaces and surrounding influences the gain/loss heat and vice versa. A low S/V ratio is preferred to minimize heat gains. In cold dry climates, S/V ratio should also be as low as possible to minimize heat losses. For example, if two buildings are of the same volume but have different surface areas, the compact one is more energy efficient (TERI, 2004). Under certain circumstances the situation might be different, for instance when it comes to a group of buildings some other factors might appear such as shading, sky view factors, day light and the interaction between the different buildings.

For example in a study done by (Ratti, et al., 2003) to compare different S/V ratios for the same built volumes, he chose a real prototype of a courtyard house with a specific configuration and specific dimensions -similar to the urban courtyard in old Marrakech city (Figure 36).This courtyard prototype has been extrapolated to form three different theoretical urban arrays (Table 6) within the same land area which was 67.5m * 67.5 m (despite the irregularity of the old Arabic pattern which is difficult to achieve in modern urban design practices). Results show that the courtyard type has the highest S/V ratio (0.58) and the second type has an S/V ratio of (0.404) while the third case has the smallest S/V ration of (0.265). By maximizing the surface to volume (S/V) ratio, the courtyard acts as a heat sink, limits extreme temperature stress and re-radiates this heat indoors and to the night sky. The main conclusion of the study is that within the same buildings' volume, the courtyard form offers a higher S/V ratio which in sequence provides a larger surface area and a higher thermal mass. In addition, the courtyard provides daylight via its inner space and provides narrow spaces for shading reducing the energy needed for cooling despite its disadvantages of adding more to the urban heat island effect (Ratti, et al., 2003).

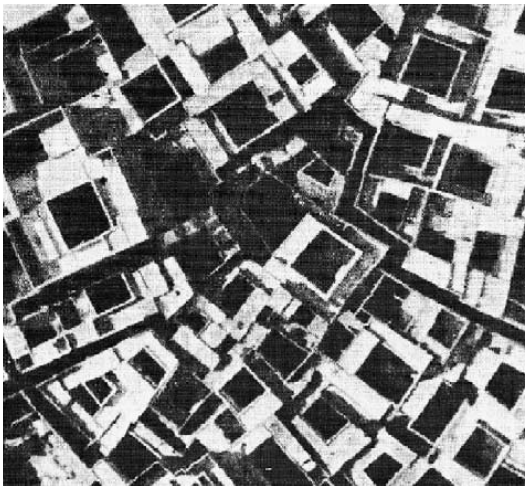
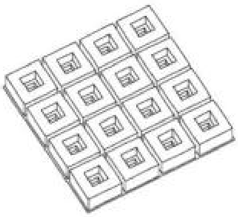
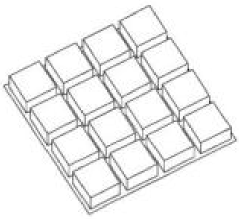
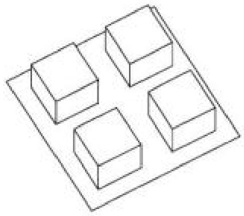


Figure 36: Image of central Marrakech, showing the 'courtyard' urban fabric
Source: effect (Ratti, et al., 2003)

			
	The first variation is the courtyard prototype with a specific configuration as extracted from the old Marrakech city. This results in 16 courtyard buildings	The second variation consists of replacing each courtyard with an urban block in the same proposed plot, preserving the height of 9m which obviously preserves the built volume. This may represent a group of residential buildings	The third variation represents a major urban regeneration by integrating four courtyards into one urban block (which may represent a group of residential buildings with wider streets and open spaces). Building height is calculated by maintaining the same total built volume which results in a height of a six storey building
Area	67.5m * 67.5	67.5m * 67.5	67.5m * 67.5

Surface m2	15797	10931	7168
Volume m3	27030	27030	27030
S/V	0.58	0.404	0.265
Shadow density	11.0	9.8	6.1
Daylight	10% in the street and 19% in the courtyard	30%	53%
Sky view factor	0.13	0.23	0.48

Shadow Density and Daylight Distribution

Concerning the mean shadow density, the courtyards recorded higher value in the streets and inside the courtyards, which is useful to protect from solar radiation. Also the daylight can be most effectively exploited via the courtyard and not via the external street facades. This has also an advantage for protecting against the noise and potentially more polluted street environment

The Sky View Factor

According to (OKE, 1981) minimizing the urban heat island suggests sparse and scattered urban from, with a high view factor. Thus the courtyard in this case increases the effect of the urban heat island, in the winter that would not to make big problems but in the summer it adds to the needed energy for cooling indoor spaces does not response positively to the urban heat island effect .

Table 6: The different S/V of different buildings forms with the same volume of built-up area. Source: effect (Ratti, et al., 2003)

2.2.9 Site Selection

The choice for selecting the location of a residential area and its development influences the energy consumption mainly due to two factors; firstly regarding the topography of the site, and secondly concerning the functional relationship with other parts of the city. Those two factors affect the suitability of the site.

Figure 37 Proximity to city level services

Regarding the topography of the site, the different slope positions to the sun result in a differentiated amount of the solar radians received (Figure 38). Such analysis for choosing the locations of buildings with regards to the topography is a factor to be considered.

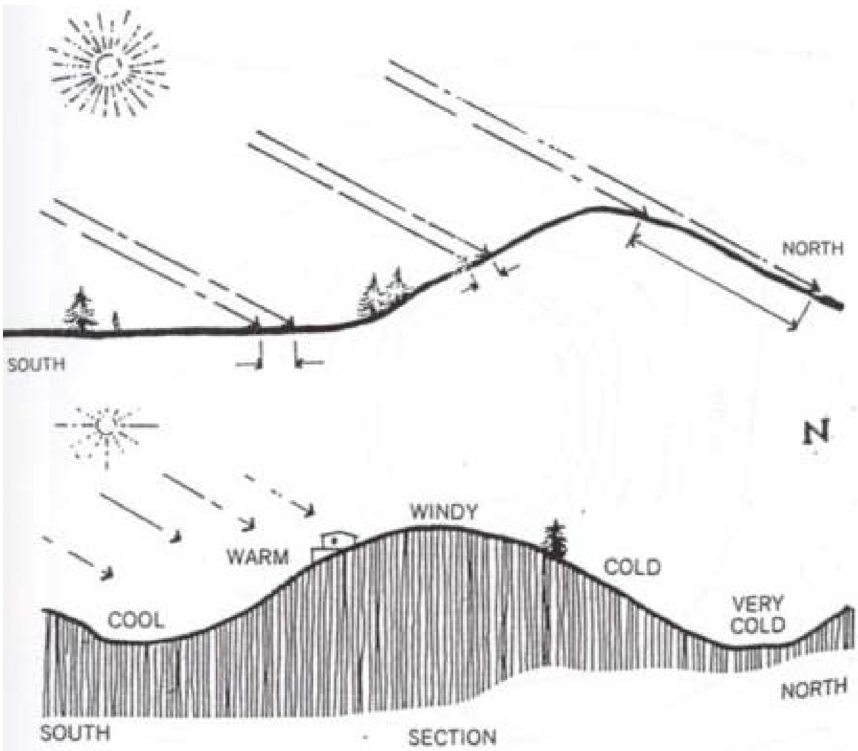


Figure 38: Site Topography influences. Source: (Peker, 1998)

Another repercussion of the site's topography is the energy required for the cut and fill, and the levelling processes of the site to accommodate it for residential land uses. Locations with easy topography are more suitable for residential use than those with varying levels. Linkage with the city level services and facilities is quite essential as well to shorten the commuting distance and reduce the energy dispensed to reach city-scale facilities. From an energy conservation point of view, it is more efficient for a residential area to be close to city-scale facilities and to have good accesses to the wider public transportation.

2.2.10 External Shading

In climates with very hot summers and mild winters, shade is always more desirable than solar access. To reduce solar radiation; unused or paved areas without shade should be avoided in order to lessen the horizontal surfaces and minimize solar radiation gains (Hindrichs & Daniels, 2007). Shadows of the buildings adjacent to each other, trees and other structures such as arcades, wood and temporary nets are common and widely used tactics for that purpose (Peker, 1998). This relates very well to the previous research results which demonstrated that shading is more efficient than wall insulation in moderate climates, as opposed to cases of extreme hot or cold climates (El-Deeb, El-Zafarany, & Sherif, 2012) The appropriate orientation of streets is a basic tool to shade streets for pedestrians -which in turn encourages walking- and to protect buildings' façades from the sun's concentration. The need for shading is generally the highest in the hours between 11 a.m. and 4 p.m. when high solar intensities are coupled with high air ground temperature (Greenwood, et al., 2000).

2.2.11 Building Forms

A building's form has an effect on energy efficiency and a building's morphology can significantly decrease the heating loads on buildings.

Controlling the heat balance of buildings is a matter of guiding the reflection, absorption and release of heat, and the movement of air. Building forms guide this flow of energy in different ways (Peker, 1998). It plays a key role in controlling energy consumption in buildings. Due to its significant effect on thermal performance, the building form itself is influenced by the other adjacent and surrounding buildings. The relationship between buildings affects the energy consumption of the buildings individually and as a whole for the neighbourhood or a residential block (Hachema, et al., 2011). On a study done by (El-Deeb, El-Zafarany, & Sherif, 2012) to test the energy performance for different buildings' geometries, a two-storey residential building of a floor area of 256m^2 was modelled as a typical single family house for either a high-end family residence or a multi-family dwelling in Egypt and Saudi Arabia. Units such as those usually range from 500m^2 to 600m^2 with a built-up area of 50%. The study compared the energy consumption of those typical units in eight different geometries (Figure 39) in three separate cases; a free standing (isolated) one, an attached one from 2-sides (linear pattern), and an attached one from 3-sides (compact pattern)

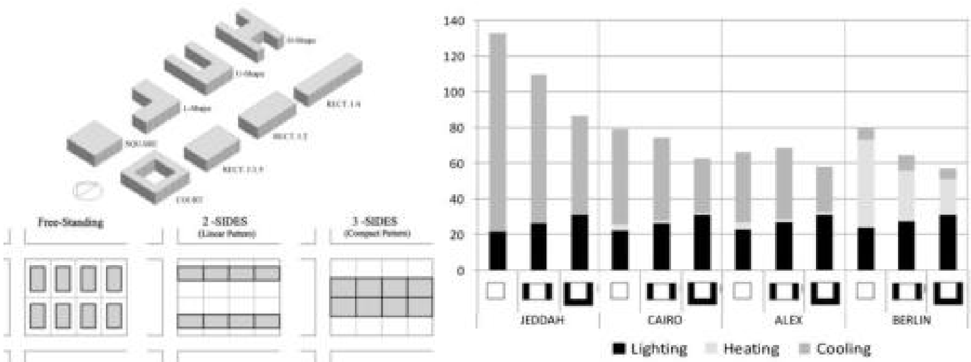


Figure 39: Comparison between energy performances for different buildings' forms.
Source: (El-Deeb, El-Zafarany, & Sherif, 2012)

The study concluded that the annual energy consumption of the free-standing square-shaped case in Cairo reaches 79Kwhr/m^2. It is composed of 67.5% cooling, 4.5% heating and 28% lighting loads. Forms with large surface areas such as U and H increase consumption by 4% to 12% and 2.5% to 11% compared to the square shaped building respectively. The units attached from three sides did not achieve the desired energy saving in Cairo. This case increases energy consumption in all of its orientations. The only exception is when it is oriented to the north which in total increases the energy consumption of community savings resulting from counting the increased loads of the buildings facing south that will be located across the street. Surprisingly enough, the appropriate building forms in Berlin were similar to those in Jeddah. This is due to the large differences in temperatures between the indoor and outdoor climate in both cities, leading to an increase in heat transfer and to high cooling loads in Jeddah and high heating loads in Berlin (El-Deeb, El-Zafarany, & Sherif, 2012).

The use of compact and linear urban fabrics was useful in extreme environments; savings exceeded 20% in several combinations (square and rectangles facing north-south) in the linear fabric. Few combinations reached 40% savings in compact tissues (rectangle 1:1.5 facing north), but this case cannot be considered as realistic without considering the performance of the opposite building facing south that achieved savings of only 3%. The average savings of both buildings is 21%. In mild deserts, the savings of properly oriented freestanding buildings (rectangles 1:2 saved 10%) and properly oriented buildings in a linear fabric (rectangles 1:2 or 1:4 saved 16%), exceeds those achieved by a few combinations of compact fabric, while avoiding extra energy use caused by other combinations of that fabric (El-Deeb, El-Zafarany, & Sherif, 2012). In general, in Cairo, the linear form of buildings (attached form two sides) offers higher saving potential than other forms, especially when the exposed facade faces the north-south direction. Even for courtyard buildings forms, its performance becomes better when constructed in a linear fabric.

2.2.12 Housing Types

Another variable of an energy efficient urban design is the housing types. Different types of housing correspond to different properties, such as differences in heights, differences in S/A ratios, and differences in distances between buildings and setbacks. The effect of housing types results in different interactions between buildings, provision of natural ventilation, in providing natural ventilation, orientation of solar radiation as well as the flow of wind movement.

a) Detached single family houses: exposed to outdoor air on all sides, but provides a potential for natural ventilation. It has a big S/V ratio.
b) Townhouses (row buildings}: The units can range from a single story up to six or more stories. From the climatic aspect, townhouse houses have smaller S/V ratio than the detached houses.
c) Multi-storey apartment buildings: Those have the smallest envelope surface area of all building types. Their rate of heat gaining in summer and heat loss in winter is also the lowest.

