

QATAR UNIVERSITY  
COLLEGE OF ENGINEERING

NET ZERO ENERGY DISTRICT NZED: A STRATEGY TOWARDS  
ACHIEVING SUSTAINABLE URBAN DEVELOPMENT IN QATAR

BY  
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## **ABSTRACT**

In the twenty first century, there are increasing pressures on energy resources, therefore; various nations are competing to lay hands on all possible fossil fuel resources. Unfortunately, these resources are endangered to run out in the near future, which depends on the manner and rate energy is being consumed. Years ago, concerned countries started looking for alternatives and for technologies to secure their future energy needs (UN HABITAT, 2004). This lead to emergences of a different nature, such as that for saving buildings, eco districts, and energy for smart projects, etc.

One of such concepts is The Net Zero Energy Districts (NZED). This new concept means that such districts are consuming enough energy equal to the amount of energy they actually produce. Added to that, these NZEDs do actually produce clean free-emission energy enough to satisfy all the energy demands of their own.

The study in hand investigates the history of NZED as a new trend, in addition to tackling definitions based on previous work of other researchers. Consequently, the study presents a method of assessment to identify Net Zero Energy Districts. This highlights the most acknowledged renewable energy systems and strategies of energy efficiency. Following, the study discusses three case studies of NZED, both on the international, regional and local domains.

Finally, the study concludes by providing recommendations of the ability to push the country toward utilizing more energy efficient projects, in addition to listing the main obstacles that prevent Net Zero Energy projects from being easily implemented in Qatar.

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## INTRODUCTION

Qatar is witnessing a revolution in gas and oil production and is becoming one of the most important global energy suppliers in the world. Unfortunately, this type of development brings about serious environmental problems. Qatar energy companies are engaged in extracting the nonrenewable resources which are likely to cause severe environmental issues that would negatively affect next generations. These resources are expected to place in jeopardy the rights of young people to enjoy the benefits of the country's gains in the energy field.

The ordinary ways of obtaining petro-chemical energy through unsustainable activities result in massive carbon emissions causing the most harmful kind of pollution. According to Kaufman, 2011, the footprint average needed by the people to cover their consumption in Qatar is five times higher than anywhere else. Thus these emissions place Qatar among the highest pollutants in the world. (Kaufman, 2011).

It is a true assumption that cities constitute the biggest consumers of energy resources at large. (European Institute for Energy Research EIER, 2011). It is therefore, the duty of considerate city authorities to play the expected major role in helping the society to switch to green life styles. Henceforth, city authorities are entitled to engage directly in developing energy-friendly planning policies aiming to reduce harmful wastage of existing energy resources. This is achievable through strict and immediate implementation of various options and alternatives that are readily available at this time in history.

Within the framework of solving such fundamental energy problems, renewable energy resources have been revealed as clean endless alternatives. Using these resources in a conscious way should produce "net zero energy projects" where consumed amount of energy equals the produced amount without harmful emissions or residues. This dissertation investigates Net Zero Energy Districts NZED, being a new concept originated as a good alternative to conserve the energy resources and to

consequently become environment friendly. NZED researchers are studying the possibility of achieving the goals of this concept at the neighborhood scale, including buildings, public realm, infrastructure, car parking, green areas, and more. This study will review the net zero energy concept and systems, followed by two case studies; one international and the other from Gulf countries.

In the same context, this research will investigate the net zero energy districts validation in Qatar due to the specificity of Qatar environment, climate, and urban fabric. Finally, the research will present a local case study to address the main obstacles against NZED in Qatar and recommendations towards achieving sustainable urban developments in Qatar.

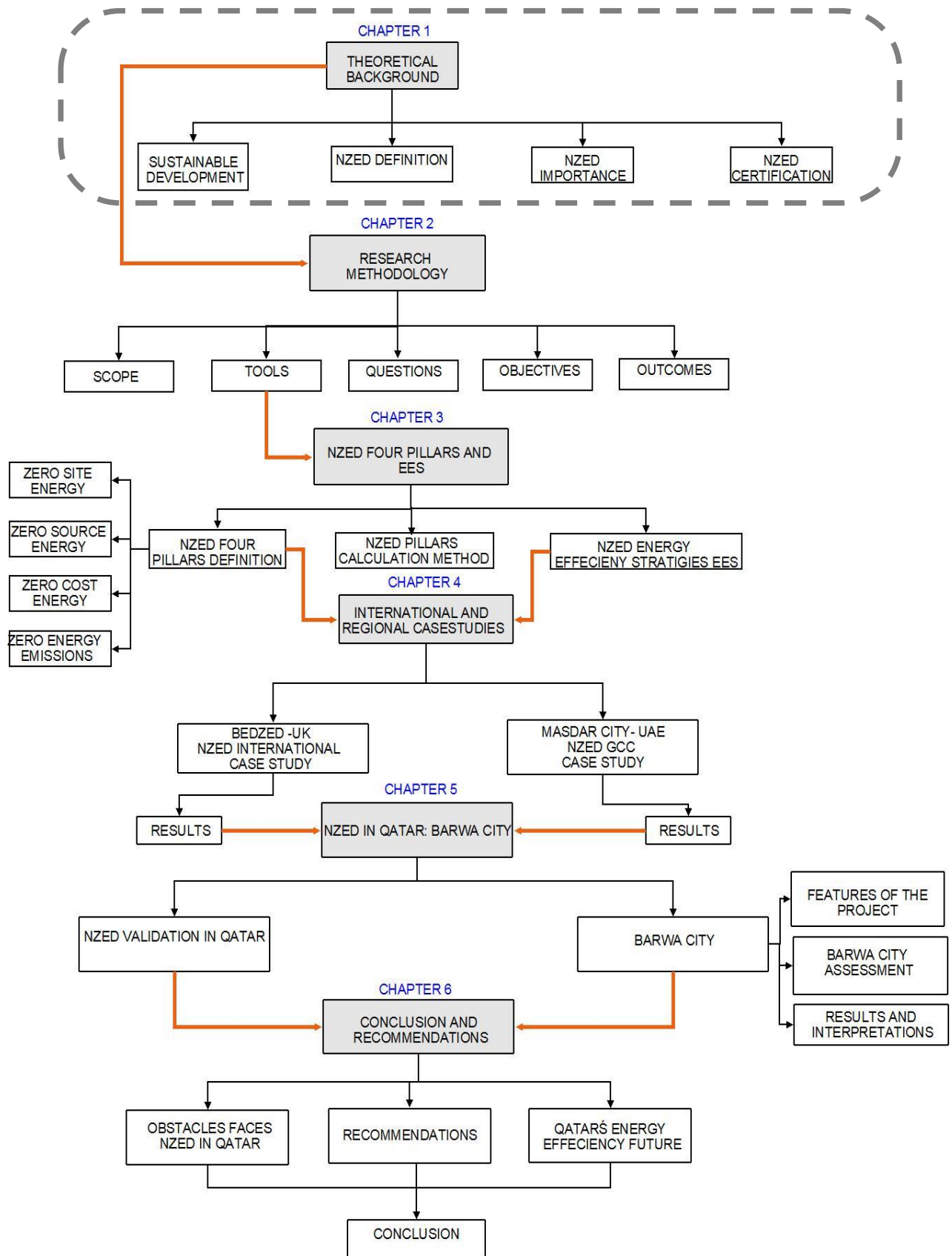


Figure 1: Flowchart of Research Phases – Chapter 1

# Chapter 1. Theoretical Background: Approach to Net Zero Energy District–NZED

This chapter reviews previous work in the field to investigate the main concept of a Net Zero Energy District (NZED). The chapter starts with the definition of sustainable development showing that sustainable environment is one of its three components. Furthermore, this chapter defines the Net Zero Energy District and presents its four Parameters. Finally, the chapter summarizes the importance of NZEDs and available certification methods to conclude the main features of it.

## 1.1 Sustainable Development

The most common definition of sustainable development is the development that meets the needs of the present without ignoring the rights of future generations to meet their own needs (WCED, 1987). Building on the traits of the previous definition of “sustainable development”, it provides, therefore, an understanding of the concept of an NZED and its applications. However, it is still of importance to trace the history of this concept.

While Rosalyn McKeown is known to be the founder of Education for Sustainable Development (ESD), Toolkit elaborated when stating that sustainable development has three components:

Environment, Society and Economy and that each one of them needs to be addressed cautiously to the edge of satisfaction (see Figure 2).

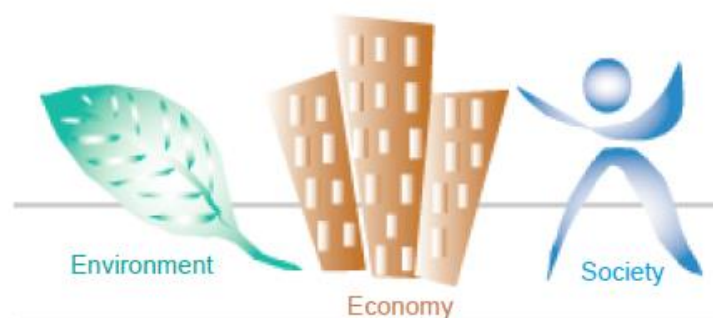


Figure 2: Three Components of Sustainable Development (McKeown, 2002)

For others, sustainable development in simple words is all our needs for our survival and well-being (Busby, 2012).

While sustainable development, for some, denotes saving the present status of environmental, social and economic aspects, future-oriented management advocates take it to mean that recent generations are held responsible to take into account the interests and the well-being of future children and grandchildren on ecological, social, and economic domains—bearing in mind that any one of the three domains cannot possibly be achieved away from others (RNE, 2005).

Consequently, sustainable development is in the interest of current generations through conserving human, natural and financial resources to satisfy their current needs, while saving needed resources for future generations as well. According to the Institute for Sustainable Communities (ISC, 2014), sustainable development seeks the satisfaction of the basic human needs of clean air, water, nutrition, and it also cares about protecting the ecosystem, as well as unrenowable resources.

It is noted that all previous points relate to energy, one way or another. Using clean renewable energy improves the quality of clean air and water, while it reflects positively on local and regional ecosystems and biological diversity at the same time. Recycling waste is yet another aspect of conserving clean sources of renewable energy, and henceforth, it cannot be ignored.

One outstanding question regarding its importance and validity pops up. In other words, why should modern communities take it seriously at all and what happens in case they do not. The simple answer comes in Roy Dudgeon's words "*because non-sustainable societies do not have the ability to exist*" (Dudgeon, 2012).

It is being established that sustainable development is directly connected to resource management, especially from the realm of energy resources, which constitutes the cornerstone of this research.

Since this research is concerned with an energy context, the terms Energy and Power will be constantly mentioned and reviewed. It is therefore worth noting that they are not meant to be synonyms. Rather, they are to be considered as two different concepts. To make the question

simpler, we look at “work” as a force needed to displace an object over a distance, while energy is the ability to do work, but power is to work over a specific period of time. Another term of constant occurrence in the thesis is primary energy source. Robert Evans (2007), a professor at Cambridge University, argues that all types of energy in use originate from primary energy sources. He states that all used energy types in our lives comes from one of three resources; fossil fuel, nuclear energy and renewable energy (Evans, 2007). He further explains that the energy in daily use is passed through many processes before reaching us, such as generating, storing, delivering.... etc.

More accurately, the worst-case scenario is a total dependence on fossil fuel sources until extinction. The world would then need to generate enough nuclear and renewable energy to cover all the world’s energy consumption needs, and this supposition seems nearly impossible. According to the United States Energy Information Administration (EIA), in 2006 86% of the United States’ total energy consumption was extracted from fossil fuel (Busby, 2012).

Figure 3 shows the U.S. primary energy consumption estimates by source, during the period of 1950–2011.

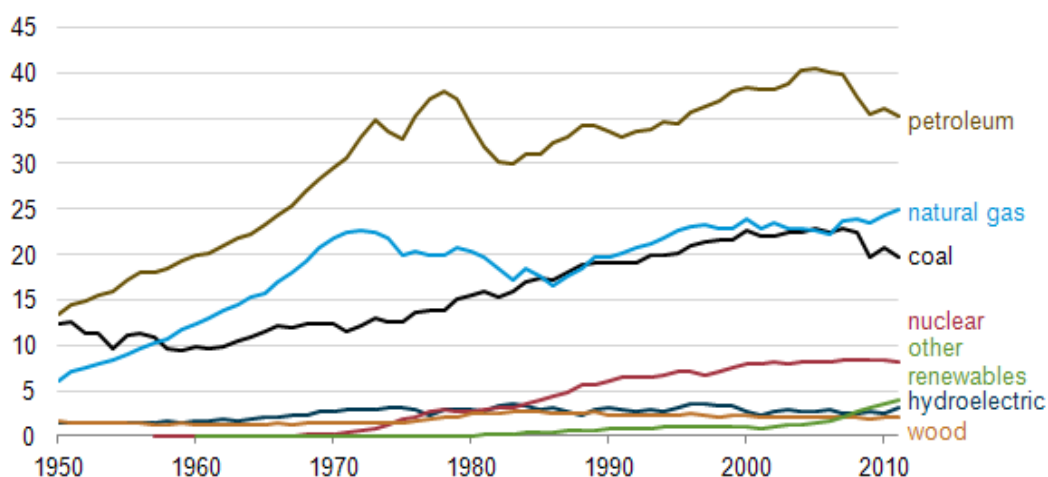


Figure 3: U.S. Annual Energy Review, by U.S. Energy Information Administration (EIA) (Btu, 2012)

It shows how the country relies on petroleum, natural gas and coal; again, showing the renewable energy as the lowest line in the graph as its total usage is almost non-existent.

Dalvin Lane, the head of Energy 360 at British Gas, once said, “*The cheapest kilowatt of energy is the one you don’t use*” (Lane, 2012). In fact, this definition forms the basic rule of reducing energy consumption and finding alternative energy sources.

Energy consumption has a serious effect on the world’s economy, including that of Qatar. It is worth mentioning here that the two biggest sectors of energy consumption are transportation and HVAC systems.

Governments around the world, including the Qatari government, should care about their countries’ natural resources. They should focus on the major energy drains like transportation, heating and cooling. This would surely help reduce energy consumption and would strengthen the economy by relieving dependency on oil and fossil fuels. Not just that, rather, it could perhaps stop using them entirely and make the place a Net Zero Energy District.

## **1.2 Net Zero Energy Districts (NZED)**

It is factual that energy consumption around the world is increasing by the day and at a very alarming rate, driven by strong economic growth and expanding populations. In fact, over 60% of global energy demand is consumed in cities. Moreover, the urban population is expected to continue increasing rapidly due to growing urbanization in emerging economies and developing countries, putting cities at the center of the sustainable energy challenge (Hoeven, 2012).

It seems certain that cities are playing a very important role in turning to sustainable energy, especially if city planners are becoming more and more knowledgeable on how to create new prevention regulations. Those regulations could help to insure reducing energy consumption and increasing the capacity of sustainable generated energy.

Increasing concerns about energy and energy consumption create many energy conservation trends (Kiely, 2010). A Net Zero Energy District is one of the conservation solutions and is just one example of sustainable development. The term “Net Zero Energy” is still a new concept, growing

prevalent during the last few years. This section will discuss its importance by definition along with some related green certification systems and sustainability assessment models.

### **1.2.1 NZED Concept and Definitions**

The NZED definition is originated from the Net Zero Energy Building definition, which is an important component of the district. The term Net Zero Energy Building (NZEB) is more popular and more in use compared to NZED. Some organizations defined an NZEB and created a certification system for it. The New Buildings Institute (NBI) (nonprofit organization in USA working to improve the energy performance of new buildings) states that a Net Zero Energy Building is a building with greatly reduced energy demand that allows the energy demand to be balanced by an equivalent generation of electricity from renewable sources (Cortese & Higgins, 2014).

In the same context, the idea of Net Zero Energy Districts is essentially the same as an NZEB only it applies to a cluster of buildings. According to an NBI 2014 status update, a Net Zero Energy District (NZED) is a group of buildings such as a city district, community or campus with a stated goal of achieving net zero energy (Cortese & Higgins, 2014). The district definition for this research is a mixed-use cluster of buildings including their surrounding environment of landscape, roads, services, *masjids*.... etc.

Nancy Carlisle in *The Definition of a Zero Net Energy Community* states that a Net Zero Energy Community is the community with reduced energy needs by increasing energy efficiency; these needs are covered by renewable energy (Carlisle, Geet, & Pless, 2009).

It is generally agreed that the high performance building is meaningless to a whole community that is wasting energy and relying on fossil fuel. Consequently, planners start to look at the larger image in a Net Zero Energy District, knowing that the individual building is not affecting the amount of energy consumption that much, if the whole community is not an energy saving one (Malin, 2010).



To achieve better results in energy saving, the designers have to deal with the integrated system of the community and not strictly address solving individual energy problems (Carlisle, Geet, & Pless, 2009).

A definition for a zero-energy district (NZED) is different and more complicated than that of a zero-energy building (ZEB) because given districts use energy not only for individual buildings but also for district-scale services like industry, transportation and infrastructure (Carlisle, Geet, & Pless, 2009).