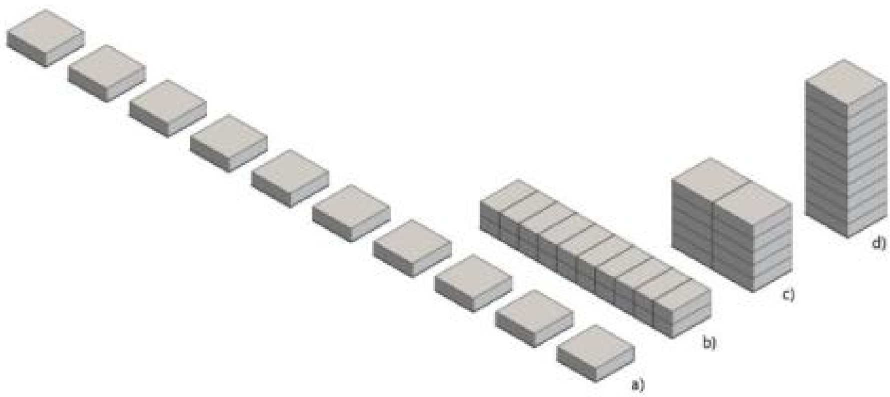


Figure 40: Hypothetical different forms of housing types
Source: (Fuchs, et al., 2008)

2.3 Summary and Reflections

The principles of energy efficient urban configurations are complex and interrelated to each other. It is difficult to suggest an optimal urban form or configurations that can be described as the most energy efficient one (Norman, et al., 2006). However the energy efficient urban form might be described as the urban configurations that consider climatic conditions, reasonable density, level of compactness that respond positively to the climate. On top of a sensible landscape and a well-balanced transportation network that integrates services, facilities and housing types while providing residential areas with their necessary uses and daily activities. An energy efficient urban form ought to pay attention to the embodied energy in all constructional and operational phases of residential areas. The energy efficient urban form in hot and arid climates gives priority to protect against solar radiation, ensure supply of fresh air, reduce car usages, encourage walking and cycling, make use of vegetation to give shades, to cool the ambient temperature, and cool surfaces (Norman, et al., 2006). Self-satisfied residential areas with mixed uses and attractive open spaces are more energy efficient that other forms. To achieve such urban configurations though applying the design principles explained in chapter two, there are a lot of contradictions and interrelationships between those principles.

2.3.1 Contradictions and Interrelationships

The previously demonstrated principles cannot be applied easily without any constraints. There are a lot of contradictions and dilemmas while trying to achieve them. Those principles sometimes support, contradict and intersect with each other. For example, on the one hand, encouraging walkability is a desired goal to reduce commuting energy consumption. On the other hand, Cairo's arid and hot climate is a major constraint. Therefore, encouraging people to cycle and walk cannot be achieved without attractive open spaces and proximity of facilities and services. Another example is the streets' orientation. It is practically impossible to orient all streets to the prevailing desired wind direction, It is difficult to impose such principles on an entire plan of a district or a neighbourhood. This conflicts with the principles of movement and network which should integrate and connect the plan elements together. At the same time, it is also challenging to offer free-obstacle wind paths due to the differences in building heights and the impact of the surrounding and adjacent buildings around the residential project.

Among those dilemmas is the compactness. As mentioned before, compact urban areas hold some advantages and disadvantages for energy efficiency therefore it is of utter importance to find the right balance that minimizes the losses and maximizes the benefits. In addition, a cultural obstacle is that compact urban areas are sometimes affiliated to poverty as opposed to other suburban areas. This necessitates a profound analysis to settle on the degree of compactness for any residential areas. Some other principles supporting each other for example the green areas and urban trees have a positive influence on the ambient air temperature and gives some external shades in the same time. It is worth mentioning that the housing type of the residential projects holds many impacts on the urban configurations of the projects and greatly affecting the circulation networks of the residential area. The housing types also have many interrelationships with the buildings morphologies, S/V ratios, Streets H/W ratios and on the density and compactness of the whole area.

The interrelationships and contradictions between the design principles, shows that the energy efficient urban configurations are in need for trade-off between all of principles, advantages, disadvantages and specific conditions of each project and area.

2.3.2 Residential Areas as Energy-Using System

Residential areas are regarded as an energy-using system (Mehaffy, Cowan, & Urge-Vorsatz, 2009). The main causes of energy consumption within this system are; a) Transportation and commuting energy. b) Cooling for the buildings and for ambient temperatures. C) Embodied energy in all constructional and operational phases. The energy efficient urban configurations and principles aim to reduce the main sources for energy consumption in this energy-using system (Figure 41).

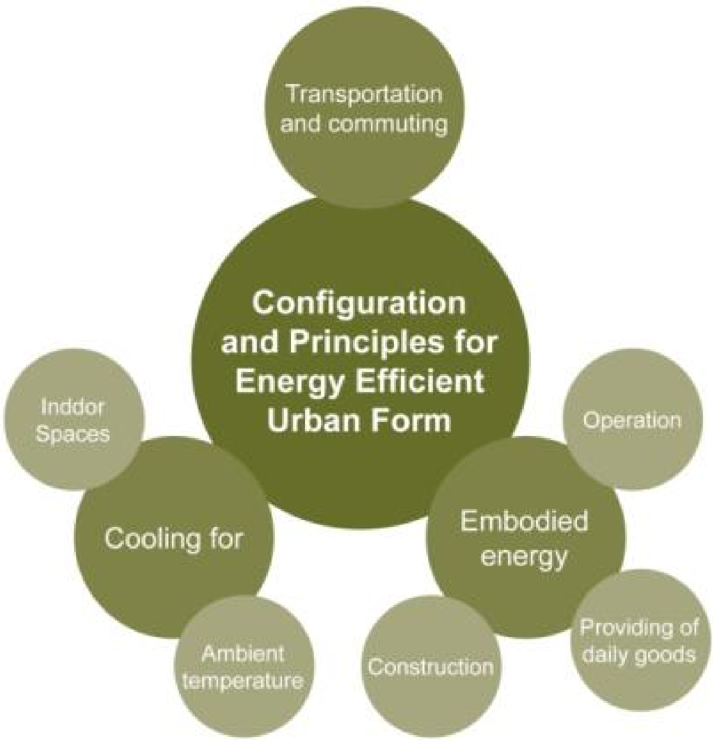


Figure 41: Main sources for energy consumption within residential areas
Source: Author as adapted from previously mentioned literature in chapter 2.

The following table 7 shows the design principles in relation to the three categories of energy consumption within residential areas. Energy efficient urban design principles might be classified into three groups:

a) The general characteristics: design principles that describe the whole district / neighbourhood, such as mobility networks, compactness and density.

b) Principles associated with buildings' morphology: principles that are related to the formation of the buildings and their geometrical characteristics. Such as heights and housing types.

c) Cooling ambient temperature: principles that deal with cooling the ambient temperature hence cooling the buildings and as well as ease walkability and cycling.

Design Principles		**Reduce energy needed for**		
		Transportation	**Cooling**	**Embodied**
General characteristics	Compactness & Density			
	Diversity and attractiveness			
	Mobility Network			
	Site selection			
Buildings morphology	Heights and S/V ratio			
	Building Forms			
	Housing Types			
Ambient temperature Mitigation	Streets Orientation			
	Central cooling & heating			
	External shading			
	Greening and Urban Trees			
	Cool surfaces & Albedo			

Table 7: Design principles in relation to the sources of energy consumption
Source: Author as adapted from previously mentioned literature in chapter 2.

Chapter 3 Analysis of Case Studies

3. Analysis of Case Studies

3.1 Analysis of Case Studies : Introduction

The research focuses on the settlements around Cairo, which are known as the satellite cities. Cairo started to change its master plans in the late 1970s by designing new cities that were intentionally planned to cope with the increasing demand on housing units (Shalaby, 2000). These new satellite cities exemplify an alteration in the urban planning spatial configurations. Figure 42 show different spatial structures for different residential areas in Greater Cairo. This transformation emerged around Greater Cairo, a shift in the urban planning and design policies when compared to inner parts of Cairo (A.Ramadan, 2010). Working on several residential projects in satellite cities, two case studies have been selected according to the following criteria:

a) Energy consumption of the middle and high income groups is higher than the rest of other social groups. The cases represent a sample of residential projects targeting high and middle income groups.
b) The first case (Al-Rehab) represents an area housing a blend of middle and high-income groups. The second case (NewGiza) represents a higher income category.
c) The two cases which exhibit examples of residential areas on the level of a district enable a perceivable comparison with the investigated principles in the literature review.
d) The two cases are almost in the same latitudes, Cairo, N 30° 7', E 31° 23' (A.Ramadan, 2010).
a) Both of the cases are new settlements located on new urban expansions, one on the east side of Cairo and the other on the west.
b) The urban pattern of both cases is western, which illustrates the prevailing urban planning pattern in satellite cities (A.Ramadan, 2010) (Shalaby, 2000).

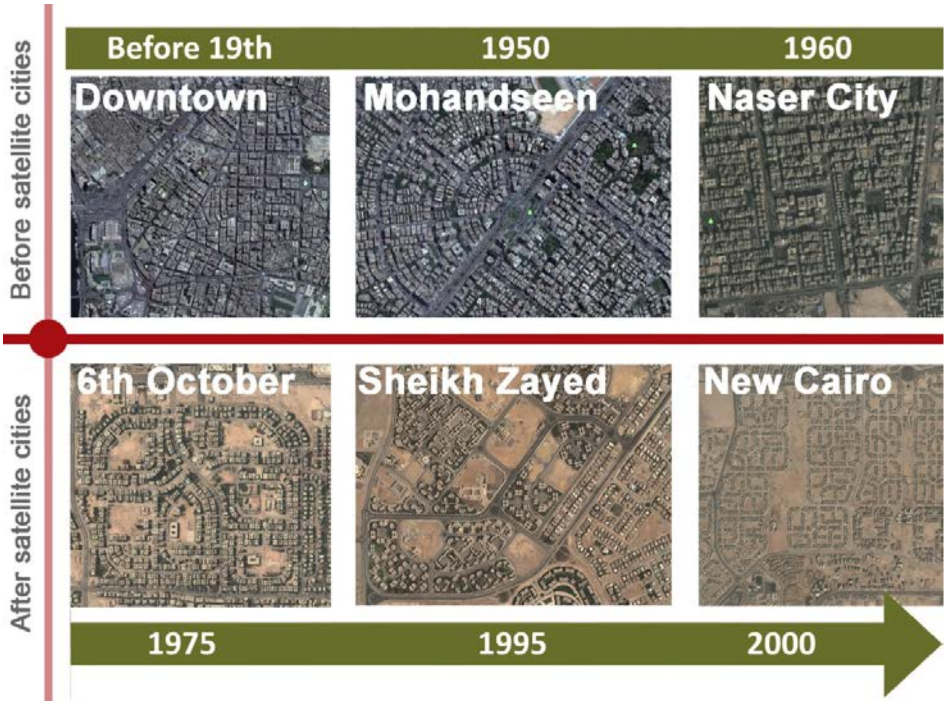


Figure 42: Different spatial configurations in inner parts of Cairo (1870 – 2005)
Source: author as adapted from (Google, 2013). (NUCA, 2008)

Figure 43: Location of the selected case studies.
Source: author as adapted from (Google, 2013)

Analysis Methodology

As previously stated, the principles of energy efficiency are complex and occasionally contradict each other. A lot of dilemmas and controversies arise in attempting to achieve all of those principles in unison yet it is unconstructive to discuss them independently from each other. To reach a concrete resolution, the analysis has tried to group the design principles of energy efficiency under three different categories for simplification. Those groups have been further discussed on two levels; the first one is concerned with the principles such as density, mobility networks and site selection on the level of the district as a whole, and the second is concerned with the principles such as compactness and colours of the buildings on the level of a group of buildings or a residential block. Table 8 shows an abstract of the two levels of discussion. It goes without saying that there is no clear boundary between the design principles, for example, the housing types affect the movement network, the S/V ratio and the H/W ratio as well. Another example is the streets' orientation which is influenced by the housing types and mobility network. Such interrelationships will be mentioned through the analysis.

Principles' group	Design principle	Level of discussion	
		Whole District	Residential Block
General characteristics	Compactness and Density	√	
	Diversity and Attractiveness	√	
	Mobility Network	√	√
	Site selection	√	
Buildings morphology	Heights and S/V ratio		√
	Building Forms		√
	Housing Types	√	√
Ambient temperature Mitigation	Streets Orientation	√	√
	Central cooling and heating	√	√
	External shading		√
	Greening and Urban Trees	√	√
	Cool surfaces and Albedo	√	√

Table 8: Design principles and level of discussion
Source: Author as adapted from previously mentioned literature in chapter 2.

3.2 Case Study: NewGiza

NewGiza is a new district on the west periphery of Greater Cairo, on a former quarry site (Gensler, 2013). It constitutes an area of 600 hectares and is located between Cairo-Alexandria road and Wahat road (NewGiza, 2011). NewGiza construction has started a few years back and is expected to be finished by the next ten years (Mohasseb, 2013).

Figure 44: NewGiza location
Source: (Google, 2013)

Upon its completion, the district will have ten residential neighbourhoods housing almost 35,000 inhabitants (Mohasseb, 2013). According to the company of NewGiza - the developer of the project- the district is aiming towards high income groups residents. NewGiza will also include a mixed use area, a sports club, educational facilities and some other land uses. Figure 44 shows the proposed land use map of the district and the proposed layout. Many developers of residential projects claim that they are establishing ‘green communities’, with the literal interpretation of the word ‘green’ i.e. ‘having a lot of green areas and sceneries’. In NewGiza, planners and developers of the project, claim that the district will be an 'Eco-friendly Community' by offering green areas, tents to shade the main pedestrian boulevard and parking cars outside in private car parks (NewGiza, 2011).

3.2.1 General characteristics of NewGiza

3.2.1.1 Site Selection

The site selection hold two main aspects related to energy efficiency and consumption. First aspect is the topography and elevations of the site; second one is the connection with the surrounding roads, with wider public transportation and with the other parts of the city.