The research in hand uses the available definitions of Net Zero Energy Buildings and expands its meaning to include district buildings and all related services as well.

On the other hand, to define a Net Zero Energy District, the suggested definition should abide by at least one of the following five concepts (see Figure 3), which are adapted from (Laustsen, 2008).

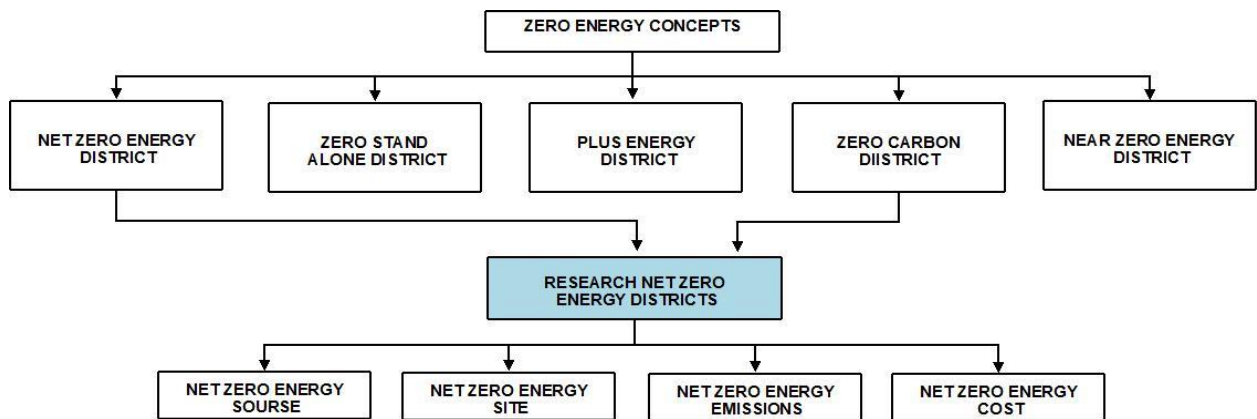


Figure 4: Zero Energy District Concepts

- a. **Net Zero Energy Districts** are those that deliver as much energy to the supply grids as they use from the grids. These districts do not need any fossil fuel for heating, cooling, lighting or any other energy usage, as they are connected to the national grid for backup and energy exchange.

- b. **Zero Stand Alone Districts** are districts that are not connected to the grid or only stand as backup. A stand-alone district can depend on itself to generate its only supply with energy and has the capacity to store energy in big batteries for night and for dark days.
- c. **Plus Energy District** is one that delivers more energy to the national grid than it uses over a year. This type of district produces more energy than it consumes.
- d. **Zero Carbon District** is the one that, over a year, does not use energy that entails carbon dioxide emissions. Over the year, this district is carbon neutral or positive in the term that it produces enough CO<sub>2</sub>-free energy to supply itself with the needed energy.
- e. **Near Zero Energy District** is a district that has a very high-energy performance but is not reaching the Net Zero energy point. The nearly zero district should be covered significantly by renewable energy use (Kurnitski, et al., 2011). Any NZED development may become near-ZED for some time during the year depending on weather, building conditions, infrastructure, operation complications, etc. For example, a well-operated NZED may become a near-ZED under circumstances like unusual weather that have above-average heating or cooling loads, with below average solar and wind resources. The NZED status should be measured, reviewed and audited yearly to test its stability. Figure 4 shows all Zero Energy Districts concepts mentioned in this thesis.

This research discusses the Net Zero Energy District (NZED), which is a combination of the first and fourth types, where it is energy neutral, and at the end of the year recording no CO<sub>2</sub> emissions since it uses CO<sub>2</sub>-free energy from renewable resources. (Renewable energy

resources are explained in greater detail in section 3.3.3). The energy performance of Net Zero Districts can be assessed in several ways.

### 1.2.2 NZED Four Parameters

Torcellini's definition of Net Zero Energy Buildings is being based on the four Parameters; this research, on the other hand, adapts them to the district scale and later uses those four Parameters as an assessment tool to evaluate NZEDs, these four Parameters are:

- 1- **Net Zero Site Energy:** Site Energy is defined by the amount of consumed and generated energy at a site, regardless of where or how that energy is sourced. In net zero site energy districts, the overall summation of the energy consumed in the district must equal zero, which means the district generates energy in the same amount of its consumption.
- 2- **Net Zero Source Energy:** Source Energy is defined by primary energy needed to extract and deliver energy to a site, including the lost energy or wasted energy in the process of generation, delivering and distribution. Metrics for net zero source energy districts account for these factors. A source zero energy district produces at least as much energy as it uses in a year.
- 3- **Net Zero Energy Cost:** Net Zero Energy Cost is the simplest metric to use. It means that the whole district has a total energy bill of \$0 after one-year cycle.
- 4- **Net Zero Energy Emissions:** Net Zero Energy Emissions District is the district that uses no energy that results in emissions or offsets any emissions by exporting emissions-free energy; this exported emission-free energy should be at least equal to the consumed energy.

It is worth mentioning that Torcellini and Pless also created another NZE classification system, consisting of categories A, B, C, and D, based on the renewable sources a building uses. While A is the building that generates all its required energy by renewable energy systems and D is the building

that failed to generate renewable energy, this classification scale is applicable for community-scale developments as well as individual buildings (Torcellini & Pless, 2010).

This research aims to create an identification method to identify an NZED, which is the district that has achieved at least one of the four Parameters as well as having the most efficiency strategies.

If the district failed to achieve any of the four Parameters for any reason, even after applying most of the energy efficiency strategies and using renewable energy, it has to produce 75% or more of its required energy to be considered a Near Zero Energy District (near zero energy district discussed in section 1.2.1). On the other hand, in some rare cases, the district may produce more energy than it needs and export this surplus energy to the national grid; in this case, the district will consider a Plus Energy District.

### **2.2.2 Importance of a Net Zero Energy District-NZED**

The investigation of a definition for and concepts of NZED led to an investigation of some important reasons for why communities should turn to NZED on all scales: internationally, regionally and locally.

#### ***a. Reasons for choosing the district scale***

There are many reasons that make “district” scale zero energy projects more worthwhile and efficient to implement than “building” scale zero energy projects. These reasons include and are not limited to the following points:

- Low-rise net zero energy building is preferred where the rooftop area is divided based on the number of floors to install a propitiate number of solar panels, but that type of building—if considered without the surrounding environment—with other similar buildings could compose a sprawl, which is an unwanted urban development shape.

- To provide energy efficiency techniques and new plants for renewable energy systems—including suitable infrastructure and materials—the project has to be large enough to deserve money and work spent, also to run supplied services properly.
- Some renewable energy systems like combined heat and power systems are more reliable in larger sizes (will be discussed in the first case study later).
- Net Zero Energy Districts can apply many services and techniques that cannot be available in the individual building like wastewater recycling, rain water harvesting, district cooling and heating, low impact transportation alternatives, local food production...etc.
- Individual buildings may have site constraints and planning grid requirements that prevent orienting the building to benefit in passive design from using solar and wind directions.
- The initial cost of Net Zero Energy Building seems to be high and cannot be afforded by individual investors, while governments can fund bigger projects like Net Zero Energy Districts if they are seeking sustainability.

For all the above reasons it seems more efficient to work on a community scale while thinking about converting to Net Zero Energy (Malin, 2010).

Developing community-scale Net Zero Energy projects also has disadvantages; some of these disadvantages are related to ownership and financing; especially, if there are more than one owner for the project, which realizes difficulties in having just one decision about implementing a net zero project. Another difficulty is that a Net Zero Energy District needs a special infrastructure, which seems hard sometimes to connect with the original existing networks that serve the whole city.

Another obstacle is phasing. Most of the district-scale projects are developed and operated in phases, which make it harder to invest a big amount of money in infrastructure—like district cooling—that

may not be in use until the next phase is finished. Some of these systems need to be tested and operated at first to be sure that it is working, and this is not possible in phase projects.

As shown later in the BedZED case study (in section 4.1), the combined heat and power system for generating renewable energy never worked as planned and was replaced by gas boilers after some difficult years for tenants.

Every net zero energy project depends basically on the full participation of its occupants to be successful, getting the agreement and participation from the tenants of one building is much easier than convincing a district's residents on the need for a net zero energy policy. This can happen only by continuous efforts in spreading awareness among people about energy saving.

Nevertheless, the advantages of thinking of net zero energy policies on the district scale are much greater than the disadvantages that support the idea of transforming to an NZED instead of an NZEB.

#### ***b. NZED international significance***

Just like any other retrofit project, net zero projects will have budget restrictions that owners prefer not to exceed. An NZED's initial costs may be higher, but there are many values added to the project beyond the initial cost such as:

- Improved individual occupant satisfaction, health and productivity. NZE projects maintain the quality of urban life by providing a clean environment and everlasting energy for daily use.
- Savings in buildings' operation costs resulted from energy and water supplied, which are maintained and insured by using better technologies that improve the efficiency of energy and water use.
- Energy is not relying totally on the national networks, which provide energy security; especially, in under-developing countries where the energy resources are not constant.
- Improved reputation and leadership of occupant enterprises.

- Move the local markets toward green buildings, demand and push investors toward applying green techniques in their developments.

These motivating factors are known as the *Value Beyond Energy Cost Savings* (VBECS) (Carmichael & Managan, 2013).

Recently, compared with conventional buildings, green buildings in the USA are found to have a higher rental value by up to 17% and higher sale value by up to 35%. That is in addition to the healthy environment advantages gained from better ventilation, lighting and clean energy and water. These benefits have been demonstrated by resident productivity and satisfaction (Carmichael & Managan, 2013).

At the global scale, Net Zero Energy projects enhance energy security and provide a sustainable clean energy resource. Unrenewable resources will be conserved for use by the next generations when needed. In fact, the idea of NZE itself gradually creates great awareness among residents about energy consumption and reduction and how to increase energy efficiency by the use of different technologies. In NZEDs, residents know their right to a clean environment and become proud of their life and their efforts in saving the environment. Consequently, after implementing NZE projects, the national economy will gradually be affected positively. In addition, compared to Qatar, many other nations will be using a relatively high percentage of their economic resources purchasing unrenewable energy.

### *c. NZED significance in the Gulf region*

For many decades, the significant oil reserves of the Gulf region have rendered the region among the most important energy suppliers in the world. Similarly, the Gulf's massive natural gas reserves suggest a future role as a major regional and global supplier of gas, at least in principle. However, the rapidly increasing rates of regional oil and gas consumption is drawing the region's future energy forecasts—affecting the security of the Gulf Cooperation Council (GCC) and the world's energy

future. In fact, the Gulf is moving away from being primarily a supply center for global energy markets; their oil and gas production can barely cover their needs (El-Katiri, 2013).GCC countries' primary energy consumption rose by an average of 5% per year between 2001 and 2014, nearly doubling from slightly more than 200 million tons of oil equivalent to almost 380, evenly divided between oil and gas. By 2020, that figure will nearly double again, to 660 (see Figures 5 and 6).

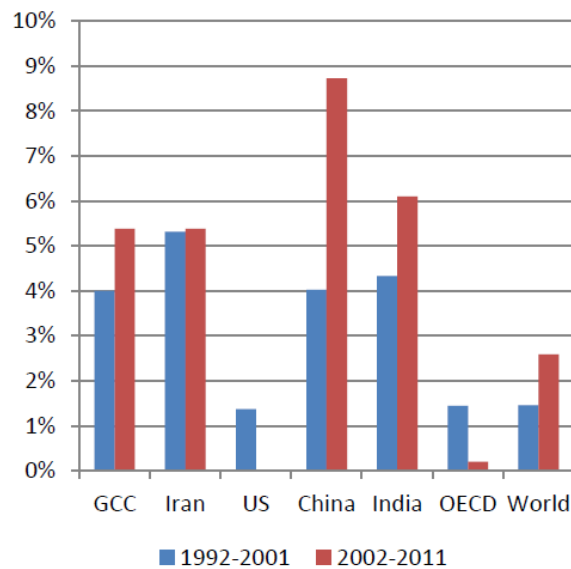


Figure 5: Worldwide Average Yearly Growth Primary Energy Consumption (Krane, 2013)

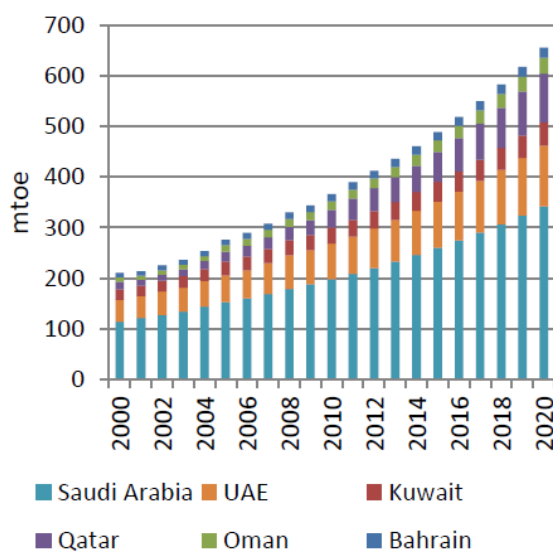


Figure 6: Gulf countries consumption per year between 2000 and 2020 (Krane, 2013)



Over the last decade, Gulf energy consumption grew twice as fast as the world average of 2.5% per year, but slower than that of China and India.

For previously mentioned reasons, some regional governments have begun looking for solutions to conserve their natural resources. This was the starting point of zero-energy projects in the Gulf area in general. However, the idea of Net Zero Energy Districts starts in the Gulf area as a branding for some cities like Abu Dhabi when it presented Masdar City as an NZED model.

Gradually, the Abu Dhabi municipality realized the benefits of such projects and the real demand for NZED projects. Starting in 2012, the Abu Dhabi and Dubai municipalities enacted new laws about using solar water-heating panels, efficient appliances and some renewable energy systems (see attached form in appendix A issued by the Dubai Municipality), and strict fines are given to punish those who do not abide by the new laws (Sahyoun, 2014).

#### *d. NZED significance in Qatar*

Qatar will become the first Middle Eastern and Arab country to host such an important mega-event as the FIFA World Cup 2022. The quest to host this event was driven by the strong desire of Qatar's government to become an internationally known country. Sustainable planning, clean and renewable resources, and predesigned legacies are conditions to be accepted as the host of the 2022 World Cup, and to become a global city. Hundreds of projects have recently been started to increase the capacity and quality of the city lifestyle to be ready to accommodate millions of people. These projects constitute a good opportunity to begin with green thinking and zero-energy projects.

Qatar National Vision 2030 seeks economic development as one of the four main Parameters of Qatar's long-term plan. The Ministry of Development Planning and Statistics defined the economic pillar by sustainable development and use of all national resources, including energy and water.

In fact, Qatar was recorded as one of the biggest consumers of energy worldwide (see figure 7), taking into account the energy used in oil extraction and production (The World Bank, 2014).

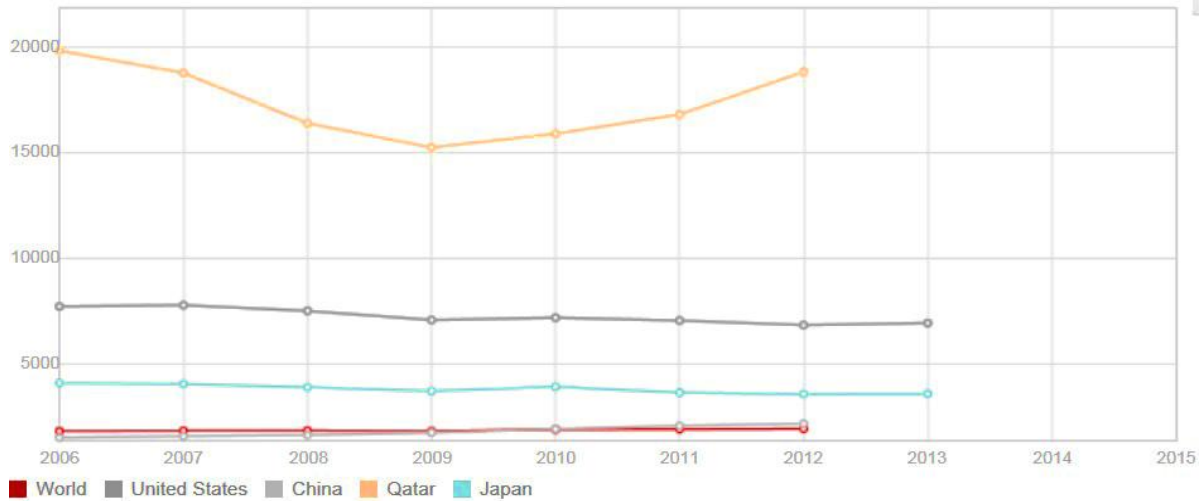


Figure 7: Energy Use by Kg of Oil Equivalent Per Capita in Global Industrial Countries Comparing with Qatar (The World Bank, 2015)

In 2011, Qatar was recorded as the country with the highest electric power consumption (average per capita consumption in kWh), which put the national resources under heavy pressure.

According to The World Bank statistics, Qatar’s electric power consumption was higher than USA and China (see Figures 8 and 9) (The World Bank, 2014).

All of the above reasons make Qatar a good testing location for NZED concepts and theories.

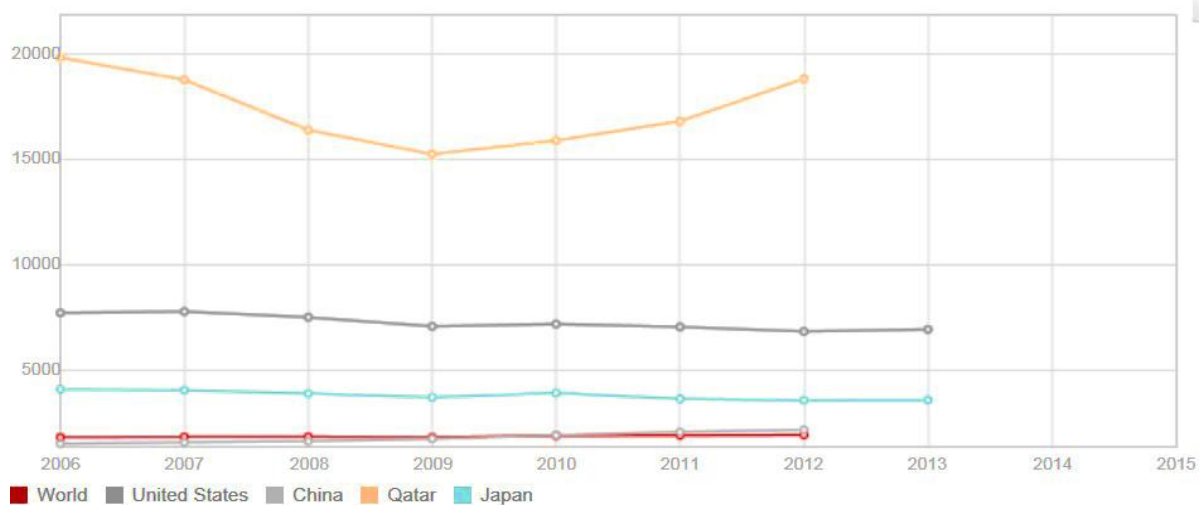


Figure 8: Energy Use by Kg of Oil Equivalent Per Capita in Global Industrial Countries Comparing with Qatar (The World Bank, 2015)

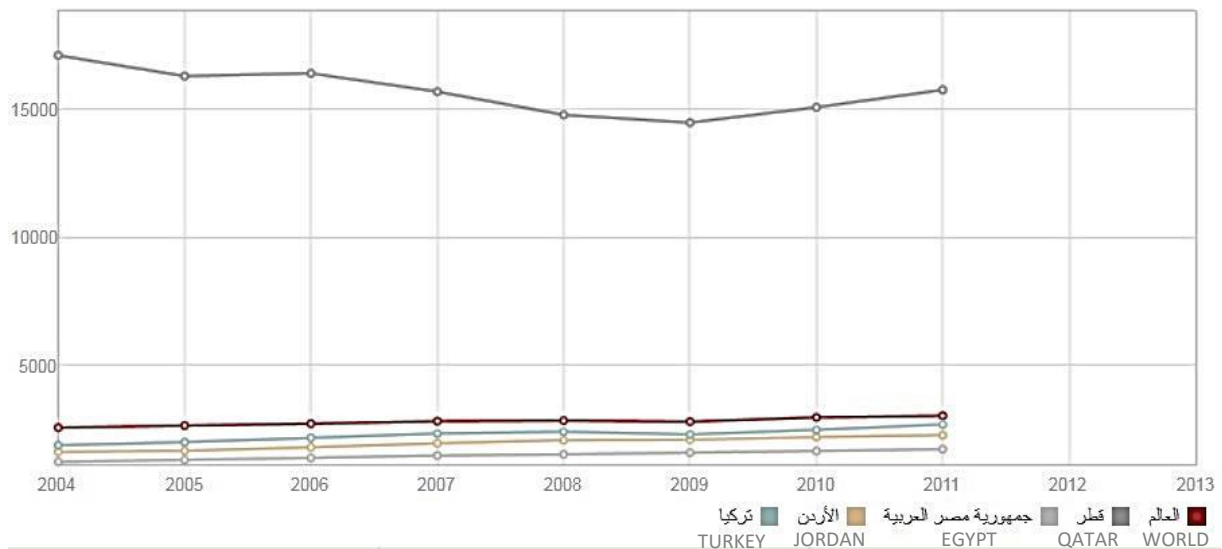


Figure 9: Electric Power Consumption Per Capita in Qatar and Regional Countries (The World Bank, 2014)

### 2.2.3 Net Zero Energy Certification

Net zero energy projects have become globally recommended practice for buildings, districts and campuses. Until now, the assessment of many developments is overstated; actual Net Zero Energy districts are still rare. Therefore, there is a real need for an evaluation system that tells the true value of these projects. This study listed four green certification systems that have district-scale certification, focusing on the energy significance in each of them.

#### *a. Living community challenge program*

International Living Future Institute (ILFI) is a hub for many visionary programs, certifications, advocacy tool and philosophy that defines the most advanced measure of sustainability possible today. One of ILFI organization programs called The Living Community Challenge, which is a new program at the institute that helps planners and developers to rethink how they design their community-scale projects, providing certification at both the master-planning stages as well as for fully built community- or campus-scale projects. Whether the project is a street, block, corridor, small or large neighborhood, or campus it has a reference in the Living Community Challenge (ILFI, 2014).

The Living Community Challenge program includes seven categories called Petals: Place, Water, Energy, Health and Happiness, Materials, Equity, and Beauty (see Figure 10).

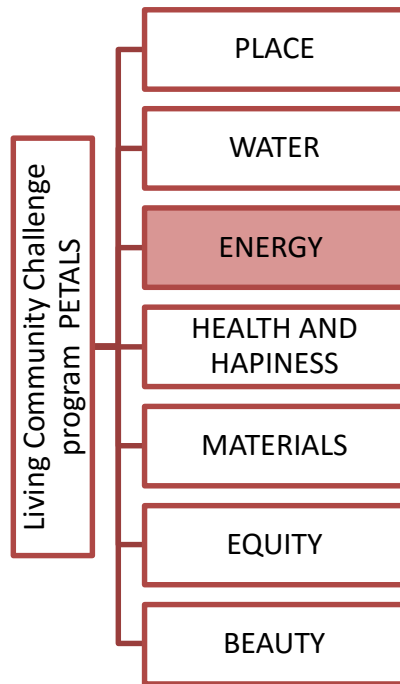


Figure 10: The Seven PETALS of Living Community Challenge Program

Petals are sectioned into twenty Imperatives. This compilation of Imperatives can be applied to almost every imaginable project, of any scale, in any location, even if it is a new or an existing structure.

Regarding Net Zero Energy, there is no specific certification tool for it at the community level, but the Living Community Challenge program is calling for “*Net Positive Energy projects*”, which states that 105% of the community’s energy needs must be supplied by community-generated renewable energy on a net annual basis, including all energy for water and waste.

In this system, use of combustion-based energy supply is not allowed. A community must provide local energy storage for resiliency (ILFI, 2014).

***b. Leadership in Energy & Environmental Design-LEED***

LEED for Neighborhood Development (LEED-ND) is designed to assess neighborhood sustainability and quality of urban life in order to create better, more sustainable, well-connected neighborhoods—as the LEED institution assumed in their official website (LEED, 2014).

The key strategies of the LEED-ND Rating System are organized into three basic sections (see Figure 11):

- Smart Location and Linkage (SLL)
- Neighborhood Pattern and Design (NPD)
- Green Infrastructure and Buildings (GIB)

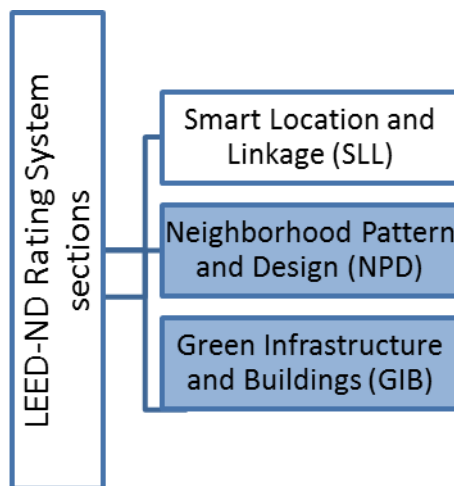


Figure 11: LEED-ND Rating System Sections

Green infrastructure and building (GIB) has six credits related to energy efficiency and energy production:

GIB Credit 1: Certified Green Building(s)

GIB Credit 2: Building Energy Efficiency

GIB Credit 10: Solar Orientation

GIB Credit 11: On-Site Renewable Energy Sources

GIB Credit 12: District Heating and Cooling

## GIB Credit 13: Infrastructure Energy Efficiency

These credits translated into points in the LEED-ND checklist, which is required to finalize the LEED certification process (see Table 1).

*Table 1: LEED ND Checklist Energy Sections (LEED, 2014)*

TOPIC	DOES THE PROJECT DO THE FOLLOWING?	YES	MAY BE	NO	LEED -ND POINTS POSSIBLE	LEED-ND SOURCE CREDIT OR PREREQUISITE
ENERGY EFFICIENCY AND CNSTRUCTION	Ninety percent of building square meets minimum energy efficiency requirements (minimum 10%improvement over ashrae90.1 (see rating system for details)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Required	Prereq2: Minimum Building energy efficiency
	Ninety percent of building square exceeds increasing threshold for energy efficiency (minimum 18% improvement over ASHRE 90.1(see rating system for details)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1-2	Credit 2: building energy efficiency.
	Orients 75% of buildings or dense blocks length wise along east-west axes (within 15 degrees) to maximize passive and active solar access.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	Credit 10: Solar Orientation
ENERGY PRODUCTION AND DISTRIBUTION	Generate renewable energy on-site, providing the following percentage of the projects annual electrical thermal and energy cost (pick just one for scoring) 5%, 12.5%, 20%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1 2 3	Credit 11: On-site renewable energy sources
	Provides at least 80% of building heating and cooling through a shared neighborhood wide system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	Credit 12: District Heating - cooling
	Provide energy efficient new neighborhood infrastructure such as traffic lights, street lights, water, wastewater pumps (15% minimum improvement over conventional model)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	Credit 13 infrastructure energy efficiency

On the other hand, under the LEED fourth version rating system, the “On-Site Renewable Energy” credit has been renamed “Renewable Energy Production”. There is also an added provision to account for solar gardens and community renewable energy systems in the overall percentage of

renewable energy production. The maximum number of LEED points that can be awarded for this credit has increased as well (Whitman, 2014).

In addition to the 34% of energy and atmosphere, the On-Site Renewable Energy credit was added to the sustainable sites category. This credit can provide up to seven possible LEED points. This could represent around 19% (see Figure 12) of the points required for certification, depending on which level of certification developers are seeking.

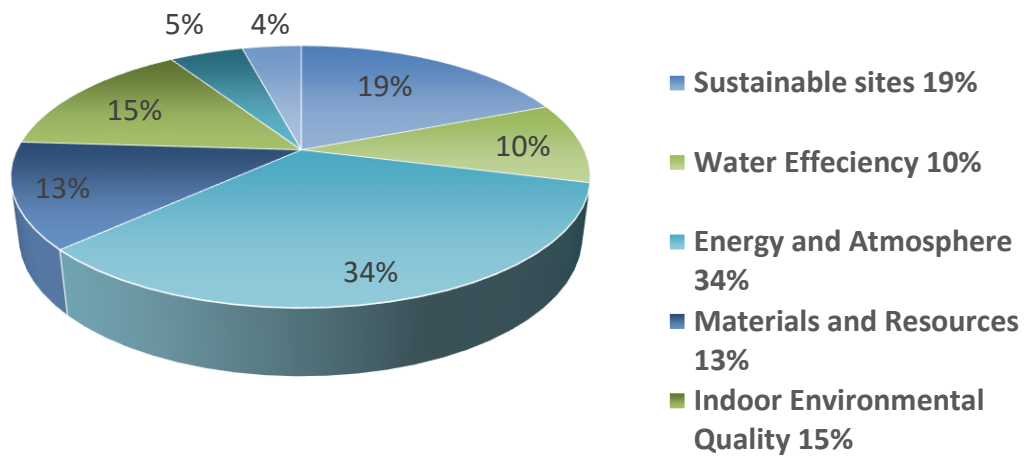


Figure 12: LEED Categories Percentage adapted from (U.S. Green Building Council, 2014)

In the LEED certification system, project performance is calculated by calculating energy produced by renewable systems; table 2 shows the number of points that can be achieved according to the percentage of used renewable energy (Whitman, 2014).

Table 2: Renewable Energy Points at LEED Certification System (Whitman, 2014)

Percentage of Renewable Energy	LEED Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

*c. Building Research Establishment Environmental Assessment Methodology- BREEAM*

BREEAM Communities is a guideline for assessing sustainable developments. BREEAM Communities starts with assessing the sustainability of a selected site for the development. Then, they assess the design in the planning stage, including all the sustainable decisions that have been taken for a project. BREEAM also assesses the sustainability at the construction stage, and then there are performance evaluations and audits for communities at the in-use and regeneration stages (BREEAM, 2012).

The BREEAM technical manual is grouped into five impact categories. The categories are listed below (see Figures 13) with a brief description of their aims (BREEAM, 2012).

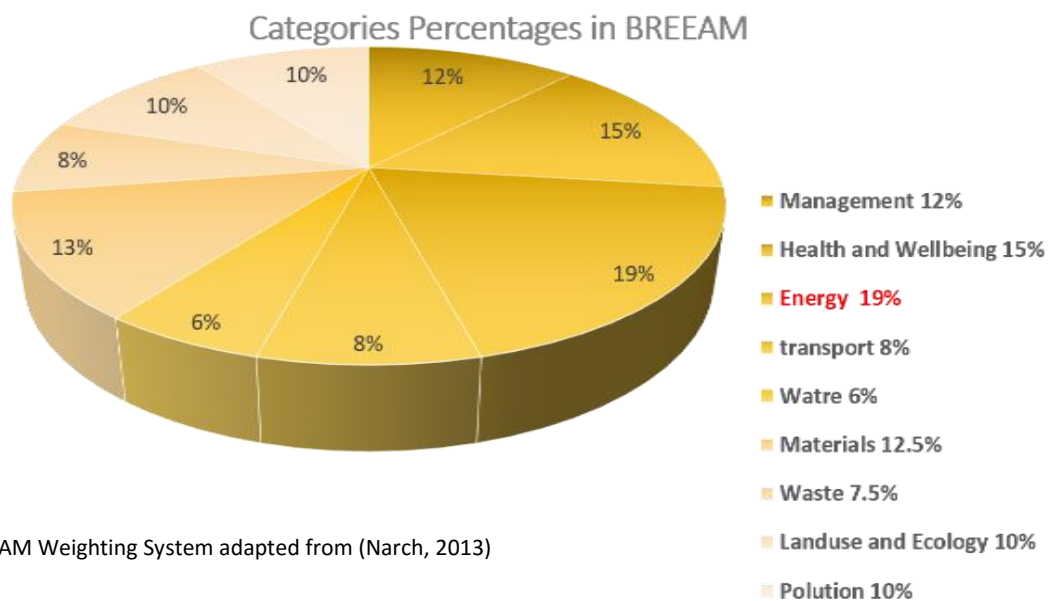


Figure 13: BREEAM Weighting System adapted from (Narch, 2013)

- Governance (GO): addresses society involvement in decision making related to the development design, construction and operation.
- Transport and movement (TM): addresses the sustainable planned transportation network including public transport and walkability and cycling encouragement.
- Social and economic well-being (SE): addresses the residents' satisfaction and their interaction with each other and with the space.



- Resources and energy (RE): assessing the sustainable use of natural resources or renewable resources without sacrificing the air and health quality.
- Land use and ecology (LE): assesses the development site and its footprint and ecological advantages and disadvantages of implementing the project.
- Innovation (Inn): recognizes and promotes the adoption of pioneering solutions that are used as solutions for the first time (see Figure 14).