Topography of the Site: The site is on an average elevation of 240 meters above sea level which is higher than the average elevation of Cairo by 133 m. The high elevation of the location allows more winds to penetrate through the area which accordingly enhances the ambient temperature. As a former quarry site with uneven surfaces and extremely sharp slopes, the site was in need for a massive "cut and fill" process to accommodate suitable residential use. The cut and fill process consumed huge amounts of energy. Figure 45 shows some sections representing the different levels of the site.

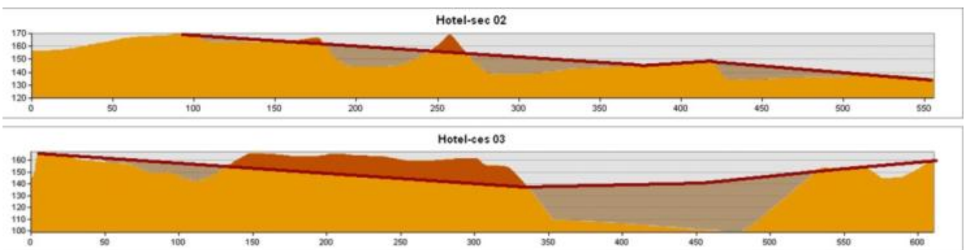


Figure 45: Sections representing different site levels in NewGiza
Source: (Mohasseb & Shehata, 2008)

According to (Mohasseb, 2013) - the principle urban planner of the project, the cut and fill process cost a few billion Egyptian pounds and is expected to take few years of work. Figure 46 shows a sample for the amount of the cut and fill of the land that was needed for the residential neighbourhood (No.02). A total amount of 2.5 million^3 of land 'fill' and more than 1.5

million[3] of land 'cut' was done for only one residential neighbourhood amongst the ten residential neighbourhoods of NewGiza.

Landuse	Area m2	%
Villa	141678.1	46.7
Green	60067.2	19.9
Road	101331.4	33.4
Total	303079.7	100

Total Fill = 2,517,120 m3
Unchanged
Total Cut = 1,106,397 m3

Figure 46: Quantities of 'Cut and fill' for neighbourhood No.02 in NewGiza site
Source: (Mohasseb & Shehata, 2008)

Connection with Surrounding Uses: The location of NewGiza lies between two other new satellite cities namely City of Sheikh Zayed and City of 6th October. Even though the location of NewGiza is well connected with the surrounding regional roads (Figure 47) the residents of NewGiza depend solely on private vehicles for commuting because the project target only high-income groups.

Figure 47: NewGiza location and main surrounding roads
Source (Google, 2013) (Earth, 2008)

3.2.1.2 Compactness and Density in NewGiza

There is no value for population density that can be affirmed as an optimum for energy efficient population density. The average density however, extracted from the literature reviews, is around 300-400 persons per hectare. The density in NewGiza is almost 60 persons per Hectare, which is a very low density compared with the average one. It is also considered very low when comparing with other residential areas in Cairo that have an average of 400 Person per hectare and sometimes reach to 2000 person per hectare in the internal parts. This could be argued that the low density is attributed to the luxuries facilities taking up a lot of land space such as the golf course and the sports club. Even though, when excluding the non-residential areas, the density of neighbourhoods would still be 150 persons per hectare, which is still very low again when compared with the average densities in Cairo or in Vauban. In terms of compactness; figure 48 shows different residential blocks with different levels of compactness in NewGiza. It is quite obvious that the urban pattern of the district could be described as a dispersed one, with exception of the mixed use area which is less dispersed than other areas. The total foot print of the buildings is around 10% of the total area, which is a very low percentage; add to that the low heights of the buildings (ranges from 10 to 18 meters). This dispersed pattern with its small percentage of built-up area, pose negative implications such as a high S/V ratio, more direct solar incidence and more land consumption.

Figure 48:Dispersed urban patterns in neighbourhood 2& 3 in NewGiza
(Selected cases are within a rectangle of 450 m * 450 m)
Source: Author as adapted from (Earth, 2008).

3.2.1.3 Diversity and Attractiveness of NewGiza

The district of NewGiza has its own mixed use area on the north part. This area will include retail shops, education facilities, health care units and other services. In addition to that NewGiza has some other facilities such as the sports club, a golf course and schools. Figure 49 shows the land use plan of NewGiza. The district is self-satisfied with its own basic facilities, a different variety of open spaces, leisure facilities, green areas and high quality of life. Although the districted contains all of these facilities, the streets will not be vibrant due the mono-residential use of the neighbourhoods. The residents will need to commute for their daily needs using their private vehicles which will result in more fuel consumption

Figure 49: Land use plan of NewGiza
Source: (Earth, 2008)

3.2.1.4 Circulation Network

Integrated Circulation Network

The mobility network of NewGiza consists of three elements:

a) Car roads which reach every villa and building
b) Trolleybus line which will go through the whole district to provide a viable public transportation network
c) Pedestrian paths and open spaces network

The proposed trolleybus is provided to reduce commuting by vehicle cars (as intended by the project planners). It covers the whole area (Figure 50), assuming the walking distance is 250 meters with 400 meters distances between stops. The efficiency of such a system is highly impacted by the dwelling types. Each trolleybus station services a limited number of housing units. In addition the buildings configurations and arrangement results in long walking distances. This raises the question of efficiency of public transportation in relation to density and the interrelationship between permeability and urban configurations

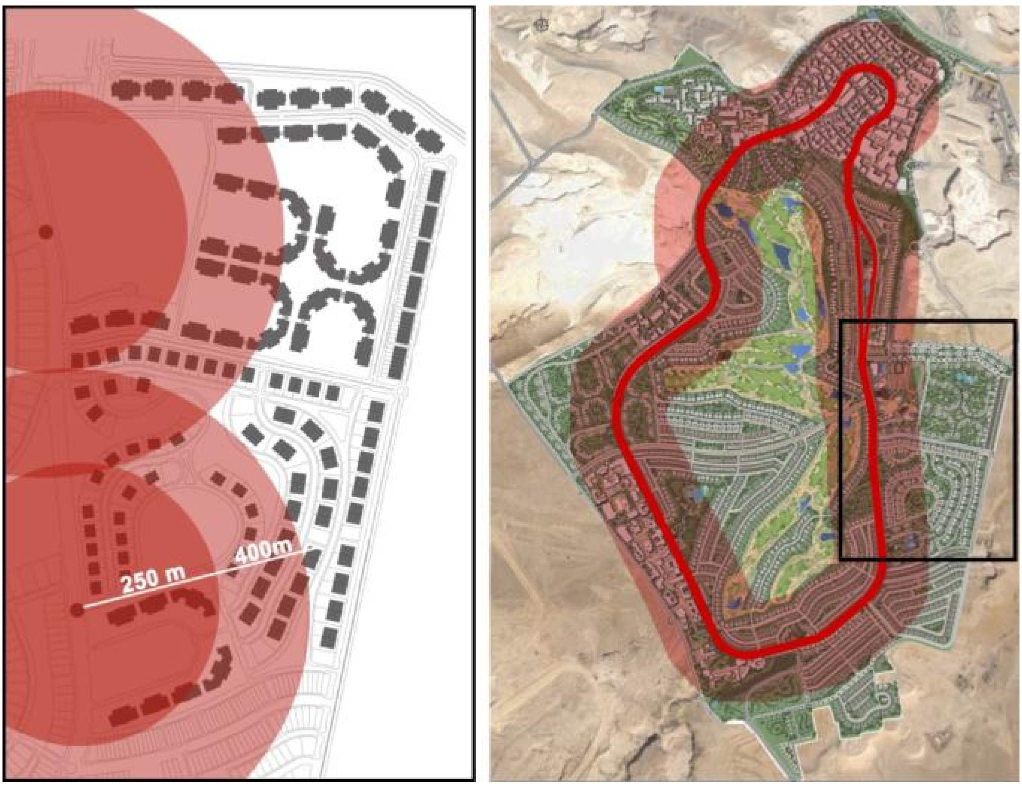


Figure 50: Trolleybus line within NewGiza
Source: Author as adapted from (Earth, 2008).

Access and connecting with surrounding city transportation network

The district is well connected with the surrounding roads with high connectivity to the nearby satellite cites (Sheikh Zayed and 6th of October Cities). But the district's internal trolleybus will not be integrated with the wider public metro network (Proposed). This means that the district will be reached only via private vehicles, which will result in high consumptions of vehicles fuel.

Streets Street Design and H/W Ratio

The proportion of street should be designed to protect against solar radiation and allow the prevailing winds to flow though the streets. The streets in NewGiza have small H/W ratios. Those ratios allow more solar radiation to hit the surface of the streets, hence heat up the surfaces and buildings.

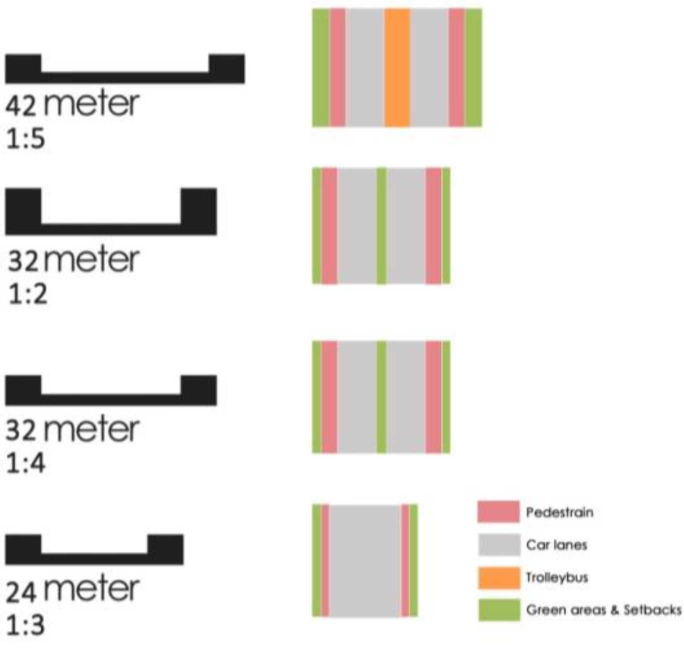


Figure 51: Different streets H/W ratios in NewGiza
Source: Author as adapted from (Earth, 2008)

The streets do not have enough shading instruments and there are no cycle lanes. The streets are dominated mostly by car lanes. All these factors make cars' usage the most convenient way to commute through the area.

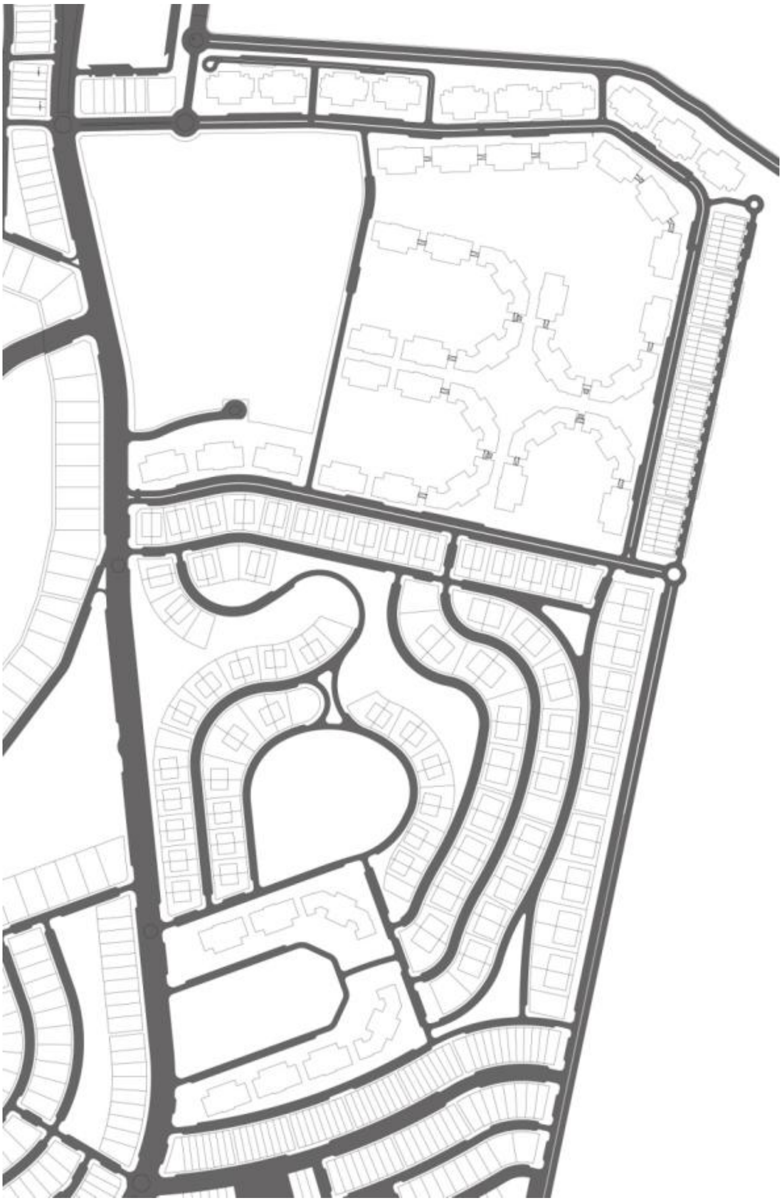


Figure 52: Car roads in neighbourhoods 2 & 3 in NewGiza
Source: Author as adapted from (Earth, 2008).

Car parking

Most of the streets are provided with the basic requirements such as pedestrian paths, cycle lanes and safe walkable areas. The design tried to free the residential areas from cars by locating car parking areas on the edge of neighbourhoods (like in Vauban's example). The design proposed an underground tunnel that connects the car parking areas constructed in underground basements. As a result, a huge amount of energy is consumed firstly in the embodied energy of the construction of such massive tunnels and basement parking, and secondly in the operational energy needed to cool, light and ventilate the underground car parking areas.