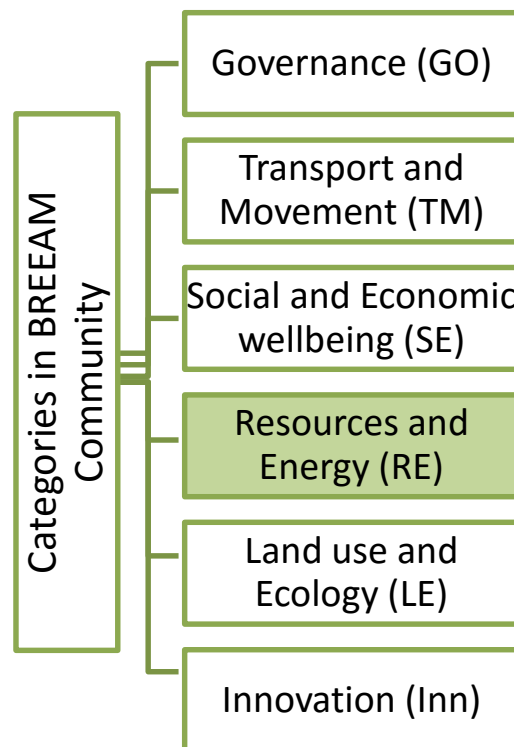


Figure 14: Categories in BREEAM Community System

There are extra credits given to renewable resources in BREEAM, especially if they mitigate CO<sub>2</sub> emissions; an additional 15 credits can be achieved when the assessed building or community applies energy efficiency strategies (BREEAM, 2012).

In the BREEAM assessment tool, two models have to be created, ideal mode and real mode. By comparing the measurements of the two models, the credits can be assessed and awarded (BREEAM, 2012).

*d. Global Sustainability Assessment System-GSAS*

The GSAS assessment tool produced by the Gulf Organization for Research and Development (GORD) states that energy in its system and toolkit consists of factors tested on buildings' energy demands, the efficiency of energy delivery and the use of un-renewable energy systems that harm the environment.

Since energy is 24% of the GSAS total assessment points for individual buildings (see Figure 15), the GSAS for Districts Toolkit 2014 version gave only 18% of total points for the energy, but on the other hand, it added many new components related to renewable energy and energy efficiency.

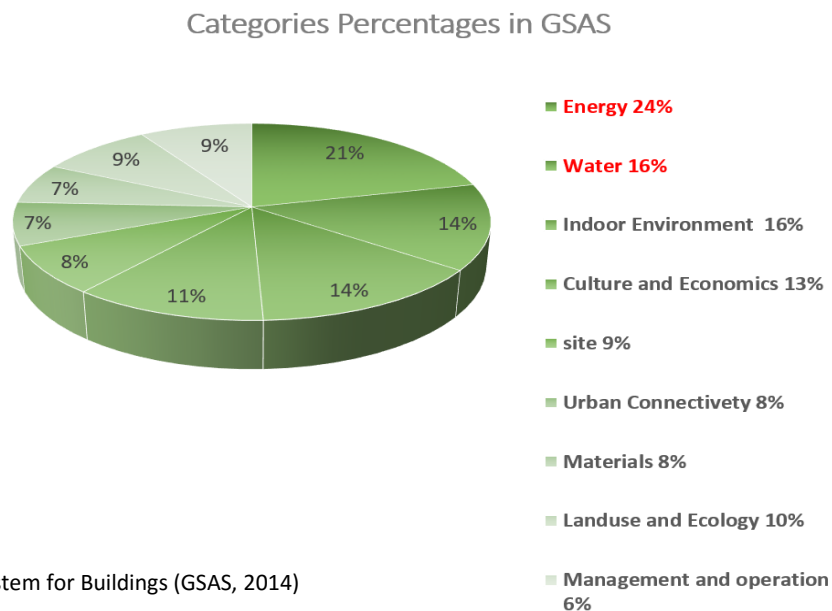


Figure 15: GSAS Weighting System for Buildings (GSAS, 2014)

The goal of GSAS/QSAS Districts is to assess the level of the environmental performance of neighborhoods. The criteria and measurements of GSAS focus on assessing the performance of buildings and the overall systems within the district and ensuring that the development follows a sustainable framework.

GSAS/QSAS Districts are designed to assess both new and existing developments. Any cluster of buildings can be assessed. There are no specific sizes for the intended districts (GORD, 2014).

In the toolkit, the four points related to energy performance in GSAS neighborhoods are weighted at 18% of the overall points (El-Sarraj, 2014) (see Table 3 below).

*Table 3: Four Criteria of Energy in GSAS Neighborhoods (El-Sarraj, 2014)*

E	ENERGY	SCORE	WEIGHT	POINT
		12	18%	0.540
E.2	Energy Delivery Performance	3	4.71%	0.141
E.3	Fossil Fuel Conservation	3	3.29%	0.099
E.4	CO2 Emissions	3	4.12%	0.124
E.5	NOx, Sox & Particulate Matter	3	5.88%	0.176

The first point is assessing the energy efficiency within the built area, while the second point is assessing the percentage of independence from fossil fuel and use of renewable energy, as mentioned in the sub-points later. Gas emissions are indicating the renewable energy systems' efficiency and the well-being of the people living in it. These four main points were divided into sub-points as follows (GORD, 2014):

- Water supply energy performance
- Wastewater treatment energy performance
- District cooling plant pump energy performance
- Irrigation energy performance
- Park lighting energy performance
- Traffic lighting energy performance
- Street lighting energy performance
- Other energy consuming components
- Overall infrastructure energy intensity for non-built area

- Percentage provided by district cooling plant to meet annual cooling demand
- Primary energy source from power plant: Electricity
- Renewable energy generation and renewables district-scale: Electricity percentage
- Total CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>x</sub> emissions
- Number of GSAS rated buildings within the district

The previous points cover most of the energy issues at the district scale. GSAS applied this rating system in many districts in Qatar like Barwa City (the case study for this study from Qatar), which obtained a one-star certificate.

### **1.3 Summary**

At the beginning of this chapter sustainable development was defined, which is closely linked to NZED in its three components: environment, economics and society. The first aim of establishing net zero energy projects is to save natural resources that maintain the environment and improve the economy since renewable energy is using free cost resources like sun and wind to produce energy and to offset used fossil fuel energy. Another aim is to reduce all kinds of pollution to provide a healthier environment and better well-being for the society. There are also many reasons to implement green projects on a district scale and not on an individual building scale; some of these reasons related to countries policies, cost, infrastructure...etc. On the other hand, there are some expected difficulties against implementing an NZED, like the challenge of having clear green decisions in the big scale projects, like districts; especially, if the green decision increased the initial cost of the project and if there is more than one owner. A Net Zero Energy district (NZED) in its ideal definition is a district that uses renewable energy to produce as much energy as it consumes. In most cases, districts can only achieve a certain percentage of renewable energy that covers some of the consumed energy and at the end of the year the total bill of the consumed energy is not zero.

In this case, the district is a near ZED and not an NZED. In some other rare cases, the district is exporting extra renewable energy to the national grid; this case is called a Plus Energy District.

Except in the Living Community Challenge system created by the International Living Future Institute, there is no particular assessment tool working as an NZED rating system, but most of the other rating systems like LEED, BREEAM, and GSAS are creating individual systems to assess projects at the neighborhood scale and give the biggest percentage of their earned points to energy performance, this can be considered as a good step toward NZED.

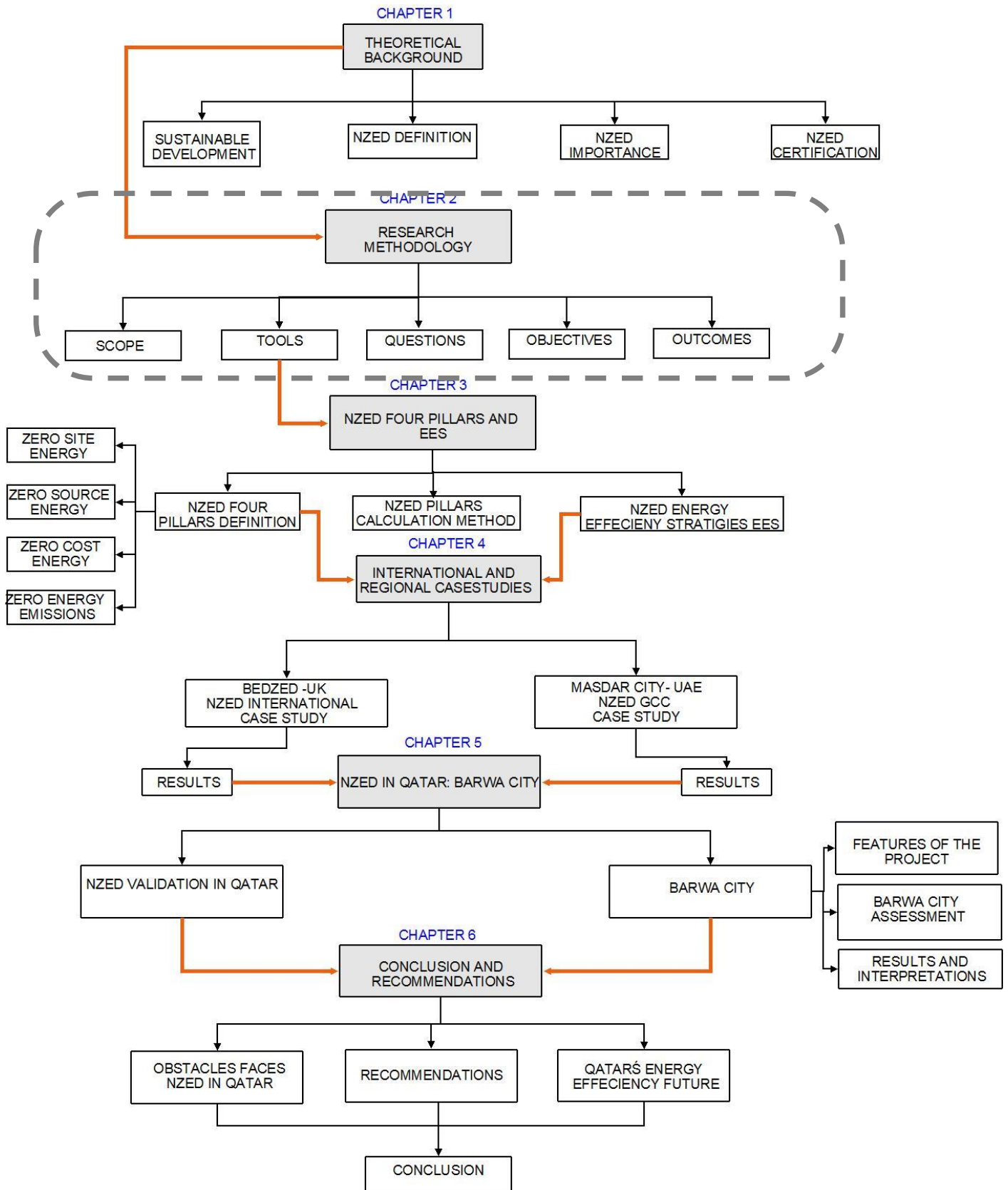


Figure 16: Flowchart of Research Phases – Chapter 2

## Chapter 2. Research Methodology

Research methodology is the process used to collect data and analyze it in order to achieve the research objectives and answer its main questions. This study starts with a literature review to define the problem and to review the previous work in the field related to NZED worldwide. After forming a clear view about the topic, the study objectives can be set, followed by defining tools used in the research to analyze the collected information. Three case studies and examples presented to clarify the application of the theory, followed by detailed analysis for each case study to come up with recommendations and results, as shown in figure 17 below.

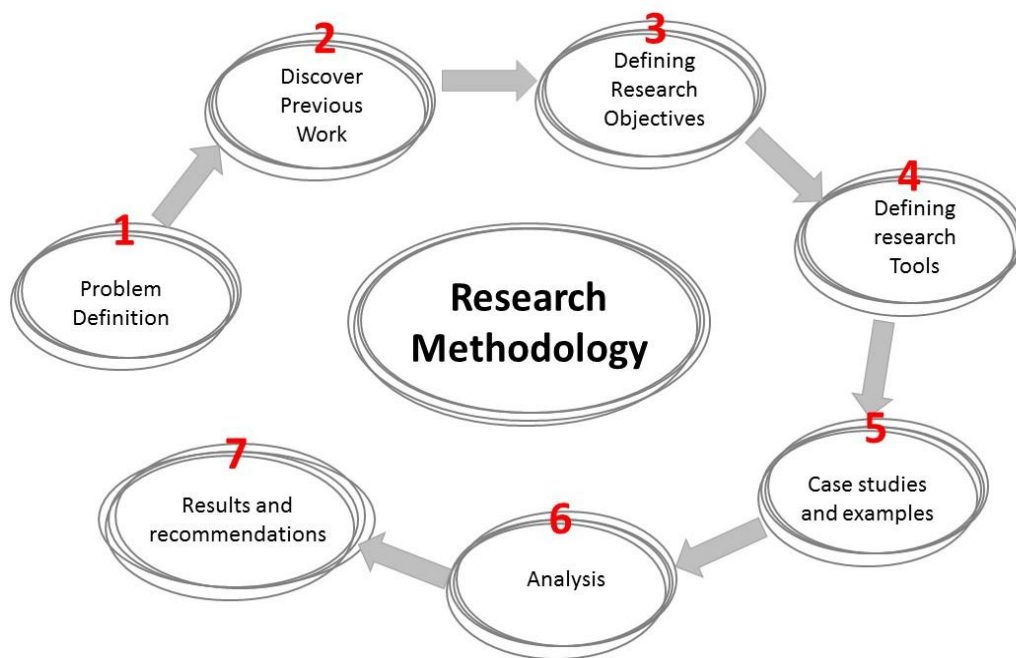


Figure 17: Research Methodology

### 2.1 Scope of Study

This study consists of six chapters. **Chapter 1** introduced the study's scope, tools, questions, objectives and outcomes. **Chapter 2** concludes the approach to Net Zero Energy Districts (NZED).

It defines sustainable development based on previous work in the field. In conjunction with the concept and definition of Net Zero Energy Districts, sustainable development is the umbrella that shades NZED.

Based on Torcellini's theories in net zero energy buildings, this thesis proposes an assessment method to identify NZEDs. This proposed method aims to identify NZED according to its energy consumption (which is known in this study by the four Parameters) and energy efficiency.

NZED is difficult to achieve in some projects; therefore, some districts can only reach some stages before the NZED stage, like Near Zero Energy District. Furthermore, this study discusses the importance of NZED at the international, regional and local level, followed by reviewing the relation between NZED and some green certification systems around the world, like LEED, GSAS and BREEAM.

**Chapter 3** focusses on the theoretical part of NZED represented by the four Parameters of a Net Zero Energy District. Achieving one at least of the four Parameters comprises the first step in the assessment method to Identify Net Zero Energy Districts. The first Indicator is the amount of consumed Site Energy regardless of how that energy originated. The second Indicator is consumed Source Energy, which defines primary energy consumed to produce and deliver energy to a site, including all the energy wasted in the generation process, transformation and distribution. The third Indicator is consumed Energy Costs, which is the simplest but least accurate Indicator. Zero Energy Cost means that the whole district has a total energy bill of \$0 (or any other used currency) over the course of a year. The fourth Indicator is produced Carbon Emissions, which is the most important Indicator according to many energy scientists. A zero energy emission project uses either no energy or free-emissions energy. To reach the NZED point, there are two lines that must parallel each other: the first line is reducing energy consumption by increasing energy efficiency; the second line is using renewable energy systems. These two parallel lines are the practical part of any NZED.



Another assessment method used in this study to identify NZEDs is using **Energy Efficiency Strategies (EES)**. Energy efficiency means using less energy to provide the same service.

Renewable energy systems are divided into On-site and Off-Site systems. This study reviews some of main, common renewable energy systems like PV solar panels, wind turbines, solar water heaters and others.

**Chapter 4** reviews two case studies: one international case study is Beddington Zero Energy Development (Bed ZED) at Beddington, UK, and the other is a regional case study located in Masdar City in Abu Dhabi, UAE. These two case studies will be assessed according to the four Parameters and EES to identify if they are NZEDs as branded or not.

**Chapter 5** defines Qatar energy status, then proceeds to a discussion on a local case study. In this context, this chapter will discuss the influence of stakeholders and the climate of Qatar on the opportunity of NZED projects. **Chapter 6** comes up with general recommendation aims to transform the case study and the similar projects from an energy consumer district to a Net Zero Energy District. In the same context, this chapter highlights the main obstacles against implementing NZEDs in Qatar and the future implementation of the energy efficiency in Qatar.

## 2.2 Research Tools

The study in hand applied various tools in the collection and analysis of data as shown in table 4 below:

*Table 4: Research Tools*

<b>Research Task</b>	<b>Implementation Tools</b>
Sustainable Development	Data collected from secondary resources like books, journals, websites and reports
NZED Definition	
NZED Importance	Data collected from secondary resources and primary resources like interviews with experts about NZED importance, then qualitative analysis was conducted.
NZED Certification	Data collected, literature review and interview with an expert about GSAS and its role in NZED certification
NZED 4 Parameters	Literature review includes qualitative analysis to identify main criteria of NZED
NZED 4 Parameters Calculations	Data collected from an interview with an expert on renewable energy systems (solar systems) and interview with an expert in energy modeling simulation programs, then quantitative analysis was conducted.
Energy Efficiency Strategies	
Renewable Energy Systems	
BedZED: The International Case Study.	Data collected from literature review, online cooperation and qualitative analysis
Masdar City: The Regional Case Study	Data collected from literature review and interview with renewable energy system supplier in Masdar City, then qualitative analysis was conducted.
Validation of NZED in Qatar	Data collected mainly from interviews with several members of technical support of Barwa City, interview with Barwa City tenants, visit and observe the project site, then comparison and qualitative analysis were conducted
Barwa City: Qatar Case Study	
Analysis and Recommendations	

Due to the fact that sustainable development has many definitions according to people, environments and resources, the researcher meant to address some of the definitions through usage of secondary resources for data collection. The study adapts Torcellini's definitions and classification system to come up with an NZED definition alongside the four Parameters (mentioned in greater detail in the first chapter).