Figure 53: Underground car parking in NewGiza
Left: The colour represents the underground car parking's that are connected via underground tunnels. Right: Massive concrete construction needed for such tunnels. .
Source: Author as adapted from (Earth, 2008)..

3.2.2 Buildings morphology in NewGiza

Housing Types, Buildings heights and S/V ratio / Building Forms

The project offers different types of housing: residential units (apartments), separate villas and townhouses (attached and semi attached). Their heights vary from three stories for villas and six stories for apartments' buildings. These housing types resulted in a dispersed pattern with a high S/V ratio, which contradicts the concept of reducing surfaces exposed to solar radiation. Figure 54 shows different housing types. It is apparent that the buildings' morphologies and configurations result in high surfaces that are exposed to solar radiations in addition to the lack of shading instruments. This increases the energy needed for cooling indoor and negatively reduces the outdoor thermal comfort.

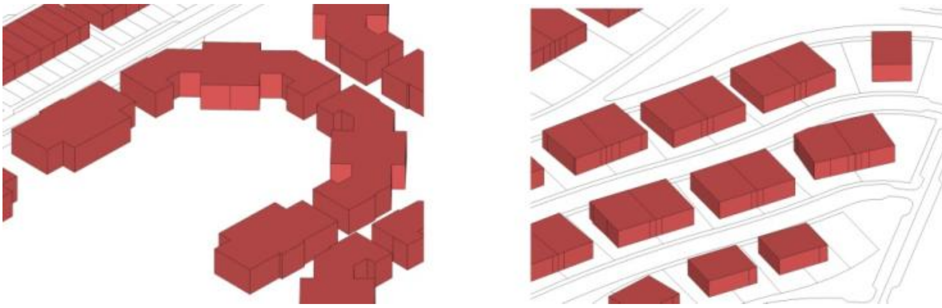


Figure 54: Proposed design prototypes of housing units in NewGiza
(Left: apartments buildings, right: villas buildings)
Source: Author as adapted from (Earth, 2008).

3.2.3 Cooling Ambient Temperature in NewGiza

Streets Orientation

The northwest-southeast is the preferred street orientation to gain maximum benefit from the privileged wind flow in Cairo, however in NewGiza the design did not pay any attention to the street orientation. The design depends solely on the high elevation of the site and the dispersed pattern of buildings will allow the air to penetrate the area and reach all buildings.

External Shading

The external shades are used in NewGiza in three cases. The first case is to shade the pedestrian paths in the main boulevard (the main movement path) to encourage walking. The second case is providing some wooden shades to protect the car parking areas. The third is in some residential areas that neither shade for protecting against sun nor for any climatic aspects, but only for beautification consideration as claimed by the architects of the project. The conclusion is that the external shades for buildings are not strongly used in the area, with a lack of shading instruments.

Figure 55 External shades in NewGiza.
Source: (Earth, 2008). (NewGiza, 2011)

Greening and Urban Trees

The green areas represent almost 87% of the total area of NewGiza. This is around 500 hectare. This vast amount of green areas has a positive benefit in refining the air but will simultaneously consume a huge amount of water considering that each square meter of green areas consume about 10 to 20 litres for daily irrigation. It is also worth mentioning that Egypt is considered as water-poor country because the present per capita water share is below 1000m3/year and might reach 600 m3/capita in the year 2025 (IDRC & Abdel-Gawad, 2011). While the water needed to irrigate the green areas in NewGiza which is almost equivalent to the share of 35,000 persons. This is the total population of NewGiza. Regarding the streets layout, the trees are arranged the trees along the two sides of streets and public spaces are provided with a considerable amount of trees in order to enhance the ambient temperature and provide shades for the pedestrian.

Figure 56 NewGiza is to have 87% of its area as green space
Source: (Earth, 2008). (NewGiza, 2011)

Cool surfaces and Albedo

Most of the buildings are light colours which have high albedo surfaces; figure 57 shows some examples for proposed and constructed buildings. Most of the other surfaces in the district are green areas (except the asphalt and paths) which help to reduce ambient temperature due to the high albedo of the green areas.

Figure 57 White colours of buildings in NewGiza
Source: (NewGiza, 2013)

3.2.4 Mixed-Use Area within NewGiza

The aim of investigating the mixed-use area is that the configurations of its urban form are different than the residential areas within the project. The urban form of this area is more compact with a higher built-up density than the rest of NewGiza. It is located on the northern part of the area right along Cairo Alex Desert Road (figure 58). The Mixed-Use of New Giza aims to become a central urban core not only for the project itself but also for surrounding areas of West Cairo. (EARTH, 2011). The area will be allocated on 26 hectares, includes around 500 housing units, business spaces, leisure and some other uses.

Figure 58: Location of mixed-use area within NewGiza
(Red colour represents the mixed-use area)
Source: (Google, 2013) (EARTH, 2011).

- **Landuse Diversity and Attractiveness**: The mixed-use area includes offices, public facilities, retail/dining, residential and cultural uses. All these uses, in addition to the to the diversity of open spaces, and paths between buildings pose some positive implications in terms of self-satisfaction of the area and providing all needed facilities for its residents.

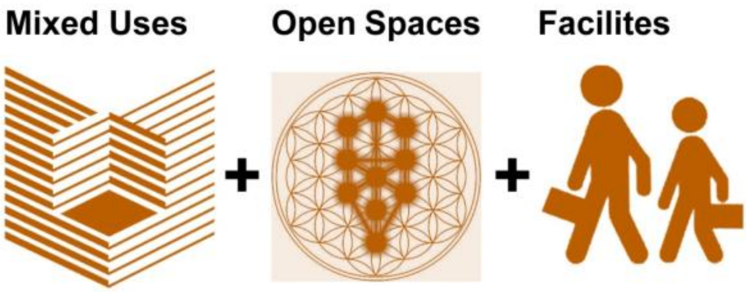


Figure 59: Elements add to the diversity of mixed-use area
Source: Author as adapted from (EARTH, 2011)

Compactness and Density: The mixed-use area in NewGiza is around 150 persons per Hectare, this density is accompanied with an employment density of (200). This is considered a much higher density than the rest of the area (60 persons per hectare). This density is of course non-comparable to the residential areas in Cairo which have an average of 400 persons per hectare. This average density (population and employment) makes better use of the land and gives some benefits in terms of sharing facilities and reducing the lengths of infrastructure networks.

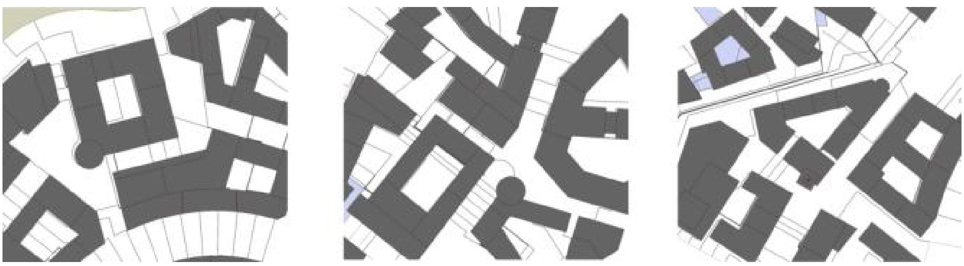


Figure 60 Different urban patterns within mixed-use area in NewGiza
(100*100 meter rectangle)
Source: Author as adapted from (EARTH, 2011)

In terms of compactness; figure 61 shows the compactness of the mixed use area. It is almost 45% of the buildings' foot print, which is much higher than the whole area of NewGiza (10%). The average heights of buildings (ranges from 12 to 20 meters) are higher than the rest of the area. This pattern results in a smaller high S/V ratio which reduces the exposure of buildings to solar incidence and increases the amount of shades on paths and on the buildings. These two implications (small S/V ratios and amount of shades) potentially save energy particularly in terms of the energy needed for indoor cooling and for outdoor thermal comfort.

Figure 61: Urban pattern of mixed-use area in NewGiza
Source: Author as adapted from (EARTH, 2011)

- **Circulation Network:** The mixed-use area in NewGiza is walkable in ten minutes. Its mobility network depends on the hierarchy of pedestrian paths. The compact urban form gives shades in paths and encourages walkability, thus reducing the energy needed for commuting. The pedestrian network of the area is well integrated with the trolleybus stations which gives more potential for energy savings. Regarding the car parking, the area will depend mainly on the basement car parking. The underground car parking areas encourage walkability due to the car spaces that have been freed at level, although it puts more pressure on the energy consumed for ventilating and lighting such an underground facility.

Figure 62: 10 min. walkability of mixed-use area
Source: (EARTH, 2011)

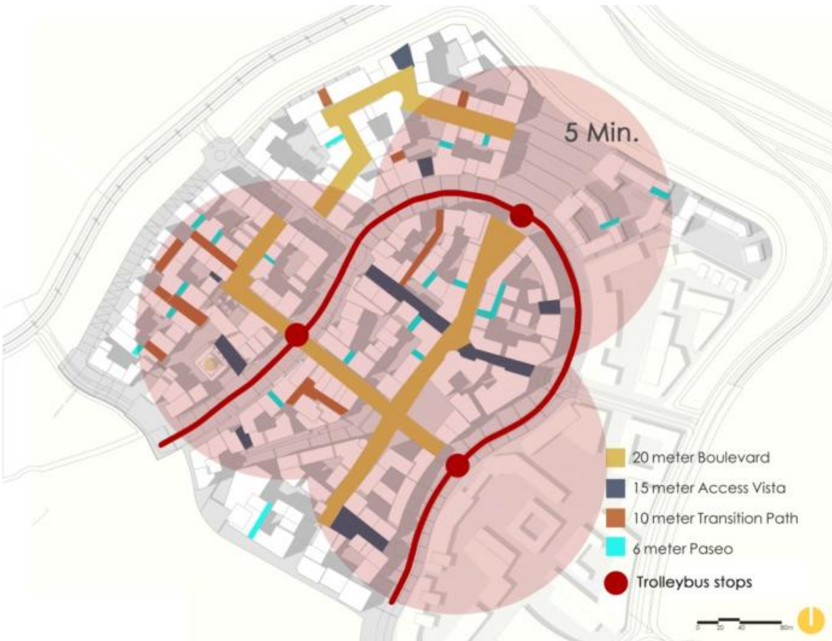


Figure 63: Proposed circulation network within mixed-use are of NewGiza
Source: Author as adapted from (EARTH, 2011)

The streets' design also includes different strategies that pose positive implications on energy savings. For example the high W/H ratios of the streets (figure 64) reduce the solar incidences on the ground and give more potential shaded spaces. In addition, the streets are provided with external shading elements and urban trees to cool the ambient temperature. These strategies aim at encouraging walkability and reduce the energy needed for commuting with potential savings for indoor cooling.

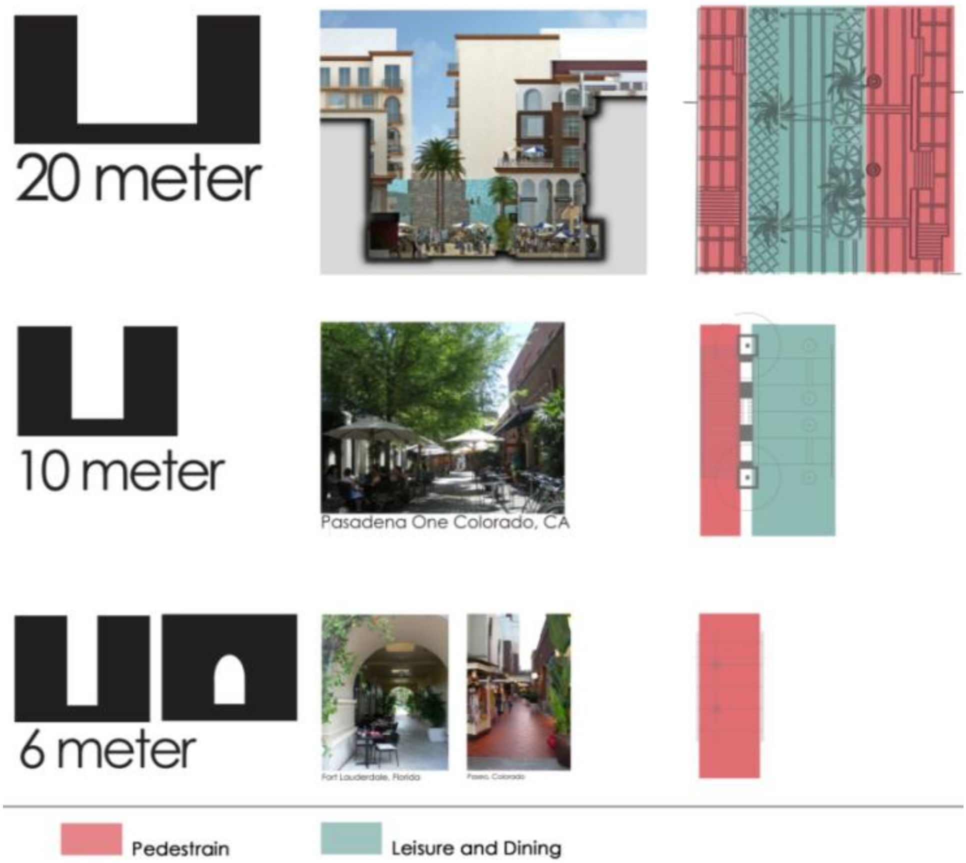


Figure 64 Samples of proposed pedestrian paths within mixed-use area of NewGiza
Source: (EARTH, 2011) adapted by Author

- **Compactness and affiliation to poverty:** As mentioned in the literature review, in some contexts compactness with a low share of open spaces and green areas is affiliated with poverty and lower income settings. However the mixed-use area in NewGiza shows that certain levels of compactness with sensible design strategies and provision of facilities could be attractive for upper income groups. It is worth mentioning that the mixed-use area of NewGiza will host a higher income group of residents. The marketing department of the developer stated that the mixed0use area is being easily promoted. It attracts a lot of people and the developer is thinking of extending the area (Mohasseb, 2013) into pedestrian leisure and dining.