The researcher relied intentionally on data collection based on secondary resources such as books, journals and websites to identify the local and international importance of an NZED. Qualitative analysis was used on some of the collected data. An expert from Qatar Green Building Council was interviewed to verify the importance of NZED projects in Qatar. For NZED certification methods, data has been collected from secondary and primary resources including an interview with the executive manager of the GORD institution (being the one that created the GSAS assessment system) about GSAS importance and its role in identifying NZEDs in Qatar.

NZED's four Parameters, EES and renewable energy resources are the constituents of an NZED identification method. The four Parameters are termed as such, based on National Renewable Energy Laboratory (NREL) conferences and reports under the topic of Defining Net Zero Energy Buildings. This study has chosen the more NZED-related EES. In addition to the fact that there are so many other strategies in the market that are used by other systems, all EES mentioned in this study are collected from secondary resources.

Basic and technical information about renewable energy systems was collected from the same resources, like most of the others, from primary and secondary data based on books, journal papers and websites, in addition to an interview with the manager of the company of solar systems for Masdar City in Abu Dhabi.

The international case study is reviewed from the International Living Future Institute (ILFI) 2014 annual report solely concerned with net zero energy projects. This case study is about the net zero energy district in Beddington, UK called "BedZED".

The purpose of this case study and the other two case studies is to apply the proposed identification method in order to investigate whether it is a net zero energy district as claimed or not; the proposed NZED identification method will be tested and lessons will be learned from both cases (NZED and non-NZED).

The regional case study is concluded from a site visit of Net Zero Energy district called Masdar City in Abu Dhabi – UAE. The investigation was conducted on the analysis of technical reports, conferences articles, published journal papers, websites, and comprehensive interview with the main supplier of renewable energy systems in Masdar City, UAE. (The findings of the analysis of Masdar case study will be discussed later in section 4.2.)

Barwa City is the considered local case study of Qatar, it is selected according to many justified reasons that will be listed later on, in chapter five (see section 5.2.1).

The data in local case study is mainly collected from primary resources. Such as: meeting with an expert from the previous owner company BARWA, and another meeting with an Assets Manager in Qatari Diar Real Estate (the recent owner of the project). One other interview was also conducted with the Facility Manager at Waseef company (the project operator and the technical manager at the same company). For further validation of the collected data; interviews are developed to involve the city tenants and residents.

### **2.3 Research Questions**

The main question of this research is:

#### **How NZED projects can be implemented in Qatar?**

To elucidate this question, the study seeks answers for the following sub-questions:

- a.** How can NZED projects be identified?
- b.** Would the resulting identification methods be successful to assess international or GCC projects?
- c.** What is the relationship between the NZED identification method and that of the present Green Assessment Systems in Qatar like GSAS and LEED?
- d.** What are the challenges facing the implementation of NZED in Qatar?

## **2.4 Aims and Objectives**

The study aims to achieve the following:

- To provide recommendations for creating and developing NZED projects in Qatar and to identify the main obstacles. (To answer question “d”)
- To develop a new assessment method for Net Zero Energy Districts in accordance to energy consumption, energy efficiency and using energy renewable systems. (To answer question “a”)
- To examine the validation of the new assessment method for international, regional and national projects. (To answer questions “b” and “c”)

## **2.5 Research Expected Outcomes**

This section aims at providing findings concerning the validation of implementing a Net Zero Energy District in Qatar. It provides guidelines for designers and for decision-makers to create NZED projects. It also aims to determine the suitable renewable energy systems for Qatar and how to manage them within the influence of local climate and other pressing factors. Consequently, it recommends the future plans of energy production and consumption, with the intention to achieve the goal of sustainable energy security in Qatar.

It is perceived that the NZED identification method in this study would provide a vital answer to the level of sustainability according to proposed assessment process. This thesis by its nature is intended to focus on the serious consequences of energy and carbon emissions and their impact on the environment of Qatar and the surrounding areas, it is meant to investigate available energy systems and to assess some related projects and case studies with a direct focus on renewable energy systems and EES.

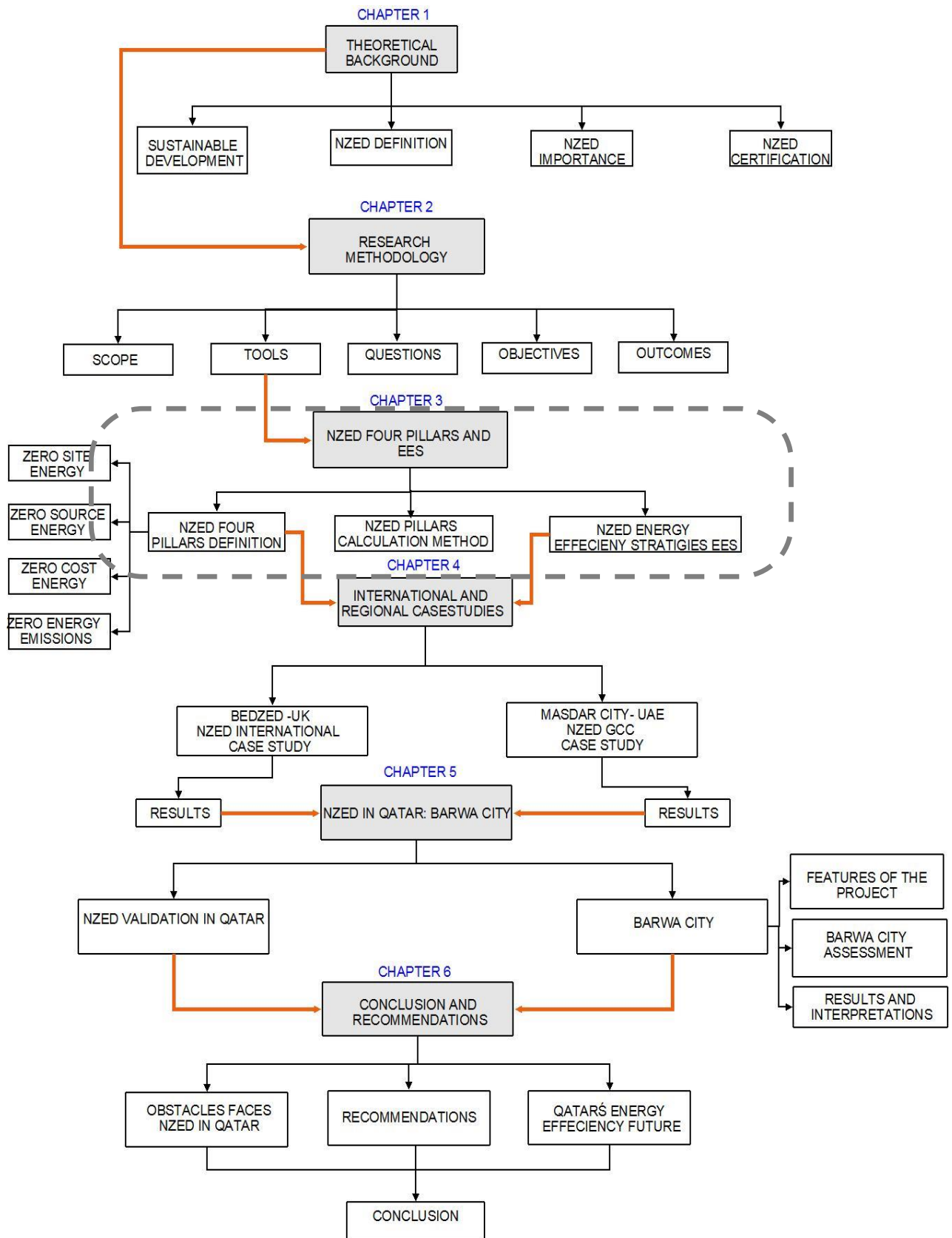


Figure 18: Flowchart of Research Phases – Chapter 3

## **Chapter 3. NZED Four Parameters and Energy Efficiency Strategies**

This study used several tools to identify an NZED. Some of these criteria are related to the district buildings (building materials, orientation, infrastructure and others). Other criteria are related to the energy sources and transmission methods.

To achieve the goal of a net zero energy district (NZED), a district must achieve the value of zero in one of the following Parameters at least: site energy, source energy, energy cost and carbon emissions (Torcellini, 2006). This research calls these four Indicators the “NZED Four Parameters”. Beside the four Parameters, an NZED can be identified by other criteria called Energy Efficiency Strategies (EES); an NZED is also identified by the percentage of used renewable energy.

### **3.1 The Four Parameters of NZED: Definitions and Concepts**

The NZED four Parameters are adapted from the National Renewable Energy Laboratory (NREL) research, reports and conference papers. This study adopted Torcellini’s work as a principle platform in the assessment tools. Paul Torcellini is a professor at the National Renewable Energy Laboratory (NREL) in USA, and he is one of the most famous researchers and writers on Net Zero Energy Projects. The literature review in this study used many NREL reports and conference papers discussing Net Zero Energy projects.

Torcellini assumed that net zero energy projects can be assessed using four energy Parameters (the Four Parameters), which are site energy, source energy, energy cost and energy emissions. This research will assume that achieving the four Parameters is not enough for any district to be classified as an NZED.

To reach NZED status, the district has to be zero value in one of the four Parameters, in addition to applying the energy efficiency strategies and successfully using renewable energy systems to

produce energy onsite; otherwise, the district will be considered a near zero energy district (near ZED).

### **3.1.1 Zero Site Energy**

Site energy is the energy directly consumed at a facility typically measured with utility meters. It is shown as the amount of heat and electricity consumed by a building as reflected in the utility bills (Barley, Deru, Pless, & Torcellini, 2005). Looking at site energy can help in understanding the rate of changing energy consumption over time.

Site energy may be brought to a district in two forms: primary or secondary energy. Primary energy is the raw fuel that is burned to create energy. Secondary energy is the energy product created from a raw fuel taken from the site.

A unit of primary and a unit of secondary energy consumed at the site cannot be compared directly because one represents a raw fuel while the other represents a converted fuel (Ueno & Straube, 2010). Therefore, units have to be unified to compare between primary and secondary energy in terms of production and consumption (Miner, 2014).

### **3.1.2 Zero Source Energy**

Source energy is the most reasonable unit of evaluation; it represents the total amount of raw fuel that is required to operate the project (either building or district). It incorporates all transformation, delivery and production energy losses to assess the real energy efficiency in the project. It is the sum of the energy consumed at a facility and the energy required to extract, convert and transmit that energy to the facility. The transmission and distribution losses are accounted for in the energy delivered to the facility (Deru & Torcellini, 2007).

### **3.1.3 Zero Energy Cost**

Energy cost is the amount of money a utility pays a building or district owner for the energy. It becomes zero when a district receives at least as much annual revenue from the utility for renewable



energy exported to the grid as the amount paid to the utility for energy used over the year (Harris, 2011).

However, some international organizations, like LEED and ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), have considered using the energy cost as a main metric instead of bothering with site-source conversions. Costs are commonly used in economic analyses, and they are what building owners care about (ASHRAE, 2013).

Unfortunately, energy costs can vary greatly by geographic region, season and even time of day. If someone is trying to compare two buildings, energy costs can easily provide a distorted picture or one only accurate for the estimated time period. A better method is to take the energy units and then determine the energy costs as necessary. This allows estimation of what would happen if energy costs change over time (Ueno & Straube, 2010).

### **3.1.4 Zero Energy Emissions**

Energy emissions or carbon emissions, as sometimes identified, is one kind of Greenhouse Gas (GHG) and is defined as the amount of pollutant gases produced from extracting, transporting and using energy. GHG emissions are generated directly and indirectly by an entity and can be classified into three categories based on the source of the emissions (EPA, 2012).

Emissions are direct GHG emissions from sources that are owned or controlled by an entity. This category includes emissions from fossil fuels burned on-site, emissions from entity-owned or entity-leased vehicles and other direct sources.

1. Emissions are indirect GHG emissions resulting from the generation of electricity, heating and cooling.
2. Emissions include indirect GHG emissions from sources not owned or directly controlled by the entity but related to an entity's activities.

Energy emissions in this research mean gas emissions produced by the first two categories. Emissions are direct GHG emissions from sources related to site energy, and emissions are indirect GHG emissions resulting from the generation of electricity related to source energy.

The United States and Qatar identify different major contributing pollutants; U.S. Environmental Protection Agency (EPA) has set national air quality standards for six principal air pollutants (also referred to as criteria pollutants): nitrogen dioxide (NO<sub>2</sub>), ozone, sulfur dioxide (SO<sub>2</sub>), particulate matter (PM), carbon monoxide (CO), and lead (Deru & Torcellini, 2007).

In Qatar, the most polluting gases are nitrogen oxides (NO<sub>x</sub>), carbon dioxide (CO<sub>2</sub>), hydrogen sulfide (H<sub>2</sub>S) and sulfur dioxide (SO<sub>2</sub>) (Badr, Al-Kuwari, & Abdel-Sattar, 2004).

Research conducted by the EPA shows that *“electrical power generation is a significant source of air emissions. In the United States, fossil fuel-fired power plants are responsible for 70% of the nation's sulfur dioxide emissions, 13% of nitrogen oxide emissions, and 40% of carbon dioxide emissions from the combustion of fossil fuels. These emissions can lead to smog, acid rain, and haze. In addition, these power plant emissions increase the risk of climate change”* (EPA, 2012).

As a result, the type of energy source and energy production is affecting our air quality; therefore, reducing carbon emissions is vital for mitigating global climate change. For this reason, some codes and standards use a zero carbon metric, rather than a zero energy metric (Amato, 2014), which is closely linked to the other three Parameters as shown in the three previous GHG categories.

Table 5 develops a comparison analysis of the four Parameters based on the previous collected information, shows the expected advantages and disadvantages of each Indicator as an assessment tool for a net-zero energy district.

Table 5: Pros and Cons of Net-Zero Energy Four Parameters adapted from (Carmichael & Managan, 2013)

NZED Indicator	Summary	Metric	Pros	Cons
Net-zero site energy	On-site renewable energy generation	watt or kilowatt	<ul style="list-style-type: none"> <li>• Simple calculations</li> <li>• Low external variations (i.e., not dependent on energy prices)</li> </ul>	<ul style="list-style-type: none"> <li>• Annual energy bills not \$0</li> <li>• Assumes electricity exported from the site can be used to offset natural gas needs on site</li> </ul>
Net-zero source energy	Energy use accounted for at the source, including the energy used for extraction, generation and distribution.	watt or kilowatt	<ul style="list-style-type: none"> <li>• More accurate representation of total environmental impact</li> </ul>	<ul style="list-style-type: none"> <li>• Annual energy bills not \$0.</li> <li>• More complicated calculations.</li> </ul>
Net-zero cost energy	Amount owner pays utility for the energy less than or equal to the amount of money utility pays building owner for the renewable energy the building exports to the grid	Qatari Riyal	<ul style="list-style-type: none"> <li>• money saving</li> <li>• easy to calculate</li> </ul>	<ul style="list-style-type: none"> <li>• Not accurate because electricity prices differ from one country to another</li> </ul>
Net-zero emissions energy	Greenhouse gas emissions produced from the energy used through renewable energy production and carbon offsets (up to 50% of net energy consumption offset by building)	CO <sup>2</sup> e (see section 3.2.4 about CO <sup>2</sup> emissions calculation)	<ul style="list-style-type: none"> <li>• Eco-friendly</li> <li>• aligns with carbon dioxide reduction efforts and climate change mitigation</li> </ul>	<ul style="list-style-type: none"> <li>• Annual energy bills not \$0</li> <li>• Challenging to track and audit.</li> <li>• Concerns regarding carbon offsets</li> </ul>

The table shows that Net Zero Energy Cost is the easiest Indicator to calculate, zero energy cost can be achieved if the total annual energy bills equal zero. But it is still not the most accurate way since the energy prices can be different from one place to another, and is not reflecting the real situation sometimes, especially in some places which are exempt from electricity bills (like the native

residents' homes and some governmental buildings in Qatar). On the other hand, Net Zero Source Energy is the most accurate indicator, it gives a real perspective about the amount of used energy. However, the most environmentally friendly Indicator is Net Zero Emissions Energy; being achieved means clean renewable energy is used, which is a positive step toward climate change mitigation.

### **3.2 NZED Parameters Calculation Methods**

As mentioned previously in section 2.1.1, to reach the NZED point, a district must achieve the zero value of at least one of the four Parameters. This part explains the suggested calculation methods and units used for each of the four Parameters.

#### **3.2.1 Site Energy Calculation**

Site energy amount is the summation of end use energy measured by the unit kilo British thermal units (kBtu). While kBtu is used in the United Kingdom and Europe, other countries use watt (W), which is equal to one joule per second. Site energy calculation for a single house is much easier than for a whole district. Simply, site energy consists of the summation of all energy types inside a project, such as electrical power, natural gas used in cooking, wood or fuel used for heating, fuel used for cars, etc.

In some cases, this summation is hard to achieve, especially for districts with unoccupied buildings or those still in the design stage. In such cases, experts are using simulation programs to calculate actual energy amounts used within the living environment (Rodriguês, 2010). An automated simulation or computer simulation technique (see Figure 19) is especially helpful for a statistical problem based on probability (Maria, 1997).

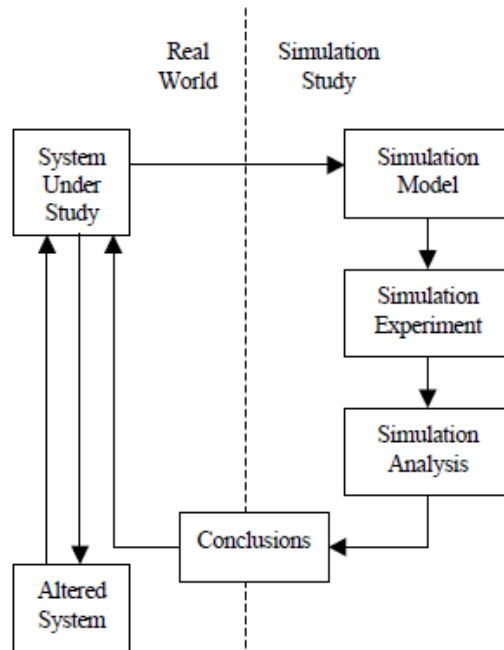


Figure 19: Schematic Simulation Study (Maria, 1997)

Energy programs are largely used to predict the total energy consumed by a project in terms of kilowatts, dollars or pollution avoidance (Paradis, 2010). A wide range of programs is simulating the indoor energy usage in internationally developed buildings. These include programs such as the Energy Savings Platform (ESP), Transient System Simulation Tool (TRNSYS), Hybrid Optimization of Multiple Energy Resources (HOMER), Targeted Retrofit Energy Analysis (TREAT), and DESIGNBUILDER. To work a simulation, these programs require numerous inputs related to energy efficiency and energy consumption, such as building mass, openings, orientation, occupancy, activity, etc.

In most of the simulation programs, the researcher used two models: one model is of the baseline building even if it is pre-existing or a new project, and the other model is of the proposed building that may be modified by increasing or decreasing the energy efficiency and energy usage Parameters to reach net-zero energy or, at least, reach lower energy consumption by a certain percentage (Attiya, 2014).

### **3.2.2 Source Energy Calculation**

Source energy calculation depends upon the types of primary fuels being consumed and the specific equipment used to produce energy. These features are unique to specific power plants and differ across countries. For example, some countries depend on wind turbine energy like Holland, while other countries are consuming oil and gas like Qatar. The source energy calculation for a district or a city is much easier than a single house; it can be obtained through a country's statistics on energy consumption for a specific area, including the energy used in production and transportation.

### **3.2.3 Energy Cost Calculation**

Cost energy calculations are simply energy bills produced by using site energy—in national currency (Qatari Riyal in Qatar). Buying efficient products can save considerable money over the years users own them. For a district, the total bill equals the summation of buildings' bills plus the street lighting bills and energy for transportation cost (Energy Efficiency and Conservation Authority, 2014). These bills can be obtained from the electricity provider company or from the operator company in private districts. (For example, in the research case study of Barwa City, the bills were brought from the operator, Waseef Company.)

In net zero energy cost, bills come with zero value in the ideal cases, which means either energy renewable resources in a district are producing energy to the main grid as much as the district consumes over a year, or all used energy of the buildings or other facilities are using free energy with no bills (such as energy produced from solar power, wind turbines, etc.). In other cases, the district considers costs as near zero energy (defined in section 2.4) when bills are lower than the average bills throughout the country.

This study will use the energy cost calculation method to identify the energy production and consumption amounts. This method is available and already calculated by governments and electricity supply companies.

### 3.2.4 Energy Emissions Calculation

To calculate energy emissions, specialists use annual carbon emissions Parameters to measure the carbon releases caused by energy consumption. Carbon calculation starts by following the energy production source; each energy source has its carbon emissions rates. The international unit for carbon emissions is a ton. Other (non-carbon) greenhouse gases are assigned a standard carbon equivalency, and the results are translated in terms of carbon. Some references use the amount of GHGs emitted per person, so the unit becomes tons per capita; this unit is more specific and fair since there are differences between regions in size and population capacity.

Every greenhouse gas has its own *global warming potential* (GWP), which is a ratio of how much heat the GHG can trap within the atmosphere to the GHG of one unit mass of carbon dioxide over a specified time period (Chamberlain, 2014).

These GWP factors were developed by the Intergovernmental Panel on Climate Change (IPCC), a scientific organization established by the United Nations Environment Program (UNEP) to lead the assessment of climate change. Because every GHG has a different GWP, the GHG estimator cannot simply rely on the typical air emission report to calculate total GHG output (Atabay, 2014). The solution to this issue is to use each GHG's individual GWP and use it to translate air emissions into a common unit that compares and relates all GHG emissions. That unit is *carbon dioxide equivalent* (CO<sub>2e</sub>). CO<sub>2e</sub> establishes all GHG emissions in relation to carbon dioxide, which is considered having a GWP of one. Carbon dioxide is used as the reference GHG that all others gases are compared to.

Technically, the procedure to convert GHG emissions into tons CO<sub>2e</sub> consists of three steps:

The first step is to calculate GHG emissions in tons, by type of GHG. For example, one should determine how many tons of methane were generated by processes this year. These calculations can be done in a number of ways, depending on used equipment, monitoring practices and the environmental management system. The most common method is the Tier 1 Calculation Method:

$\text{GHG emission} = 0.001 * \text{Fuel Usage} * \text{High heat value} * \text{Emission factor}.$

These values are listed in EPA's GHG Reporting Program (GHGRP) documentation. This Tier 1 methodology can readily be used for a handful of GHGs, including CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, but only if the GHGRP ruling documentation has the district energy specific operating scenario.

The second step is to do a fairly easy conversion from tons to tons CO<sub>2e</sub>. To do this, tons emissions must be multiplied by the GHG type's GWP:

$$\text{CO}_{2e} = \text{GWP} * \text{GHG emission (tons)}$$

International estimators, like EPA, only accept GWP factors developed by the IPCC's Second Assessment Report (SAR). Also, the EPA has developed an easy to use online CO<sub>2e</sub> calculator that a user can employ to convert emissions into CO<sub>2e</sub>.

The third step is summing up all tons CO<sub>2e</sub> (Chamberlain, 2014). The previous calculations address the amount of GHG gases produced from energy but cannot be used to estimate the air quality and the amount of GHG in the atmosphere. Reaching net-zero emissions in this research relates to the type of energy used and not zero emissions in the air. For example, CO<sub>2</sub> exists in the air, along with other gases, as one of the natural components having a percentage of 0.040% in ideal cases and not zero (Gunther, 2012).

### **3.3 Strategies to Develop a Net Zero Energy District**

Net-zero energy is a motivating goal for any community; this goal needs every single detail in the project to be planned previously. To be a net-zero district there are some strategies that have to be followed in order to reduce the average energy consumption to the lowest possible amount, then cover the rest of the required energy by using renewable energy systems (Malin, 2010).

#### **3.3.1 Energy Efficiency Strategies (EES): Application and Design**

Energy efficiency can be defined as the balanced use of energy to provide proper environmental conditions of comfort and productivity gains (Santos, Zófoli , Soares , & Garlet, 2012).



The critical interaction between environment and energy efficiency in achieving sustainable growth has spread rapidly in recent years. On the assumption that buildings' lifetimes are 50 years or more, optimizing efficiency as early as possible is critical for maximizing potential energy savings while avoiding further lock-in to inefficient building stock (REN21-Renewable Energy Policy Network for the 21st Century, 2014).

EES are important tools for analyzing the interactions among economic and human activities, energy use and CO<sub>2</sub> emissions (International Energy Agency, 2014). These strategies are related to a project's criteria even if the project is new construction or similar to an existing district. Following the most important EES chosen for this study among many others, these chosen strategies are more related to districts than the individual building and applicable to be used when analyzing case studies.

*a. District appropriate location*

District location is one EES that affects several energy Parameters: source energy, site energy, energy emissions and energy costs. Location of a district or a city affects the transportation method and the amount of energy used for it. In the initial construction stage of a project, faraway countries consume more energy to transfer raw materials to the site.

On the other hand, countries differ in energy policies and sources of energy. Some countries still use coal to produce energy while others rely on oil and gas. Recently, some countries have developed policies to organize energy consumption by requiring more energy efficient equipment and the use of renewable energy. (Figure 20 shows the countries having renewable energy related policies.) Consequently, countries differ in types of infrastructure and energy sources (see in the infrastructure section 3.3.1- e).

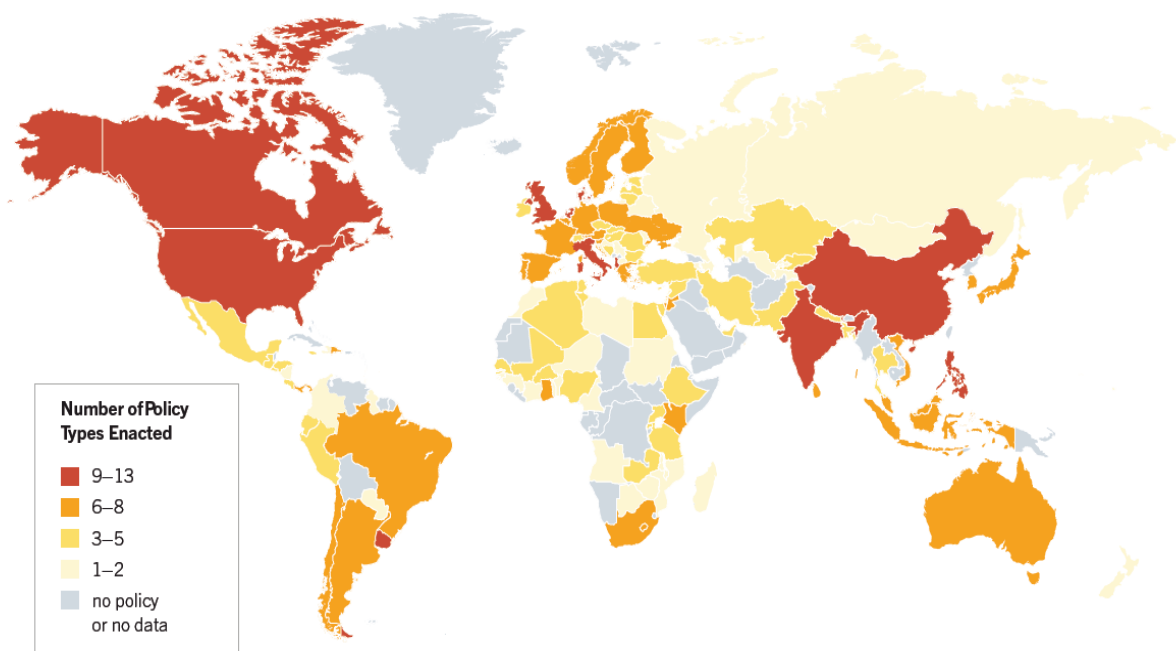


Figure 20: Countries According to Enacted Renewable Energy Policies, Early 2014 (REN21-Renewable Energy Policy Network for the 21st Century. 2014)

In addition, location affects the climate of the country, which is the main need for consumer cooling or heating energy to adapt the environment. Cooling and heating consume around 35% of the whole site energy, and this percentage is much higher in some countries like Qatar. Figures 21 and 22, created by the U.S. Department of Energy, show the average percentage of energy used for HVAC (heating, ventilating and air conditioning) in the commercial and residential areas (Jordan, 2012).

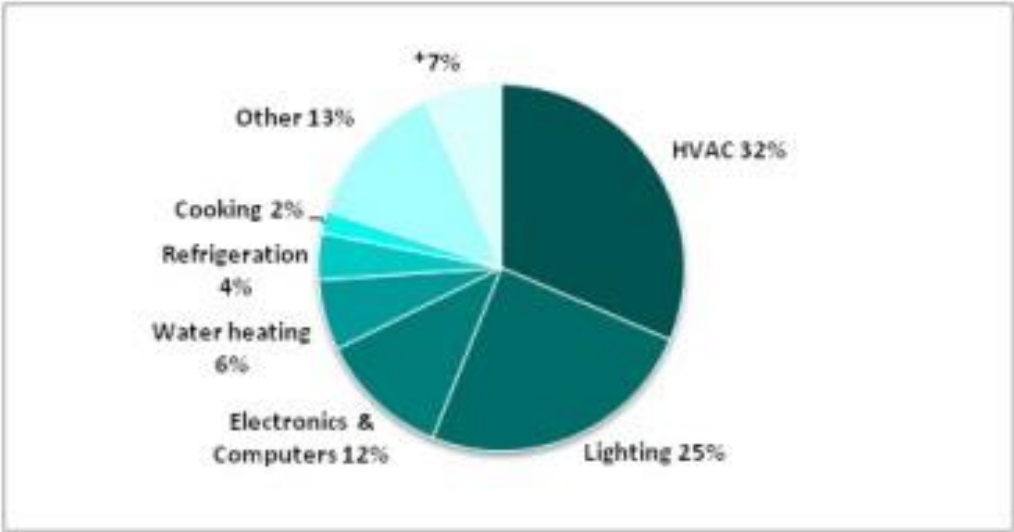


Figure 21: Commercial Buildings Total Energy End Use 2011 (Jordan, 2012)

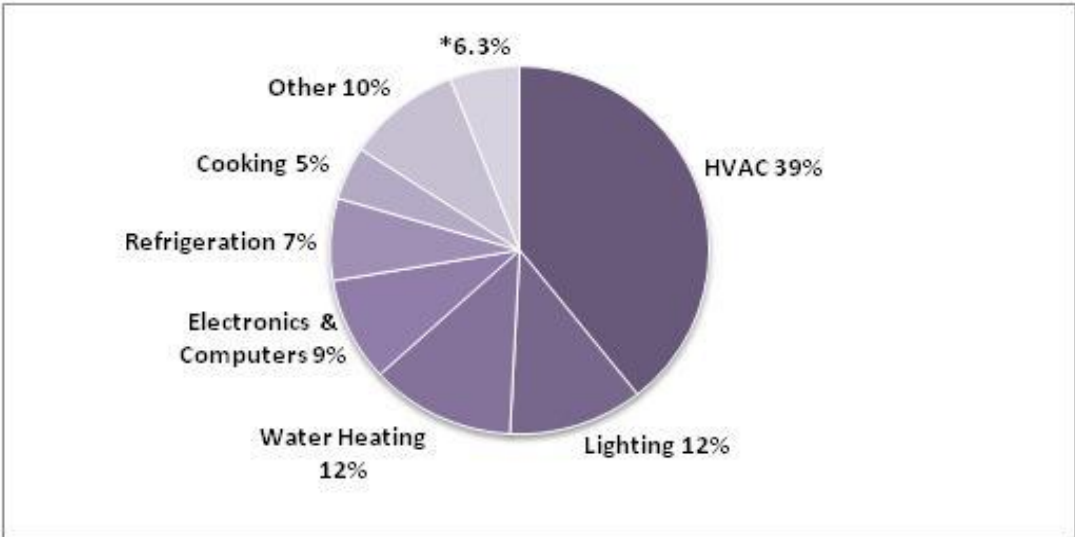


Figure 22: Residential Buildings Total Energy End Use 2011 (Jordan, 2012)

Countries differ in building techniques and materials as well. These techniques and materials affect building responses to the surrounding environment, such as the climate. As previously mentioned, these techniques also affect the energy consumption needed for adapting to the climate.

### ***b. Orientation***

Selecting the best orientation for a new district and its internal buildings is one of the critical energy efficient design decisions that can affect a building's envelope and its energy performance. Good orientation can be used to decrease the direct sun radiation and its effects into buildings. Orientation can also affect the decision of designing the windows, building openings and external walls. For the hot humid climate, like Qatar's, the opening with the least direct sunlight is considered the best; it receives the least heat gain and, therefore, reduces the cooling load. It is also reducing glare problems (Al-Tamimi, 2011).

There was a study conducted in 2007 to investigate the influence of orientation on the building's energy performance. The results showed up to 43% lower cooling demand in effectively oriented buildings. Results have also shown that an efficiently oriented building has a positive impact on electrical power consumption. In addition, researchers investigated the impact of a façade's orientation on the power of the direct and indirect solar radiation. For instance, the results showed that in the Middle East the north façades have the lowest solar intensity, while solar intensity on the east and west façades is similar (Al-Tamimi, 2011).