3.2.5 Summary of NewGiza Case Study

Table 9 shows the compliance of the mixed use area in NewGiza with the design principles. The table indicates that the compact urban forms which have a diversity of landuses comply with many of the design principles and that those compact urban form hold many positive repercussions such as short distances of travelling, shades and small S/V ratios.

Design Principles		Compliance of the design principles		
		YES	Somehow	No
General characteristics	Compactness & Density	■		
	Diversity and attractiveness	■		
	Mobility Network	■		
	Site selection		■	
Buildings morphology	Heights and S/V ratio	■		
	Building Forms	■		
	Housing Types		■	
Ambient temperature Mitigation	Streets Orientation		■	
	Central cooling & heating			■
	External shading	■		
	Greening and Urban Trees	■		
	Cool surfaces & Albedo	■		

Table 9: Compliance of the mixed use in NewGiza area with design principles
Source: Author as adapted from previously mentioned literature in chapter 2.

Table 10 on the other hand, indicates that the design of the district as a whole does not consider most of the energy efficiency design principles such as, the compactness, lack of shading instruments and the dispersed urban pattern. The design of NewGiza alleges to be an eco-friendly district and a green community through the implementation of some strategies such as; providing the area with vast green areas, providing transportation network means such as the trolleybus, separation between pedestrian and cars, planting urban trees and using high albedo surfaces. Even though those trials are more likely to enhance the ambient temperature and provide the area with fresh air, they apparently do not save energy. This is because many of the other design strategies result in wasting energy such as; the extremely low density, the low percentages of built up areas, the high s/v ratio of the buildings, the huge amount of energy needed to irrigate the ever-green areas and last but not least the massive cut and fill process needed for handling the site.

Design Principles		**Compliance of the design principles**		
		YES	**Somehow**	**No**
General characteristics	Compactness & Density			■
	Diversity and attractiveness	■		
	Mobility Network			■
	Site selection		■	
Buildings morphology	Heights and S/V ratio			■
	Building Forms			■
	Housing Types			■
Ambient temperature Mitigation	Streets Orientation			■
	Central cooling & heating			■
	External shading			■
	Greening and Urban Trees			■
	Cool surfaces & Albedo		■	

Table 10: Compliance of NewGiza with the design principles
Source: Author as adapted from previously mentioned literature in chapter 2.

Table 11 shows an abstract depicting the main deficiencies of the urban configurations in NewGiza. It shows a summary analysis for the design of NewGiza in comparison with the energy efficient design principles. As a conclusion the urban configuration of NewGiza does not consider many aspects of the energy efficiency design principles, reflecting in the main deficiencies which are the low density, the huge amounts of cut and fill processes and the irrigation of green areas.

Summary of NewGiza Case Study

Massive areas of green spaces that consume huge amount of water

Buildings with high S/V ratios that expose the buildings to solar radiation

Dispersed urban pattern with mono-functional landuse, result in long travel distances and high solar incidence

Dominance of car movement pattern results in high fuel consumption

Main Deficiencies				
Dispersed urban pattern	Massive surfaces of green areas	Mono-functional landuses	Car Dominance	Long travel distances

Table 11 Main deficiencies of urban configurations of NewGiza
Source: Author as adapted from previously mentioned literature in chapter 2 and (Earth, 2008). (NewGiza, 2011)

3.3 Case Study : Al Rehab / Middle Class Area

Al Rehab is located in the north of New Cairo City, which is situated in the east part of Greater Cairo (Figure 65). Al Rehab is the first city built by the private sector in Egypt (Yousry, 2009). It spreads on an area of 1000 hectares and is expected to accommodate 200,000 inhabitants upon its completion. Al Rehab is also widely acknowledged as being one of the most successful gated communities in the GCR (Yousry, 2009). According to officials in the (NUCA, 2008) - New Urban Community Authority, Egypt - it represents a model that has been extensively repeated across other satellite cities (Abdullah, 2013) (Nosair, 2013).

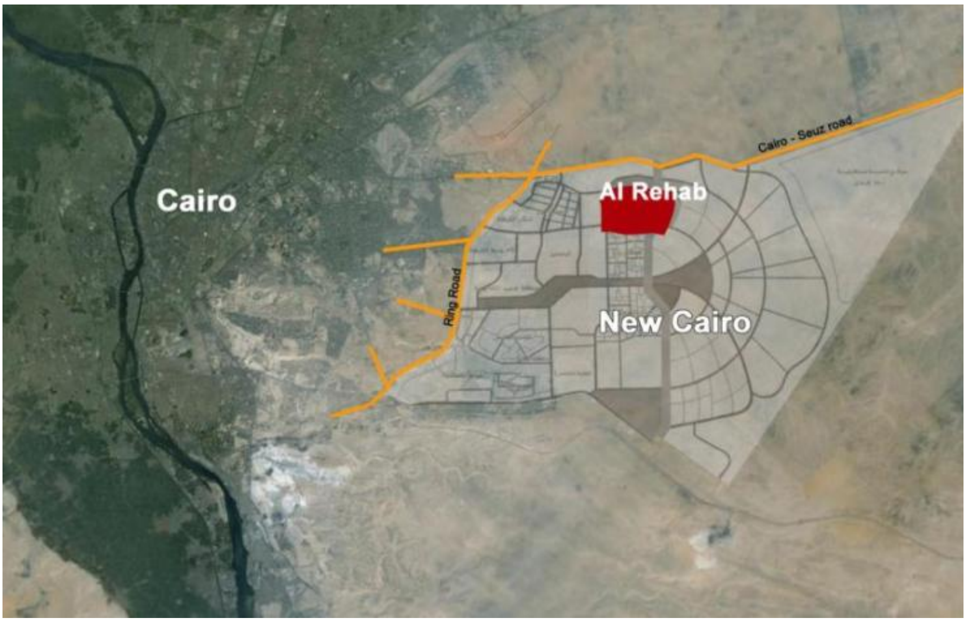


Figure 65: Location of Al Rehab north of New Cairo City
Source: (Google, 2013) (NUCA, 2008)

Al Rehab was planned to have six residential neighbourhoods, and was later extended to ten, including a variety of amenities and facilities such as schools, banks, markets and malls. The development of Al Rehab aimed to accommodate middle income and high-middle income groups. For that reason, it offers a wide range of housing choices such as flats that vary from

60m² to 320 m² with a majority of medium sized flats that range from 120-150 m². It also offers different types of villas including attached, semi-attached and detached villas with a majority of the attached and semi-attached types.

3.3.1 General Characteristics of Al Rehab

3.3.1.1 Site selection

The site selection was made by the New Urban Community Authority, Egypt (NUCA, 2008) and was later handed over to the developer. The location lies between the centre of New Cairo and the Cairo-Suez Regional Road. (Figure 66) shows the location of Al Rehab within the surrounding spatial features. The site is well connected with the surrounding city level services (New Cairo City). The proximity to the city centre is beneficial to reduce the energy needed to commute for the city-level facilities such as universities, schools, hospitals malls and etc.

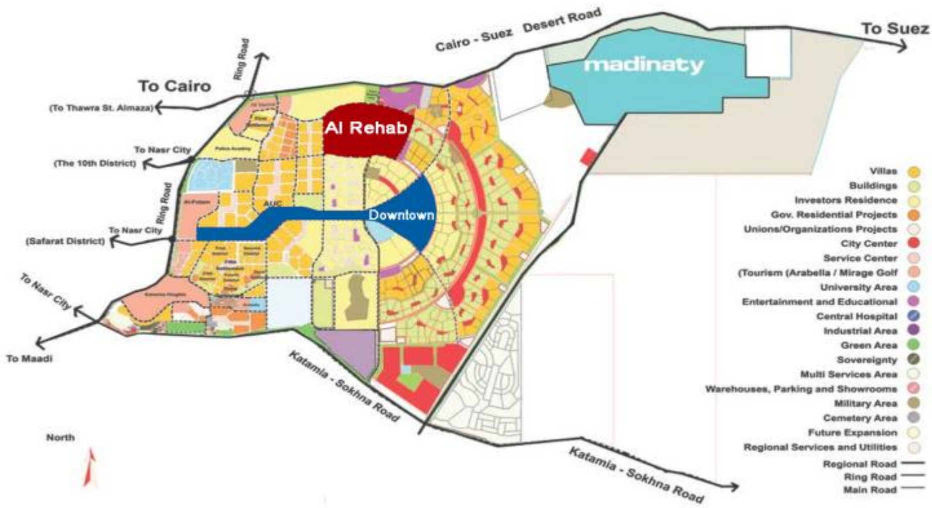


Figure 66 Location of Al Rehab within New Cairo
Source: (NUCA, 2008) (Madinaty, 2011)

The site surfaces and differentiation of levels were almost even with very small variations. Therefore, it did not need a lot of cut and fill processes to prepare it for residential uses (Eissa, 2013). The site was in need only for basic levelling process.

3.3.1.2 Compactness and Density

Al Rehab is on an area of 1000 hectares and has a population of 200,000, with an average density around 200 persons per hectare. Density varies from 100 persons per hectare in the villas' areas to 400 persons per hectare in the buildings' areas. This density is lower than the average residential density in Cairo (400 persons per hectare and which sometimes reaches 2000 persons per hectare in the inner parts of Cairo). Nevertheless this low density can be attributed to the suburban and to the middle income groups of residents. Regarding the compactness of the residential blocks, Figure 67 shows the built-up areas of a group of residential blocks and also a group of villas. The building foot prints and heights form an urban pattern with medium level of compactness (when compared to NewGiza and to internal parts of Cairo). In the three shown cases the built-up area is around 15% - 25%. This is the average built-up area within Al Rehab. This pattern allows more wind to penetrate between buildings but results in a high exposure of solar incidence which heats up the surfaces of the buildings and pedestrian paths.

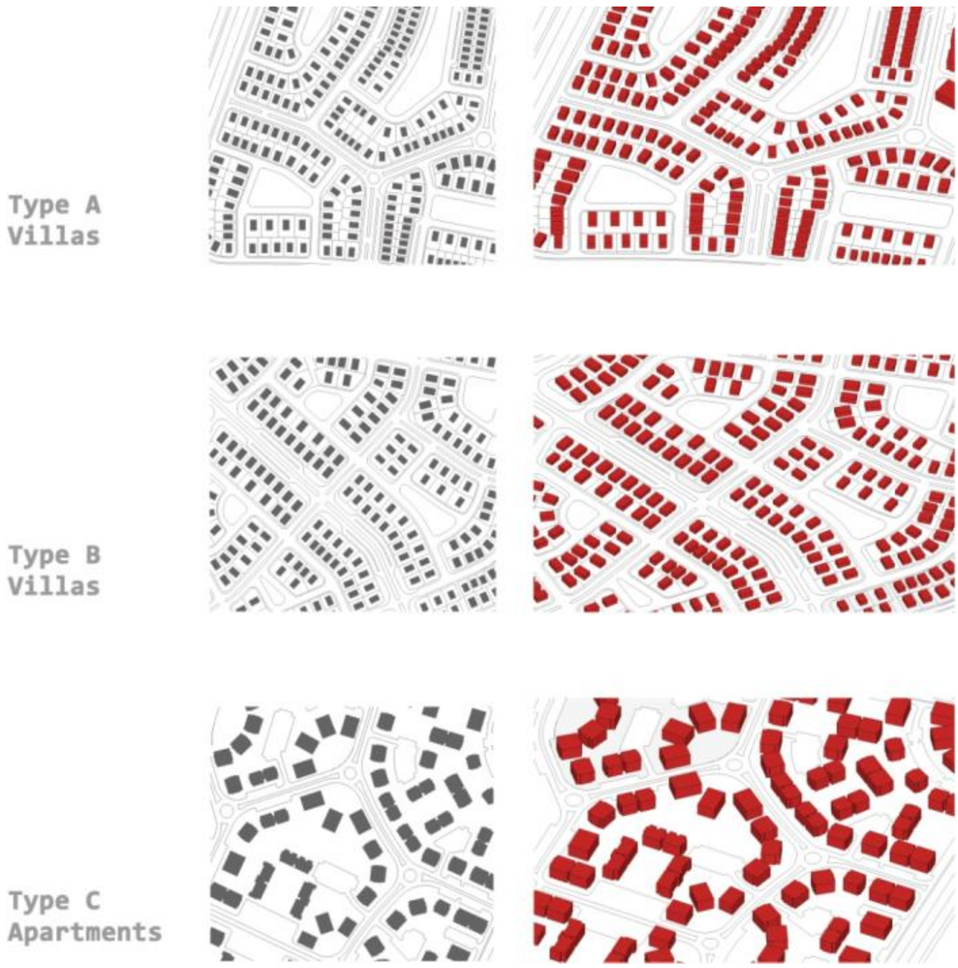


Figure 67 Different level of compactness within Al Rehab area[3]
Source: (Yousry, et al., 2005) adapted by Author

3.3.1.3 Diversity and Attractiveness

Al Rehab is provided with a variety of services and facilities such as daily markets, banks, restaurant, schools, parks and recreation areas in proximity of residential buildings. Figure 68 shows the diversity of landuses and different facilities within the area.

[3] The selected cases are within a rectangle of 450 m * 450 m

Figure 68: Al Rehab landuse plan
Source: (Yousry, Nabih, & Rabei, 2005)

Figure 69: Diversity and facilities in Al Rehab
Source: (Yousry, 2009)

Those facilities and services add to the attractiveness of the area and reduce the energy needed for commuting to meet the basic and daily services. Nevertheless the only adverse affect of those facilities is that the area has become over-attractive to the surrounding districts. This occasionally results in traffic jams cause by commuting cars from the neighbouring districts which raises the question of the extent to which diversity and attractiveness should be provided. For example the area of the food court and daily market of Al Rehab experiences congestions and crowdedness due to the high number of visitors from outside residents. These conjunctions result in high Co2 emissions as well as the usage of more fuel.

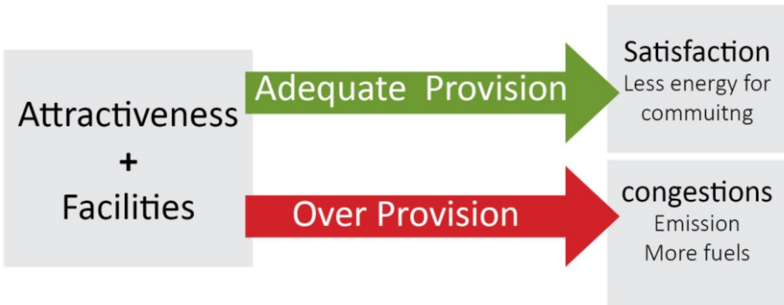


Figure 70 Potential adverse affect of attractiveness on energy consumption
Source: Author

3.3.1.4 Mobility Network of Al Rehab

Access and connections with the surrounding transportation network

Al Rehab is well connected with the wider road network of Greater Cairo, via Cairo-Suez regional road, and also well connected with the internal parts of New Cairo through many internal roads. Al Rehab applied two strategies to have better connectivity with the surroundings:

- Firstly, the construction of a shortcut road to reduce the travel distance to Cairo-Suez road (Figure 71).
- Secondly, offering some public buses to connect with other parts of Cairo such as to Heliopolis and New Cairo downtown.

Figure 71: Access and connections with the surrounding transportation network
(The blue line represents the road from Al Rehab to Cairo – Suez road, and the black line represents the shortcut road that has been constructed by the developer)
Source: (Yousry, et al., 2005) adapted by Author

Integration of Mobility Network

The internal movement network of Al Rehab depends mainly on vehicles' roads with pedestrian paths allocated along the two sides of the roads (Figures 72 and 73). This internal network also depends on some pedestrian spaces and paths that connect between residential buildings and neighbourhoods.

Al Rehab is provided by a quite simple internal public transportation network. This network consists of only three lines of public buses to serve the residents. Those lines do not cover the whole area of Al Rehab; hence commuting with the private cars is still the dominant movement choice. The internal circulation network of the neighbourhoods depends mainly on private cars. The neighbourhood gave priority to cars by designing and constructing vehicles' roads that extend to reach every single plot and every single building. That ostensibly results in a high percentage of roads and asphalt surfaces. For example Figure 73 shows that in neighbourhood no.9 and no.10, the roads constitute almost 45 % of the total land area and the asphalt surfaces almost 22% of the total area. These enormous amounts hold some negative implications on energy consumption such as:

- The wastage of land area as a resource, considering this percentage (45%) is for low rise buildings.
- The percentage of exposed land to the solar radiations (particularly the asphalt as it has a very low albedo) which heats up the ground surface.

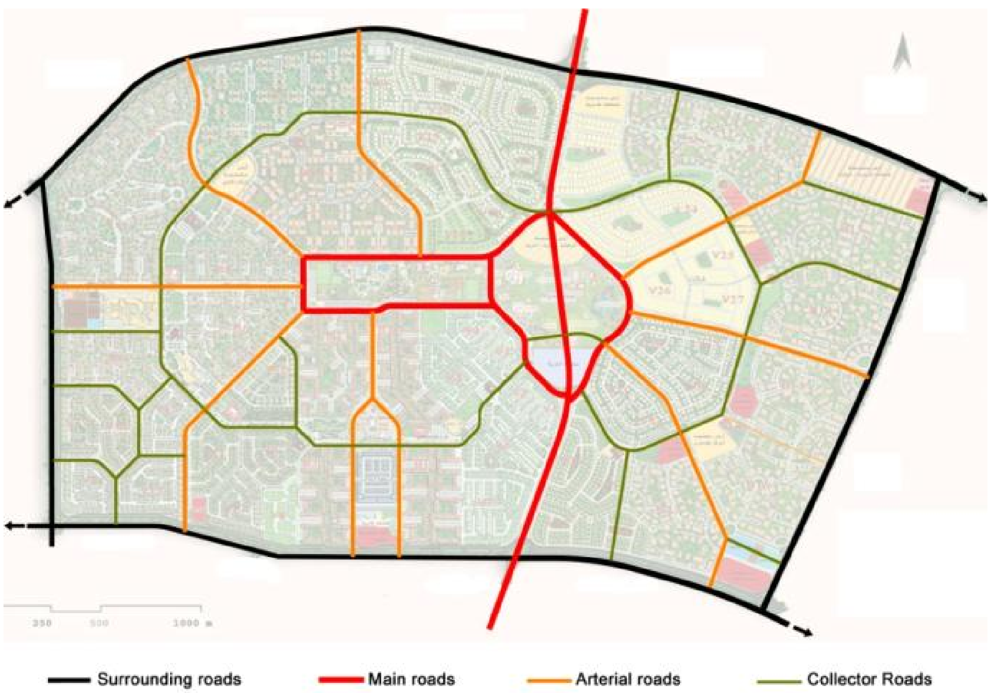


Figure 72 Hierarchy of main roads within Al Rehab
Source: (Yousry, et al., 2005) adapted by Author

Figure 73 Percentage of roads and asphalt in neighbourhoods 9 & 10 in Al Rehab. Source: (Yousry, et al., 2005) adapted by Author

Streets Design and H/W Ratio

Figure 74 shows some examples for the streets H/W ratio. Most of the streets have high value of H/W ratios. Those high ratios expose most of the surfaces of buildings and streets to a high incidence of solar radiation. Looking at the street layouts; the streets are not provided with the basic requirements that support walkability. The dominance of asphalt and car movement attribute to the lack of cycle lanes and lack of shading instruments along the pedestrian paths. These factors make the private car the most convenient way to move within the area, which puts more pressure on the energy needed for travelling and moving within the area.

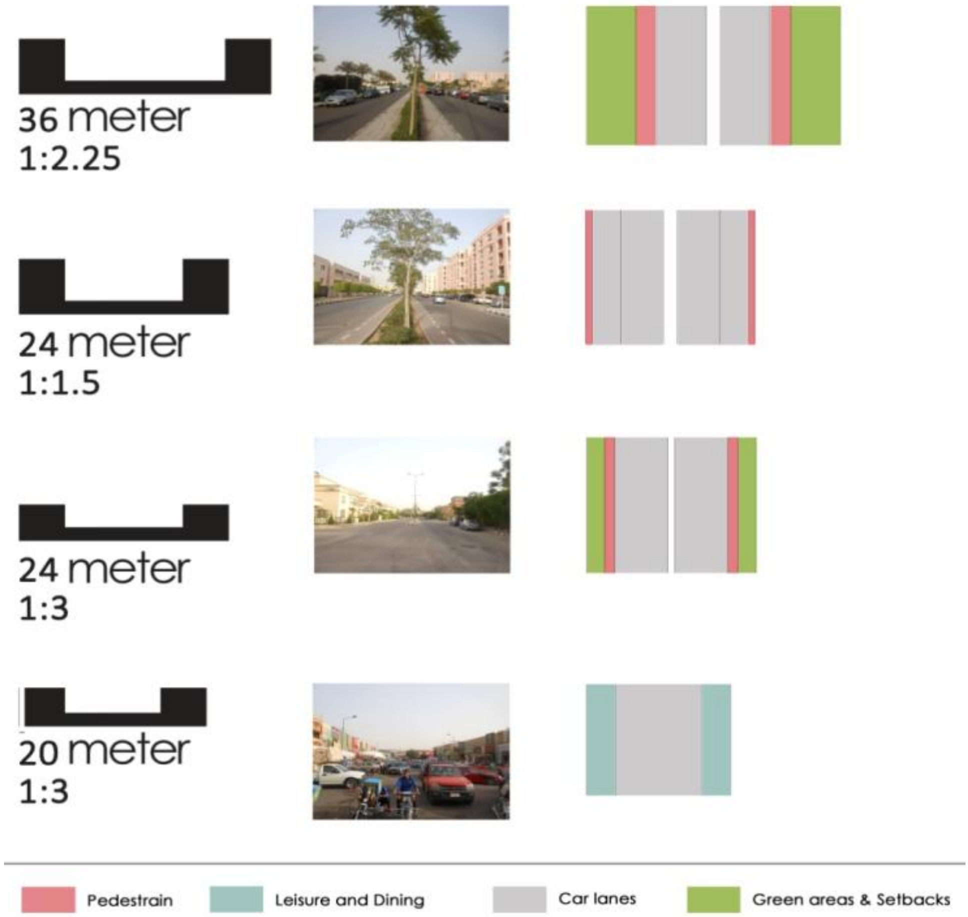


Figure 74:High H/W ratios, dominance of car lanes & asphalt in Al Rehab
Source: (Yousry, et al., 2005) adapted by Author

Car parking

Since the design of Al Rehab gives priority to car movement, the parking areas are provided in two types. The first type is the parking lanes along the two sides of the streets (Figure 75). The second type is the parking spaces in front of the residential blocks. Those car parking areas not shaded and paved with asphalt (with low albedo surfaces) which reflects more solar radiation to the ambient air thus raising the temperature of outdoor spaces.

This is in addition to the massive amount of land and energy needed to construct such car parking spaces.

Figure 75 Forms of car parking areas within Al Rehab
Source: (Yousry, et al., 2005) adapted by Author

3.3.2 Buildings Morphology and Housing Types in Al Rehab

The residential uses in Al Rehab district mainly include villas and apartment buildings. A variety of housing units are offered. Apartment sizes range from 60 to 320 square meters in area. Heights vary from five stories for apartment buildings and two stories for villas. All apartment buildings' areas are designed in groups, where clusters of buildings enclose green open spaces and pedestrian paths connect the buildings with each other and with vehicle roads (Yousry, 2009). There are 26 Villa prototypes which range from 170 square meters in the semi-detached villas to 520 square meters in the luxurious ones. Villa plots range from 200 to 800 square meters, with private gardens taking up at least 60% of the total plot area.

Figure 76 Housing types and building forms for neighbourhoods 9 & 10 in Al Rehab
(Left are detached villas and the apartment buildings on the right)
Source: (Yousry, et al., 2005) adapted by Author

3.3.3 Cooling Ambient Temperature in Al Rehab

3.3.3.1 Streets Orientation

The northwest-southeast street orientation is the preferred one to gain a maximum benefit from the privileged wind in Cairo. In Al Rehab the design did not pay attention to the street orientation; however there are some streets that have been unintentionally oriented to the preferred wind direction, besides some green areas that work as a free-obstacle for the channelling wind movement.

3.3.3.2 External Shading

The external shades are important for outdoor thermal comfort to encourage walkability and reduce solar incidence on buildings surfaces which simultaneously reduces the energy needed for cooling indoor spaces. Not only does Al Rehab have a limited usage of shading instruments, but also shading of buildings on each other are quite inadequate due the far distances between buildings. There are few different forms of external shades though, such as some tents on outdoor dining areas and some trees within the internal spaces of residential blocks. Figure 77 shows the lack of shades' instruments in daily markets, streets and spaces.

Figure 77 Lack of shades instruments & shades between buildings in Al Rehab.
Source: Author

3.3.3.3 Greening and Urban Trees

Green areas are around 300 hectares which stand for almost 30% of the total area of Al Rehab. Residential buildings are clustered in groups around green spaces (Figure 78). On the one hand, these entire green areas benefit the neighbourhood positively in refining the ambient air and reducing its temperature. On the other hand it stipulates a huge amount of water consumption, considering that each square meter of green areas needs around 10 to 15 litres per day for irrigation. The total water needed for irrigation is around 25 million of cubic meters (per annual) according to (Eissa, 2013). This is equivalent to the share of 40,000 persons in the total water share.

Figure 78 Examples for residential clusters in Al Rehab
Source: (Wikimapia, 2011)

3.3.3.4 Cool Surfaces and Albedo

Most of the buildings are in light colours and have high albedo surfaces; Figure 79 shows examples of some buildings within Al Rehab. The adverse effect is generated from the asphalt surfaces which constitute around 42% of the total surfaces within the area.

Figure 79 High albedo buildings' colours in Al Rehab
Source: Author

3.3.4 Summary of Al Rehab Case Study

Tables 12 and 13 show the compliance of the mixed use area of Al Rehab with the design principles; the table shows that the design of the area does not fulfil most of the principles of energy efficient urban configurations. Even though the design of Al Rehab deployed some of the energy efficient urban design principles such as attractiveness, provision of facilities and services, the design applied many other strategies that employ high energy consumption such as the huge amount of asphalt surfaces, the car dominant circulatory movement and buildings which have a high S/V ratio.