Since more than 25% of the district areas are covered by streets, studying those urban streets plays an important role in forming the urban climate. Urban streets differ in their geometry as defined by a height/width ratio (H/W), length/width (L/W) and the orientation of its long axis. Streets' orientations directly influence the absorption and emission of solar radiation allowing protection from irradiation for pedestrians (Al-Tamimi, 2011).

Orientation also affects urban ventilation. Both issues create a significant impact on the pedestrians' thermal comfort within the street as well as the surrounding environment. Geometry and orientation

of the street valley affect outdoor and indoor environments, solar access to inside and outside buildings, the airflow availability for urban ventilation, and the potential of cooling off the whole urban system.

Human health, outdoor and indoor thermal comfort, air quality, and the building's energy efficiency all benefit from the well-planned orientation and ventilation of the street canyons.

*c. Integration of the city*

Energy efficient design for a district is not easy; the planner has to think of the full image of the district with all possible related factors that can affect its energy consumption. Integrated energy planning has to be conducted with the consideration of the following points (Gilmour & Warren, 2008):

- Integrated plans to reduce energy consumption in all possible community sectors.
- Integrated plans to develop energy efficiency and the performance level of the buildings, services, transportation...etc.
- Integrated plans to manage community waste and use it to generate renewable energy.
- Create other sources of renewable energy to cover the whole consumption.
- Use integrated district networks to control energy distribution and energy saving.

District energy protocol and design should be planned from the beginning to serve the project goals, which called for an integrated design process (IDP) (Gilmour & Warren, 2008).

*d. Urban structure*

To deal with population increments in the limited available space, increasing density becomes inevitable. But at the same time, urban density affects the total energy demand of a city. While a compact urban plan has advantages for energy distribution and transport system design, especially in the district network's case; on the other hand, crowded conditions may create congestion and undesirable local microclimate. Table 6 summarizes advantages and disadvantages of urban density (Hui, 2001).

Table 6: Effects of Urban Density on City's Energy Demand (Hui, 2001)

Positive Effects	Negative Effects
<p><b>Transport:</b></p> <ul style="list-style-type: none"> <li>• Public transport is more energy efficient and it can replace private cars needed.</li> </ul> <p><b>Infrastructure:</b></p> <ul style="list-style-type: none"> <li>• Streets reduced in number and lengths</li> <li>• Infrastructure pipes have been shortened as well, which reduced the needed energy for pumping.</li> </ul> <p><b>Thermal performance:</b></p> <ul style="list-style-type: none"> <li>• Overall buildings external envelope reduced and heat loss consequently.</li> <li>• Shading becomes easier using higher buildings.</li> </ul> <p><b>Natural lighting and energy systems:</b></p> <ul style="list-style-type: none"> <li>• District cooling and heating system is usually more efficient than individual units.</li> </ul> <p><b>Ventilation:</b></p> <ul style="list-style-type: none"> <li>• Such urban structure creates airflow and breezes around buildings in the case of good passive wind designs.</li> </ul>	<p><b>Transport:</b></p> <ul style="list-style-type: none"> <li>• High density usually causes congestion, which reduces fuel efficiency of automobiles.</li> <li>• High-rise buildings need more electricity for vertical transportation (elevators).</li> </ul> <p><b>Ventilation:</b></p> <ul style="list-style-type: none"> <li>• Concentration of high-rise buildings where not calculated properly may affect the urban ventilation.</li> </ul> <p><b>Urban heat island:</b></p> <ul style="list-style-type: none"> <li>• Heat released in compact urban areas may increase the need for air conditioning.</li> <li>• Natural lighting chances in general reduced in high density areas, which increases the need of electric artificial lighting and increases the load on air conditioning.</li> </ul> <p><b>Use of solar energy:</b></p> <ul style="list-style-type: none"> <li>• Roofs in high-rise buildings used for solar energy panels installation are limited.</li> </ul>

Dense development patterns can reduce infrastructure demands and the need to travel by car. As population density increases, public transportation becomes more effective, so per capita consumed fuel is much lower in the high dense developments.

Urban density also affects urban ventilation conditions, as well as urban temperature; urban development with a high density of buildings can suffer from poor ventilation and high temperature. In warm-humid regions like Qatar, these features cause extra load on the cooling systems, which leads to an increased use of energy. The best solution is a mixture of high and low buildings, which can improve ventilation conditions (Vasant, Barsoum, & Webb, 2012). In addition, too many high-rise buildings badly affect the use of natural lighting and solar energy. In general, high density development has to be properly planned to help in energy saving; if not, it will need more energy for

electric lighting, mechanical cooling and ventilation, and the application of renewable energy systems will be greatly limited.

Renewable energy systems like solar PV panels are more efficient on low-rise buildings where the roof areas serve less numbers of floors, and the quantity of energy use remains under control. Some solar energy system suppliers assume that to use renewable energy systems, a building should not be more than three to five stories high; otherwise, a system will be less effective and unable to serve the whole building to reach net-zero energy point (Sahyoum, 2014).

In summary, denser district designs require more careful analysis and studies to maximize energy efficiency and satisfy other social and environmental requirements. Studying urban fabric and its relationship with energy efficiency not only ensures energy and cost savings; it also provides better indoor and outdoor environments where the quality of urban life is the most important and critical of issues. On the other hand, less dense districts are not recommended in the case of seeking NZED; it increases the need of construction areas, which harm the environment. In addition, low density areas have longer distances between facilities, which consume more energy for transportation. Furthermore, low density districts could compose a sprawl structure, which is an unwanted urban development shape.

*e. Infrastructure (District Energy Networks)*

District energy systems are a highly efficient technique to heat and cool many buildings from a central plant. These systems use a network of underground pipes to deliver steam, hot water or chilled water to multiple buildings in a cluster like a district, college, hospital, campus, airport...etc. This system needs less fuel to operate than individual systems (Environmental and Energy Study Institute, 2011).

In fact, district energy processes passed through several stages including:

- Energy generation and collection
- Transformation into thermal energy; heating or cooling.

- Delivering thermal energy into HVAC plants.
- Consumption by end user.

District energy networks is the best available method to increase energy efficiency, reduce energy emissions, and it working better with high density communities, while reducing maintenance costs, is one of its advantages (Gilmour & Warren, 2008).

District energy networks is one of the best solutions for those who are using renewable energy systems; where the designer can calculate the overall energy needs and provide a suitable number of renewable energy generating units as a central energy plant covering the whole district’s needs instead of providing a single unit for each dwelling, Furthermore; many renewable energy systems such as Combined Heat and Power CHP is not able to work in the single building projects ( see example of CHP system in section 4.1.2) (Gilmour & Warren, 2008).

Figure 23 shows the typical district energy process starting with the source to the production plant and ending with the electrical utility.

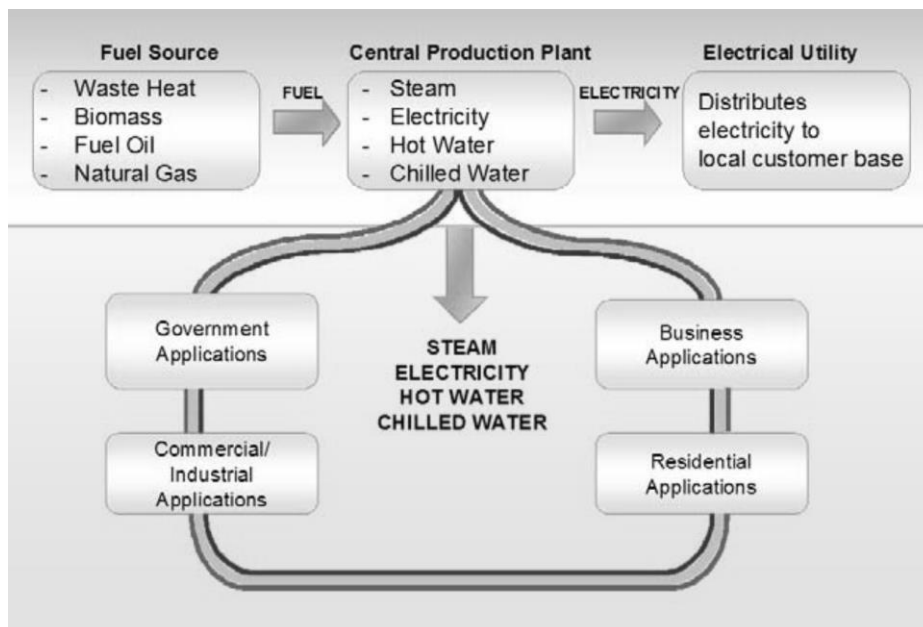


Figure 23: Typical District Energy Configuration (Gilmour & Warren, 2008)



District energy networks can distribute different amounts of heating, cooling or hot water to the different distribution plants upon their demand. There is a control unit at each dwelling to adjust needed cooling, heating or hot water services. This is an important point that should be considered while designing a district energy system. One of the big failures in BedZED (the international case study of this research) is the hot towel bar that is not provided with a control unit, which was wasting energy and making it overheated (Gilmour & Warren, 2008).

*f. Façades*

Façades do not consume energy directly. They affect energy consumption by air conditioning, ventilation and lighting, and windows and doors. Façade materials have a significant impact on the thermal performance of a building's envelope.

Windows, as well as doors, can strongly affect people's productivity and comfort. Heat obtained through exterior windows accounts for around 25-28% of total heat gain, and it can move up to 40% in a hot summer zone (Al-Tamimi, 2011). Actually, glazed windows as a façade element are becoming an important component of modern architecture. They allow natural light, offer a visual communication with the outdoors, reduce a structural load, and enhance the aesthetic appearance of buildings. On the other hand, glazed windows are a real absorber of heat and radiation (see Figure 24) into the building, which is the reason external elevations need a smart design.

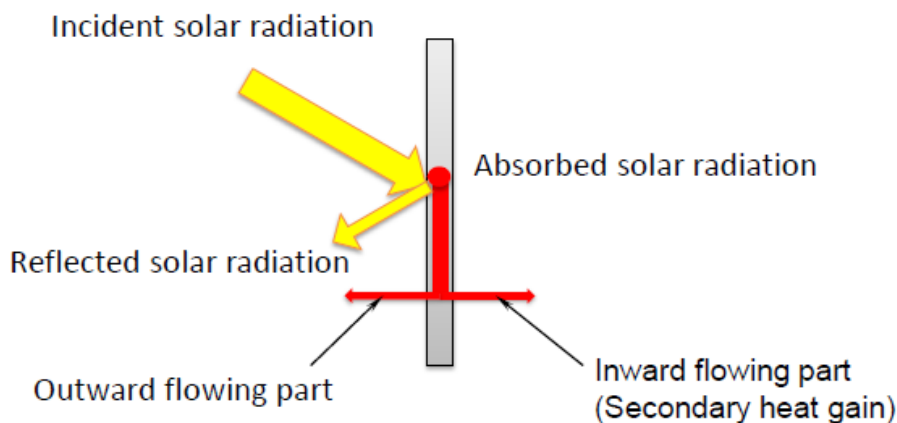


Figure 24: Outer Surface Solar Behavior (Fangzhi, 2013)

Natural ventilation—if designed properly—can reduce the negative effect of solar radiation on the building’s envelope. In addition, the building’s façade orientation can significantly affect the energy needed to cool or heat the internal space (Tokbolat, Tokpatayeva, & Al-Zubaidy, 2013). The best façade orientation for buildings differs from one country to another as the location and latitude of a country contribute to what determines the best façade orientation (see Figure 25).

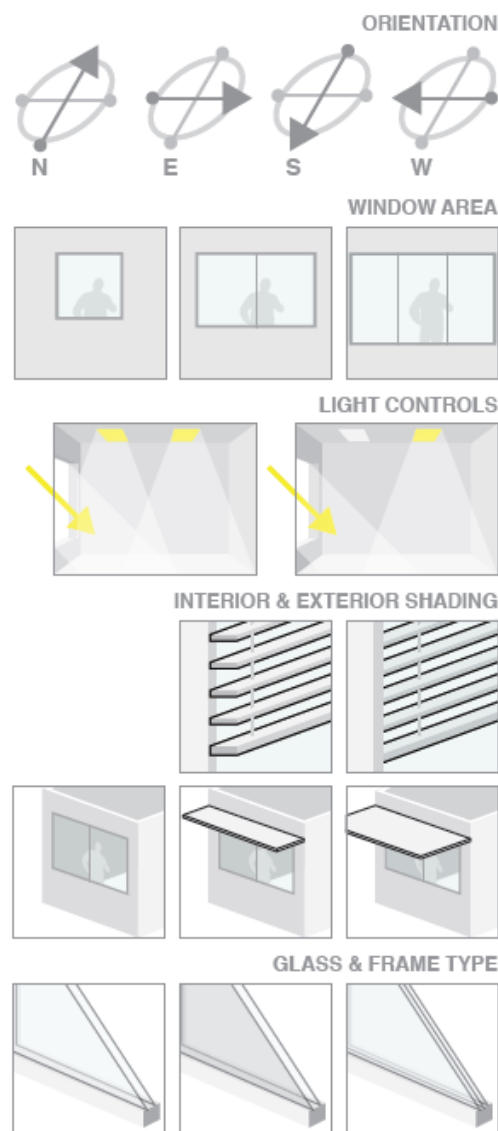


Figure 25: Some Facades’ Factors Affect Energy Consumption (Haglund, 2012)

A façade’s materials like the roof, wall, cladding and frame, etc., are important factors affecting the energy consumption inside and outside the building. The outside surface materials absorb heat, and

part of the absorbed heat flows to the indoor space. Some materials behave in a different way and reflect heat radiation and emissions to the surrounding environment; in this way, the façade affects the outside of the building.

In addition, a good façade shading design can block a certain amount of solar radiation from entering the building. These efficient façades can benefit from natural daylight while controlling solar heat gain and glare. Exterior solar shading can significantly reduce air conditioning loads caused by the sun's radiations.

The DESIGNBUILDER program (mentioned previously in section 3.2.1) can calculate the total energy consumption by modeling the influence of all façade elements on it. By assessing the energy consumption before and after use of a façade element, like windows, the program can determine exactly (the error rate is maximum 7% in the results) the best materials, elements and orientation of the façade to increase its energy efficiency.

***g. Thermal insulation***

Many types of insulation are available, such as moisture insulation, acoustic insulation, insect insulation and thermal insulation. Energy efficiency is most directly affected by thermal insulation. Thermal insulation refers to insulation that reduces the heat and cool conductivity of a building by inserting extra materials into the envelope layers.

In fact, thermal insulation is one of the most effective ways to improve building energy efficiency and increase the thermal comfort inside a building because it acts as a barrier to heat flow. Building thermal insulation reduces the amount of warmth escaping in winter and reduces the amount of heat entering the space in summer. Actually, the proper installation of thermal insulation on building elements can effectively reduce heating and cooling energy loss by up to 50% and help to reduce GHG emissions (Fletcher, 2013).

#### ***h. Materials***

Materials have a variety of properties that can affect their performance against temperature, solar radiation, wind, dust, humidity, pollution, noise, etc. Material properties are a broad topic without ample space to expand on in this research; however, the most important properties affecting NZED performance can be mentioned. One of the important material properties related to energy saving is U-value and is defined as “*a measure of heat loss in a building element, such as a wall, floor, or roof. U-value can also be referred to as an overall heat transfer co-efficient and measures how well parts of a building transfer heat*” (Brennan, 2014). In Net Zero Energy Districts, the materials’ U-value should be as low as possible, which makes energy loss less consequential.

In addition, materials can emit toxic chemical gases after fixtures called volatile organic compounds or VOCs. These toxic chemicals are found in higher concentrations inside compared to outside; they damage indoor air quality (IAQ) and indoor thermal comfort (Weber, 2009). Low-emitting materials or VOC-free materials have properties that can be used in NZEDs and are required by some environmental rating systems like LEED and GSAS.

#### ***i. Efficient electrical equipment***

Installed systems, other than HVAC systems, (see section 3.3.1-e) can affect a building’s energy performance in two ways: by their own energy demand and by their production of waste heat, which can increase cooling loads or decrease heating loads (Laustsen, 2008).

The most important electrical equipment in the twenty-first century is lighting equipment. The need of artificial lighting is a response to the building’s design. The lighting demand during daytime, for instance, depends on the size, orientation and materials of a building’s windows (Laustsen, 2008).

In addition, the type of lighting equipment affects the amount of energy the lights consume as well as the amount of side effects the equipment produces, like heat in the form of wasted energy. The amount of wasted energy depends on the installation types that can reduce energy needed for outdoor

lighting, such as street or façade lighting, and indoor heating in cold climates or winter; likewise, the type of installation can raise demand for indoor cooling in hot climates or summer (Laustsen, 2008). All electrical machines, like white appliances, are emitting waste energy when working, and usually appears in the form of heat energy. This energy affects the need of heating and cooling the building. In other words, in a cooled building wasted energy from inefficient appliances causes double energy loss because the appliances are using more energy themselves and they are producing wasted energy, which has to be cooled away later by the cooling or ventilation system. In smart, efficient buildings, heat from installed appliances can significantly replace the need of heating and cooling (Von, 2011).