Design Principles		Compliance of the principles		
		YES	Somehow	No
General characteristics	Compactness & Density			■
	Diversity and attractiveness	■		
	Mobility Network			■
	Site selection		■	
Buildings morphology	Heights and S/V ratio			■
	Building Forms			■
	Housing Types			■
Ambient temperature Mitigation	Streets Orientation			■
	Central cooling & heating			■
	External shading			■
	Greening and Urban Trees		■	
	Cool surfaces & Albedo		■	

Table 12 Compliance of mixed use area of Al Rehab with the design principles
Source: Author as adapted from previously mentioned literature in chapter 2 and (Yousry, et al., 2005)

Summary of Al Rehab Case Study

Main Deficiencies			
Dispersed urban pattern with high exposure to the sun	**Mono-functional landuses**	**Car Dominance**	**Long travel distances**

Table 13 Main deficiencies of urban configurations of Al Rehab
Source: Author as adapted from previously mentioned literature in chapter 2 and (Yousry, et al., 2005)

3.4 Comparison between Different Urban Configurations of selected neighbourhoods within the Case Studies

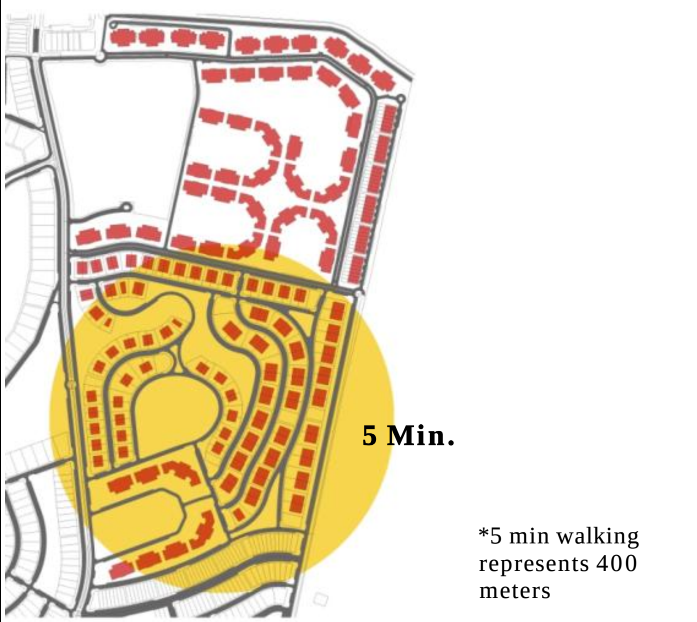
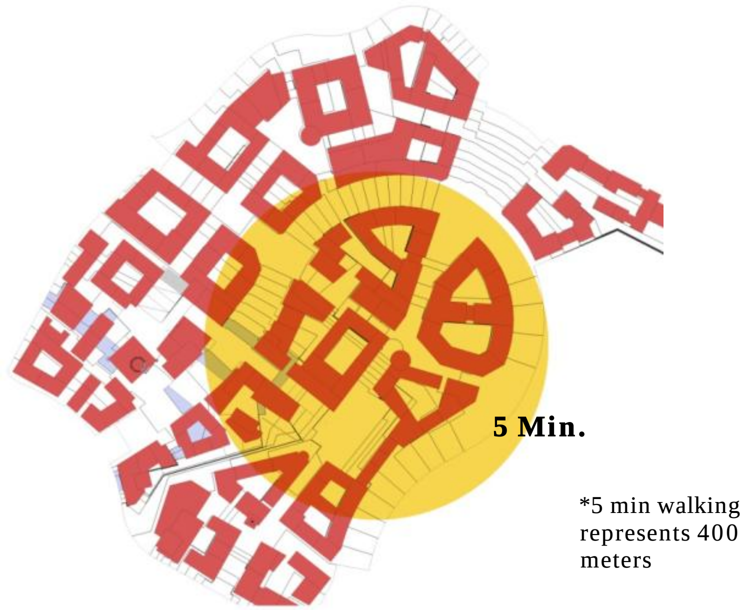
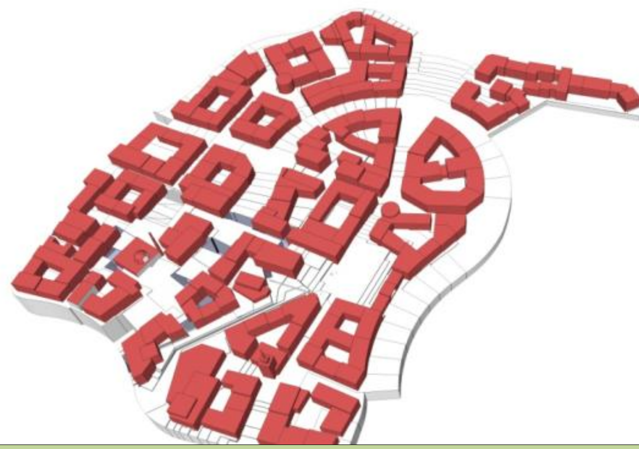
NewGiza Residential Neighbourhoods	NewGiza Mixed Use Area	Al Rehab Residential Neighbourhoods
		
		
• Dispersed urban pattern • Highly exposed to solar radiation • Travel Long distances • Huge amount of green areas • Mono-functional land use	• Compact urban pattern • Protection against solar radiation • Short travel distances • Pedestrian based circulation networks • Mixed landuses	• Dispersed urban pattern • Highly exposed to solar radiation • Travel Long distances • Car based circulation networks • Mono-functional land use
It is apparent that the compact urban form of the mixed use area in NewGiza, is faster to achieve and meets with the energy efficiency design principles		

Table 14: Comparison between different urban configurations within case studies. Source: Author as adapted from previously mentioned literature in chapter 2 and (Earth, 2008) (Yousry, et al., 2005)

Chapter 4 Conclusion

4.1 Existing Urban Planning Regulation of Residential Projects in Cairo

4.2 The Main Deficiencies of Urban Configurations Related to Energy Consumption

4.3 The Way Forward

4. Conclusion

The research concludes twelve design principles for energy efficiency on the scale of districts and neighbourhoods. Those principles have been extracted from a variety of literature, and then applied and tested on the selected case studies. Table 15 shows an abstract for the fulfilled and neglected principles within the case studies. The only fulfilled principle in both is the diversity of landuses while most of the other principles have not been considered in the design of both case studies with an exception for the mixed use area at NewGiza.

		Compliance of the principles					
Design Principles		NewGiza			Al Rehab		
		YES	Some how	No	YES	Some how	No
General characteristics	Compactness & Density			■			■
	Diversity and attractiveness	■			■		
	Mobility Network			■			■
	Site selection		■			■	
Buildings morphology	Heights and S/V ratio			■			■
	Building Forms			■			■
	Housing Types			■			■
Ambient temperature Mitigation	Streets Orientation			■			■
	Central cooling & heating			■			■
	External shading			■			■
	Greening and Urban Trees			■		■	
	Cool surfaces & Albedo		■			■	

Table 15 Compliance of the case studies with the design principles
Source: Author as adapted from previously mentioned literature in chapter 2 and (Earth, 2008) (Yousry, et al., 2005)

As shown in the case studies there are some common characteristics and deficiencies in the two case studies, such as the high S/V ratio and lack of integrated transportation networks. Therefore it is important to highlight the urban planning regulations behind those case studies in order to investigate the requirements that led to those common characteristics.

4.1 Existing Urban Planning Regulation of Residential Projects in Cairo

In Egypt, the constructions and urban planning projects are under Law no.119 promulgated in the year 2008, also known as Unified Building Law (Qanon Al Bena'a Al Mowahhad). This law was released by a presidential decree and ratified by the parliament on 2008 in order to systemize and regulate the process of building and construction (Ayyad & Gabr, 2012). It eliminates some former laws such as the Law no.106 for the year 1976 concerning construction works, Law no.3 for the year 1982 known as the Law of Urban Planning, Law no.49 for the year 1977 concerning selling of real estate and the relationship between landlords and renters (Ayyad & Gabr, 2012).

Law no.119 outlines the main guidelines for urban planning regulations and codes regarding the residential projects. The detailed regulations are posed by the government through the New Urban Community Authority (NUCA, 2008) and through the General Organization of Physical Planning (GOPP). Both organizations impose detailed regulations on new cities and are responsible for issuing the official permits for the masterplans of residential projects. In order to assure that the construction is taking place accordingly with the regulations and given permits, the City Department (of the new city) is responsible for monitoring the residential projects construction and for giving the single buildings constructions permits. NUCA and GOPP have the right to impose some special requirements for specific projects. However there are some other requirements from other governmental bodies such as the Ministry of Environmental Affairs, Ministry of Defence, and Ministry Of Transportations (Nosair, 2013) (Alqadi, 2013) (Abdullah, 2013). All special requirements are managed by the NUCA.

The table in appendix 1 shows a summary of the urban planning regulations that may affect the urban configurations of the residential areas. The table shows that most of the regulations on an urban design scale are few, descriptive mostly and not relevant to the design principles of energy efficient urban configurations. Most of the relevant ones do not represent a strict goal for energy efficiency anyhow. Those regulations impose general aims and considerations such as provision of facilities and connectivity with the surrounding roads and infrastructure networks. Some regulations are more likely to contradict with others such the setbacks regulations where most of buildings have to leave setbacks from at least two sides within the land plots. Such a requirement results in building configurations with high S/V ratio, dispersed urban pattern and long travelling distances between buildings. All these factors negatively produce higher energy consumption particularly for cooling indoor spaces and commuting.

It is paradoxical that the word “energy” has been mentioned only one time in the Unified Building Law. It has been mentioned under the article number 139 in the explanatory appendix. This article imposes some regulations regarding the energy consumptions in buildings such as; the window percentage must not be less than 10% of the window wall, and that the buildings must commit to the Egyptian code for lighting and thermal insulations of air conditioning channels. Hence, all of the regulations that are related to the word ‘energy’ impose a few requirements for operating buildings and lighting systems, as opposed to the architectural design of the buildings themselves.

Urban planning regulations for energy consumption negatively affect the urban configurations. It is stated by (Abdullah, 2013) (Alqadi, 2013) (Nosair, 2013) that the urban planning regulations are confusing because of the generalization, lack of details and absence of a holistic vision that takes the green concept into consideration, when formulating those regulations (Ayyad & Gabr, 2012). There is a crucial need to update the urban planning regulations in order to work for more energy efficient urban design. The regulations should include more considerations for energy efficiency for all urban scales.

4.2 The Main Deficiencies of Urban Configurations Related to Energy Consumption

The case studies analysis shows that the design of both case studies do not fulfil most of the design principles extracted in the literature review. However energy consumption is extremely affected by urban configurations of residential areas. One the one hand, the urban configurations of the case studies and urban planning regulations demonstrate some positive implications such as providing the areas with basic facilities and connectivity with the surrounding areas. On the other hand the same urban configurations and applied regulations result in deficiencies such as undersized built-up areas, immense setbacks, low urban density and high exposure to solar radiation in addition to difficulties of providing proper public transportations systems. The car-based circulation networks also result in the misuse of land as a resource and massive spaces of asphalt and unshaded surfaces. Those deficiencies and problems are closely interlinked and could be summarized in the following points:

- Mono-functional land uses
- Buildings morphologies
- Air conditioning and space cooling
- Transportation and circulation networks
- Interpretation of Eco-friendly settlement or green community
- The Need for Passive Air Cooling Techniques

4.2.1 Mixed-Use versus Mono-Functional Uses

The mono-functional land use plan is the typical form of landuse plan in the demonstrated case studies, as well as in many other areas in new satellite cities with a few exceptions. This separation of landuse lessens the neighbourhood liveability and stipulates more trips to meet the daily needs of the residents, hence increasing the energy consumption. Hypothetically the mixed form of land uses is more efficient than the mono functional landuse. Encouraging the concept of mixed uses instead of mono-residential landuse ought to be a desirable target in order to diminish the need to travel and reduce the energy consumptions resulting from commuting. It is recommended to develop the mixed use development concepts and try to promote it through the municipalities, developers, architects and planners.

4.2.2 Buildings Morphologies: Compactness versus Dispersal

The design of selected case studies, gives priority for detached buildings with a high S/V ratios. Most of the buildings and villas are being built in the centre the of land plots with enormous setbacks. The argument behind the setbacks is to achieve more privacy for the residents. But such a concept result in low density urban areas with buildings that are highly exposed to the sun.

Landuse / Facility	Built up area %	Heights	Setbacks		
Educational	30	4 stories	6	6	6
Health	30	4 stories	5	5	6
Youth centres / clubs	10	2 stories	6	6	6
Social clubs	20	2 stories	6	6	6
Commercial	40	4 stories	4	4	5
Administrative	40	4 stories	5	5	6
Religious	40	2 stories	6	6	6
Cultural	30	2 stories	5	5	6
Social	40	2 stories	5	5	6
Open spaces and public parks	2	1 stories			
Business buildings	30	5 stories	5	5	6

Table 16: Examples of setbacks & public facilities regulations in New Cairo
Source: (NUCA, n.d.)

Figure 80 Examples depicting setbacks regulations parts in New Cairo
Source: (Google, 2013)

The regulations also require that the built-up area be 30% to 40 %. This results in dispersed urban patterns which contradict with the principles of compactness. The highly exposed building surfaces and wide distances between buildings with no means of shades affect the energy efficiency unconstructively. Another concern is the lengthy infrastructure networks and the long travel distances, which consume a lot of embodied energy and lead to energy wasting through transmission. Aiming towards densification and compactness would be beneficial for that matter. Consequently there ought to be detailed studies that define an acceptable level of compactness to gain from the positive impacts of compactness and eliminate its negative ones.

4.2.3 Transportation and Circulations Networks: Car Dominance

Cars are the mainstream trend of movement within residential projects such as the ones presented earlier. The end result is the mismanagement and misuse of land resources, high demand on car fuel and the construction of massive asphalt surfaces. Providing the residential areas with an integrated transportation network that includes public transportation, proper pedestrian paths, cycle lanes and high accessibility for facilities is significant to save energy wasted in car commuting. Taking into consideration Cairo's hot climate, it is essential that there be outdoor thermal comfort design strategies such as shading elements, cool surfaces and the usage of urban trees.

4.2.4 Interpretation of Eco-Friendly Settlement

Concepts of eco-friendly cities, low carbon cities, green communities, eco cities and smart growth have become the main approaches to work towards a more sustainable and an environmental development in the last few decades. While those concepts differ and vary from each other, there is large widespread stand for all of them such as; applying energy efficiency principles in buildings and settlements, reducing Co2 emissions, enhancing the ambient air, and eliminating pollutants. Those principles and concepts mainly concentrate on the specificity of each location and give high priority to the energy efficiency and green gas house emission. In Egypt (for example in NewGiza) the designers intended and claimed to establish an Eco-friendly community, but the interpretation of Eco-friendly (in NewGiza and in many cases) was to provide more green areas as much as possible and avoid the intersection between cars and pedestrian paths. This on the contrary neglects many other aspects of the energy efficiency principles such as those massive green areas require huge amounts of water irrigation. It is of utter importance to promote for more strategies beyond 'green' sceneries.

4.2.5 The Need of Passive Air Cooling Techniques

In Al Rehab city, every single room has its own air condition (Eissa, 2013). There is an increased usage of electricity-consuming cooling devices such as air conditioning units, fans and refrigerators. For example in Egypt, air conditioning units have increased dramatically over the last few years. The number of AC units rose from 196,000 in 1999 to three million in 2009 (Raslan, 2013). According to the Minister of Electricity in Egypt (Emam, 2013), this number doubled to six million units by 2012. In addition to accounting for 20% of energy consumption (Raslan, 2013) the use of these devices add to the UHI effect through the release of waste heat into ambient air.

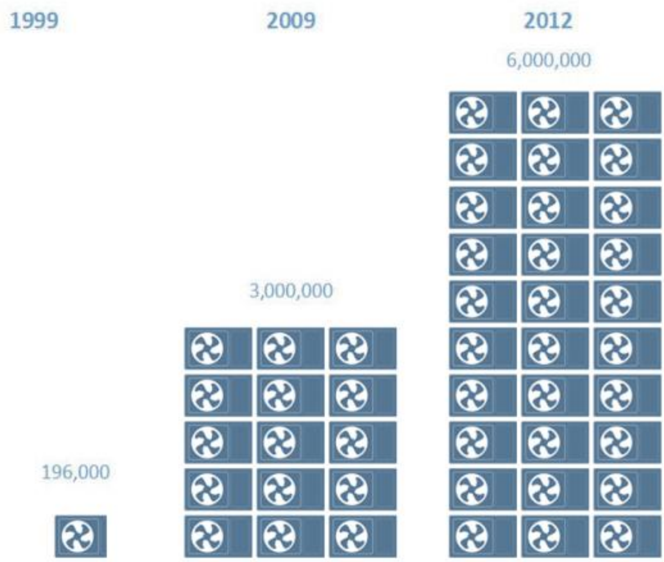


Figure 81: Increase of air conditioners numbers in Egypt
Source: (Raslan, 2013)

Any design strategies to provide energy efficiency should address the reduction of energy consumption in cooling. It is important to use passive cooling techniques. It is natural of course that the passive design strategies differ according to the location of the site and microclimate conditions. Nevertheless, the main stand is to protect against solar radiation and provide enough shades while taking into consideration the influence of the buildings' configurations.

4.3 The Way Forward

There is a crucial need for further improvements on the legal and organizational level to establish energy efficient residential projects. Adopting and posing particular guidelines for the land uses, transportation and cooling is a major requirement. The strategic and detailed design of the residential projects should encourage the different concepts of energy efficiency. The approaches of a sustainable and green urbanism should be endorsed in the field of designers, planners and architects. The integration of energy efficiency in the curricula of urban planner's educations in line with developing the regulations is recommended (MED-ENEC, 2013).

There appears to be a challenge to enforce the implementation of energy efficiency design principles on the urban and city level planning. Hence, there ought to be detailed studies on how to promote such ideas in a way that can be accepted by municipalities, planning authorities, developers as well as designers. It is important to update urban planning regulations and enforce a certain system towards applying the energy efficiency principles on the district level. Even though there are many challenges encountered to apply them, but the role of NUCA as the sole authority that gives approval and permits for residential projects, bestows upon it a high responsibility to impose and demand such regulations.

The research also suggests that there are further studies to be pursued for more concrete results regarding the following issues:

A. Differences between privately and public owned residential projects.
B. More case studies form different cities, to draw robust conclusion concerning urban configurations in the residential projects.

C. More investigations and studies on the developers' roles and market forces that impose certain configurations depending on the preferences of residents.
D. Comparison between the old and new urban configurations, such as the comparison between residential projects before and after the satellite cities strategy.
E. Development and updating of the current building regulations particularly those on the urban and district scale.

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Appendix 1: Urban Planning Regulations from the Law no.119 Promulgated in the Year 2008, A.K.A "Unified Building Law"

Regulations from the Unified Building Law	Energy Efficient design principles for										
	General characteristics				Buildings morphology			Ambient temperature Mitigation			
	Site selection	Compactness and Density	Diversity and Attractiveness	Circulation Network	Heights and S/V ratio	Building Forms	Housing Types	Streets Orientation	External shading	Greening and Urban Trees	Cool surfaces and Albedo
Article 50											
The master plan should be prepared to comply with the comprehensive strategic plan of the city while considering the spaces needed for streets, public parks, schools and all needed facilities.											
The master plan should show the following :											
• The integration and coherency with the neighbouring residential areas, particularly in the issues related to connectivity of roads and infrastructure.											
• The provision of public facilities should give appropriate spaces and locations, considering the residents needs. This will be applied considering the influence of adjacent public facilities.											
• The relationship with the natural environment and its influence on the wind directions and buildings orientation.											
• The masterplans must be based on the city detailed master plan and on the zones regulations, especially for landuses, traffic, availability of infrastructure networks and public facilities.											
• The dimensions and spaces of residential, industrial and commercial blocks should be designed to provide appropriate ventilation, lighting, open spaces, car parking, and loading and unloading areas.											
• Streets and blocks must be arranged to achieve the maximum benefit from the topographic characteristics and natural features. The arrangement should as much as possible conserve the wooded areas and large individual trees											
• Each land plot must be surrounded by at least on street / road form one side.											
• The urban blocks dimensions should consider the following :											
o To select the appropriate locations of the buildings within the land plot in a way that meets the specific needs of the use of the building.											
o To meet the requirements of connectivity between buildings and streets while ensuring the ease of traffic movement.											
o The topographic characteristics.											
o The maximum length of a residential block is 250 meters, measured form the axis of the block. In case the block length is more than 250 meters it has to be divided by a 4 meters pedestrian corridor. The distance between the corridors and end of the block must not exceed 150 meters.											

Regulations from the Unified Building Law	**Energy Efficient design principles for**										
	General characteristics				Buildings morphology			Ambient temperature Mitigation			
	Site selection	Compactness and Density	Diversity and Attractiveness	Circulation Network	Heights and S/V ratio	Building Forms	Housing Types	Streets Orientation	External shading	Greening and Urban Trees	Cool surfaces and Albedo
o The block width must be suitable for the intended use.											
The design of residential land plot must meet the following:											
• Every land plot must be overlooking at least one road.											
• The minimum land plot area is 150 square meters.											
• The roads bordering the land plot must be not less than 8 meters width in the cities and 10 meters in the suburban areas.											
• The land plot width must be not less than 10 meters and the depth of the land plot must not exceed the double of its width.											
• The project must specify the included housing types within the project such as (high rise buildings, medium height buildings, villas) and the project may include all of these types or some of them.											
• In case of projects that need an internal road network, public facilities and infrastructure, the project must allocate third of the area of the project for roads, open spaces and public parks, while considering the following:											
o The area allocated for roads must not be less than 20% of the total land area of the project and cannot exceed third of the of the total land area.											
o The streets design and car parking should be in line with the level of the project land.											
o The open spaces and public parks should consider the actual needs depending on the strategic comprehensive master plan of the city.											
Article 69											
It is possible to exempt some areas, buildings, and projects from some regulations. This exemption is to be decided upon request form the developers and is to be permitted by the responsible governmental bodies.											
Article 126											
The environmental influences should be considered in the design and construction. Such as (climate conditions, solar radiation, land nature, noise level and environmental pollutants). The appropriate arrangements and programs for collecting, categorize and store wastes must be considered.											

Specific regulations have been set by NUCA for Al Rehab project	Energy Efficient design principles for										
	General characteristics				Buildings morphology			Ambient temperature Mitigation			
	Site selection	Compactness and Density	Diversity and Attractiveness	Circulation Network	Heights and S/V ratio	Building Forms	Housing Types	Streets Orientation	External shading	and Urban Trees	Cool surfaces and Albedo
For apartments buildings:											
• The maximum height of the buildings is six stories.											
• The apartments' buildings are to be constructed on 30 percent of their allocated land and the rest is to for open spaces and pedestrian paths.											
For the land subdivision / villas											
• Every land plot is to be considered as one unit and cannot be divided into two lands.											
• The fences for each land plot should not be more than 2.5 meters and not less than 1.80 meters in the shared border of the plot. The façade / front border is to be defined by trees or flower box that are not more than 80 centimetres height.											
• In case of merging two land plots in order to fold the area, they will be considered as one land plot.											
• The maximum height is two stories or 10 meters with expectation for the stairs towers, elevators rooms and storages.											
• The maximum built up area is 40 percent of the total land area.											
• The setbacks areas are considered as a part of the land plot and it is not permitted to be built: o From front 4 meters o From back 4 meters o From two sides 3 meters											

Example for residential districts regulations Set by NUCA

Housing	Built up area %	Setbacks			Built up area %	Heights meters
		Back	Side	Front		
Medium / economic	50	3	3	4	50	8 -16
Above average	45	3	3	4	45	
Luxurious	40	3	3	4	40	

Examples for public facilities regulations

Landuse / Facility	Built up area %	Heights	Setbacks		
Educational	30	4 stories	6	6	6
Health	30	4 stories	5	5	6
Youth centres / clubs	10	2 stories	6	6	6
Social clubs	20	2 stories	6	6	6

Commercial	40	4 stories	4	4	5											
Administrative	40	4 stories	5	5	6											
Religious	40	2 stories	6	6	6											
Cultural	30	2 stories	5	5	6											
Social	40	2 stories	5	5	6											
Open spaces and public parks	2	1 stories														
Business buildings	30	5 stories	5	5	6											

Table 17 Comparison between urban planning regulations and energy efficiency urban configurations principles
Source: (Jurispedia, 2008) (NUCA, n.d.), Translated by the author

ملخص

تعتبر ندرة مصادر الطاقة في مصر واحدة من أهم تحديات التنمية العمرانية. ونظرا للطلب المتزايد على الإسكان فإن هناك العديد من المشروعات السكنية التي يتم إنشاؤها وتحديدا حول القاهرة. بالإضافة إلى ان المباني تستهلك جزء كبير من الطاقة أثناء عمليات التشييد والتشغيل. لذلك فمن الضروري العمل من أجل بيئة مبنية ذات كفاءة أفضل في استغلال الطاقة. بينما تتعد المنهجيات والطرق التي تستهدف تحقيق كفاءة أعلى في استغلال الطاقة، يركز هذا البحث على الدور الرئيسي للتصميم العمراني في الحفاظ على الطاقة.

من دراسة الأدبيات والدراسات السابقة يستنتج البحث أثني عشر مبدءا تصميميا يؤثرون بشكل مباشر في تكوين التشكيلات العمرانية ذات الكفاءة في استغلال الطاقة. تلك المبادئ التصميمية تم استنتاجها من خلال مصادر مختلفة مثل المبادئ التصميمية للتجمعات الصديقة للبيئة و معايير التصميم العمراني البيئي وكذلك تم استنتاج بعد المبادئ التصميمية من التشكيلات العمرانية في المدينة العربية القديمة.

المبادئ التصميمية المستنتجة تم استخدامها لتقييم ومناقشة التشكيلات العمرانية لمشروعين من المشروعات السكنية في القاهرة الكبرى. من خلال تحليل حالات الدراسة يوضح البحث أهم أوجه القصور المتعلقة بكفاءة الطاقة في التشكيلات العمرانية للممارسات التصميمية الحالية في القاهرة. كذلك حاول البحث لفت الانتباه للاشتراطات العمرانية الحالية. توضح نتائج البحث أن تصميم حالات الدراسة المختارة لا يتفق ومعظم المبادئ التصميمية التي تحقق كفاءة استهلاك الطاقة وهو ما يؤدي إلى استهلاك وفقد الطاقة بشكل كبير. وهو ما يؤكد ضرورة تطوير الممارسات التصميمية الحالية وكذلك أهمية تحديث الاشتراطات العمرانية الحالية من أجل الوصول لتشكيلات عمرانية أكثر كفاءة في استغلال الطاقة.

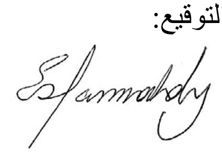
إقرار

هذه الرسالة مقدمة في جامعة عين شمس وجامعة شتوتجارت للحصول على درجة العمران المتكامل والتصميم المستدام. إن العمل الذي تحويه هذه الرسالة قد تم إنجازه بمعرفة الباحث سنة 2013.

هذا ويقر الباحث أن العمل المقدم هو خلاصة بحثه الشخصي وأنه قد اتبع الإسلوب العلمي السليم في الإشارة إلى المواد المأخوذة من المراجع العلمية كلٌ في مكانه في مختلف أجزاء الرسالة..

وهذا إقرار مني بذلك،،،

التوقيع:



الباحث: اسلام محمد مهدي يوسف

التاريخ:31/07/2013

التشكيلات العمرانية وكفاءة استخدام الطاقة في المشروعات السكنية بالقاهرة

مقدمة للحصول على درجة الماجستير في العمران المتكامل والتصميم المستدام

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تاريخ المناقشة:..............

الدراسات العليا

ختم الإجازة

أجيزت الرسالة بتاريخ:.............

موافقة مجلس الكلية .../.../...

موافقة مجلس الجامعة .../.../...

جامعة عين شـــــمس

جامعة شتوتجارت

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(2013)