*j. Efficient landscape*

A properly studied landscape can make a district or neighborhood significantly more energy efficient and reduce air pollution by reducing greenhouse gases. Trees can have a canopy large enough to shade roofs, reduce cooling costs and increase comfort. The best locations for trees differ from one country to another. For instance, in the Middle East, in countries including Qatar, the best locations for canopy trees are on the south and east sides of the building. In this way, shade can block around 60% of the summer's direct sun and allow low-angle winter sunlight to warm a building (McGee, 2013).

Furthermore, proper landscaping can reduce needed cooling and heating loads to reach thermal comfort and can consequently reduce energy consumption. Shading A/C units, for example, can increase a unit's efficiency as much as 10% (Young, 2014) while windows shaded by landscaping can reduce heat gain by 40%.

Considering urban scale, heat sinks, such as dark roadways, patios, paving and roofing materials, like asphalt can absorb then radiate significant amounts of heat into the surrounding atmosphere, which increases the internal temperature of buildings and affects the comfort level of people in the external landscape. Shading these surfaces, especially during the summer months, will mitigate

urban heat island, which ensures thermal comfort for these areas' residents (American Society of Landscape Architects, 2014).

Plants remove water pollutants by capturing, breaking down and binding water pollutants when storm water, absorbed by plants and healthy soils, moves to the lower underground layers.

On the other hand, landscapes consume energy through maintenance and irrigation. Irrigators, like Qatar, who pump from deep wells or desalt seawater, have experienced rapidly increasing energy costs, which are remaining relatively high. In Qatar, landscape irrigation in public spaces uses desalted seawater and treated grey water, which reduces underground water consumption but increases energy consumption. However, irrigation in Qatar is consuming the largest amount of water. In 2005, the total water consumption was estimated at 444 million m<sup>3</sup>, of which 262 million m<sup>3</sup> or 59% was for agricultural purposes, 39% for municipal purposes, and 2% for industrial use (see Figure 26) (Frenken, 2008).

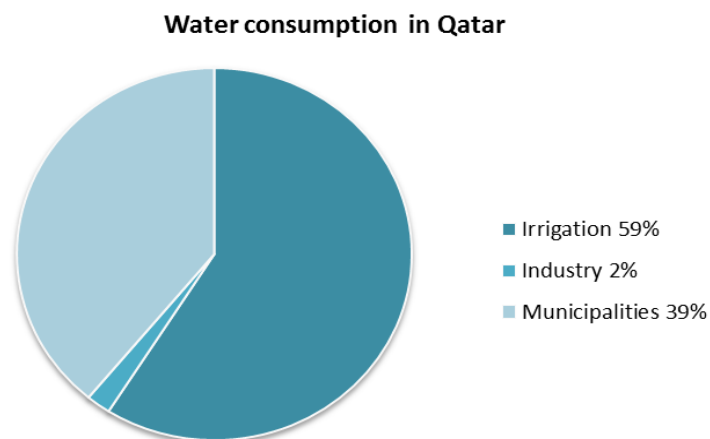


Figure 26: Water Consumption in Qatar in 2005 (Frenken, 2008)

***k. Efficient water strategy***

Addressing irrigation leads to water consumption and water strategy issues because water and energy are closely linked. The life cycle of water (potable water or treated) consumes energy in most of its stages, from extracting the water from the source or desalting seawater, treating it, pumping it into

containers for transfer by pipes, and to pumping it again to the users; even after delivering water, consumers burn more energy to heat, cool, and use it (Mielke, Anadon, & Narayanamurti, 2010).

The U.S. EPA listed the benefits of improving energy efficiency in water as (U.S. Environmental Protection Agency, 2013):

- reduced air pollution and GHG emissions;
- reduced energy costs;
- extended life of infrastructure/equipment;
- improved energy and water security; and
- protected public health.

However, Net Zero Energy Districts should have strategies for reducing water consumption to reach zero energy or near-zero energy points. Some of these strategies are listed by rating systems or eco-friendly organizations like the U.S EPA, which created a program called *Water Sense* and aims to help users assess the water efficiency of their properties. *Water Sense* defines water efficiency as “*using improved technologies and practices that deliver equal or better service with less water*” (EPA, 2012).

Conversely, the countries in the GCC have an extremely limited amount of renewable water resources per person, with an average of 119.5 cubic meters per person per year; compared with the United States, which consumes 6815.8/person per year. Figure 27 shows actual renewable water resources per capita for several countries (QSAS, 2010).

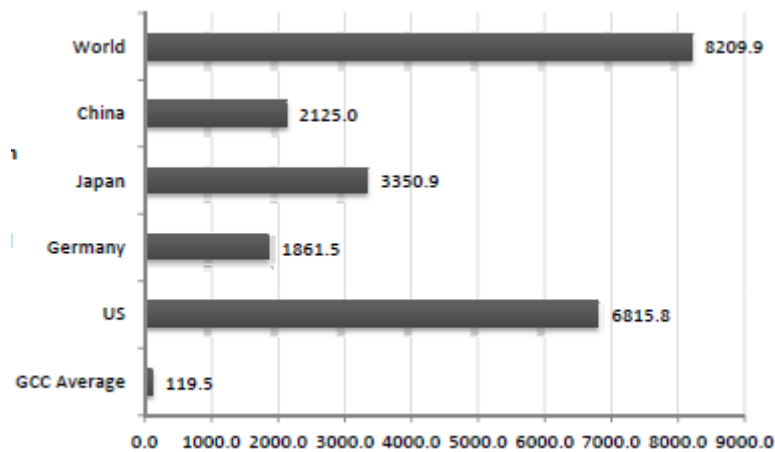


Figure 27: Actual Renewable Water Resources Per Capita (Units: Cubic Meter per Person per Year) (QSAS, 2010)

In Qatar, the Ministry of Environment introduced a new section in the latest version of the Qatar Construction Specifications (QCS, 2010), entitled Section 7 Green Construction, this section advises mitigation of environmental impacts and demands on water by:

- Choosing efficient plumbing fittings;
- Creating systems for the collect and store.
- Treating water on-site for later using.
- Designing efficient landscaping plans that can minimize irrigation need.

Furthermore, new GSAS districts put a weight of 16% on the water consumption category, while LEED gives only 10% for water efficiency. LEED designed for European and American use where the water is not considered as serious of a problem as energy. On the other hand, GSAS is designed to fit with Qatar and GCC countries where the water is a main issue.

GSAS for districts emphasizes reduced water consumption in order to reduce the burden on municipal supplies and treatment systems (GSAS V2 Toolkit for Districts, 2014) by:

- maintaining landscape and irrigation consumption;
- maintaining rainwater and storm water collection and reuse strategy; and
- maintaining grey water and black water collection and reuse strategy.



Notably, GSAS districts do not have rules to reduce buildings' water consumption by requiring more water-efficient equipment or more energy-conscious lifestyles. However, the previous three points are necessary but are not enough to assess water consumption and water efficiency performance within the districts.

In this context, *KAHRAMAA* (Qatar General Electricity & Water Corporation) released a new awareness program called *TARSHEED*. This program published best practices for the conservation of electricity and water among the Qatar population. In addition, this program developed guidance for water conservation. *TARSHEED* imposed regulations for internal water installations and connection works, such as (Conservation & Energy Efficiency Dept. at KAHRAMAA, 2012):

- Fix low flow faucets and taps in all public buildings;
- Fix faucet aerators (water flow reducers) in all public and private buildings;
- Install low-volume flush tanks in toilets in all public and private buildings;
- Use best practices in water conservation in all water using fixtures like faucets, wash basins, kitchen sinks, toilets and showers;
- Select native species of plants in landscaping, which consume less water in irrigation;
- Use drip irrigation;
- Use non-potable water for irrigation;
- Sub-meter and monitor water consumed for irrigation to detect any possible leaks in the irrigation system;
- Use moisture sensors and weather-based controls to reduce the water consumption for irrigation;
- Display clear, informative posters above dual flush toilets to demonstrate their use;
- Do not fully open water taps;
- Immediately report and fix water leaks in toilets or elsewhere;

- Provide motivational slogans in conspicuous locations to practice water conservation;
- Educate housekeeping and kitchen staff on how to use the minimum amount of water during cleaning or washing dishes and penalize those caught wasting;
- Run appliances like washing machines and dish washers at full load; and
- Choose water efficient fixtures and appliances on new purchases.

Such specific guidelines are very important but still not effective unless compulsory laws and penalties are imposed for those not following the guidelines.

#### *l. Energy efficient transportation*

Transportation, defined as giving motion to masses (people, vehicles, cargo, etc.), is the most consuming of energy, it accounts for approximately 25% of the world's energy demand and for about 61.5% of all the oil used each year. The relationship between transport and energy is a direct one, but it differs among modes of transportation, each mode having its own energy performance level (Rodrigue & Comtois, 2013).

Starting from vehicle manufacture, to maintenance, and, finally, to disposal, energy is consumed throughout vehicle manufacturing. Vehicle operation is next in transportation energy consumption, vehicle operation involves energy used to provide movement to vehicles, mainly fossil fuels. In addition, infrastructure construction and maintenance consume energy accounts on transportation, roads, railways, bridges, tunnels, terminals, ports, and airports required significant amounts of energy (Kamal, 2013).

Even though transportation systems include other strong modal variations than cars and busses, the most common mode of transportation is still land transportation. Road transportation, for instance, consumes on average 85% of the total used energy in transportation in developed countries (Kamal, 2013).

In Qatar, road sector fuel consumption per capita (kg of oil or equivalent) is more than Saudi Arabia, UAE, and the whole world’s average consumption per capita (see Figure 28) (The World Bank, 2014).

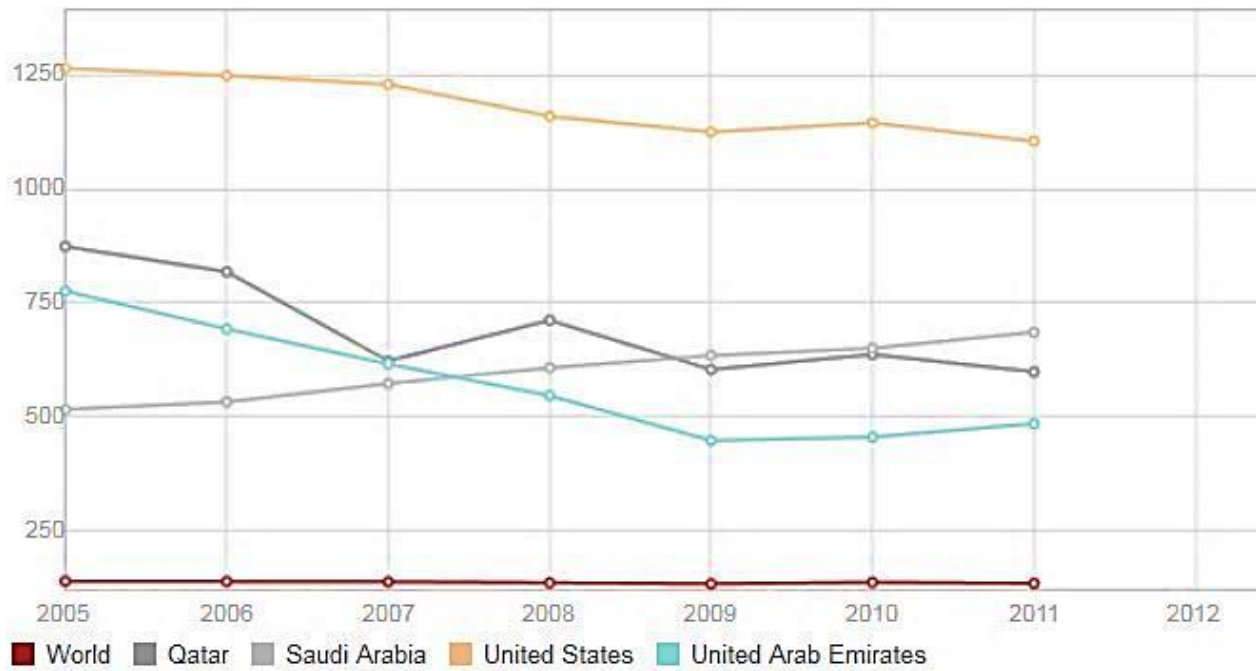


Figure 28: Road Sector Fuel Consumption Per Capita (The World Bank, 2014)

In a Net Zero Energy District, the designer can reduce transport energy employing several strategies, such as:

- Reduce travel need.
- Decrease the level of car dependence
- Encouragement of walking and cycling.
- Activate public transportation.
- Promote alternative sources of energy and fuels.

Designing a Net Zero Energy District requires consideration of the previous points in order to create an energy efficient transportation system.

### *m. Waste management*

The consumption behaviors of modern societies are producing huge worldwide waste problems. All living organisms are creating wastes, but humans produce the most waste on the planet. To prevent damaging what remained of Earth's ecosystems and maintain a high quality of life for the planet's inhabitants, humans must start managing their wastes efficiently and safely. Waste management is one of the important NZED Parameters. Collecting waste and transferring it from one landfill to another is consuming energy in lifting, transportation and ventilation.

However, humans have been practicing irresponsible waste management practices for thousands of years. Early humans were simply digging a hole and burying their garbage. This was kind of effective for early people when their population was relatively small, and they were not producing as much garbage as modern humans do. Burying the trash at that time was helping to prevent bugs, rodents and diseases (Sharma, 2014).

In the modern world, waste management is more complicated. Humans cannot simply bury their trash. Modern humans produce large amounts of waste. Additionally, many types of waste may be damaging to the soil, aquifer water and the existing ecosystem.

When waste is thrown in a landfill, it is emitting greenhouse gas in the form of methane. Although methane can be used to generate energy (see biomass energy section 3.3.4.6), it is generally dangerous on human health. Non-biodegradable wastes buried in landfills also tend to leach chemicals that can contaminate soil and groundwater (Sharma, 2014).

Waste management is an important part of developing an NZED with two strategies: the first one is waste reduction, and the second is waste recycling. Waste management gives the opportunity of reducing waste materials sent to landfills and burners. Consequently, GHG emissions and other forms of pollutants will be reduced by a large percentage. Reusing and recycling of waste items will also result in less need of new production processes. These practices will help to conserve natural resources (Nathanson, 2014).

#### *n. After operation audit*

Performing an energy audit after operation is very important to develop a successful energy conservation program; it helps to target the unworkable EES. Some projects consider their audits based on an analysis of utility bills and equipment metering data. Others may rely on a general walk-through audit. Depending on the degree to which equipment and processes are metered, the level of disaggregation in the analysis may depend on the level of details needed and type of information that can be gathered from its bill, source and site energy calculations. The electric utility or a third party, such as an independent energy services company, may perform the energy audit. Some electrical companies' suppliers offer free audits to their customers to help them reduce their energy consumption (U.S. Environmental Protection Agency, 2013).

### **3.3.2 Renewable Energy Systems**

There is one important question raised about why humans cannot remain dependent on fossil fuels consumption; first, everybody needs to know that fossil fuels are not renewable. They cannot be reused; once fossil fuels are used they are gone forever. Second concept is that fossil fuel is one of the three primary energy sources. If fossil fuels are used totally, then people must rely entirely on nuclear and renewable energy generation to cover all their energy consumption (Busby, 2012).

Renewable energy systems are used to produce electricity, mechanical energy, steam or/and hot water at the point of usage. They are also installed to provide supplemental or backup power. A variety of generation technologies exists, such as the internal combustion engine, gas turbine, fuel cells, batteries, gas engine and solar photovoltaic cells (Gellings & Parmenter, 2002).

Like any other system, renewable energy systems have some advantages and disadvantages. The first advantage of this system is the increase of energy efficiency; these systems are very efficient since they have relatively small energy losses associated with them. The second advantage is the benefits of a back-up generator; the system can provide reliable standby generation capacity during

emergencies and scheduled power outages. Moreover, on-site systems provide fuel diversification. In this way, they reduce full reliability on fossil fuel as a power source. The power produced by on-site systems is higher in quality and lower in greenhouse gas emissions.

On the other hand, renewable energy systems have some disadvantages, like high capital requirement. Even though the running cost is less than fossil fuel energy source projects, the initial cost seems to be very high compared to other projects. Furthermore, renewable energy resources need additional, large spaces for the generation equipment, which can be hard especially in revitalizing existing districts.

In general, the benefits of these systems are greater than the fail points, especially those benefits related to environmental impact mitigation.

***a. PV solar panels (photovoltaics)***

PV is a system that uses photovoltaic cells; these cells are thin slices of chemically treated silicon elements that produce direct, current electricity, which can be used in many applications. Solar cells connected together in modules mounted on a frame and called PV array. PV arrays produce multiple direct current electricity, which can power appliances or be stored in batteries for later use (Busch, et al., 1998).

As shown in Figure 29, solar panels system consists of: PV array, *“storage batteries, a charge controller to regulate battery charging, an inverter to convert direct current electricity to alternating current, and a balance of system components including switches and fuses. This system includes a generator to provide a backup power”* (Busch, et al., 1998).

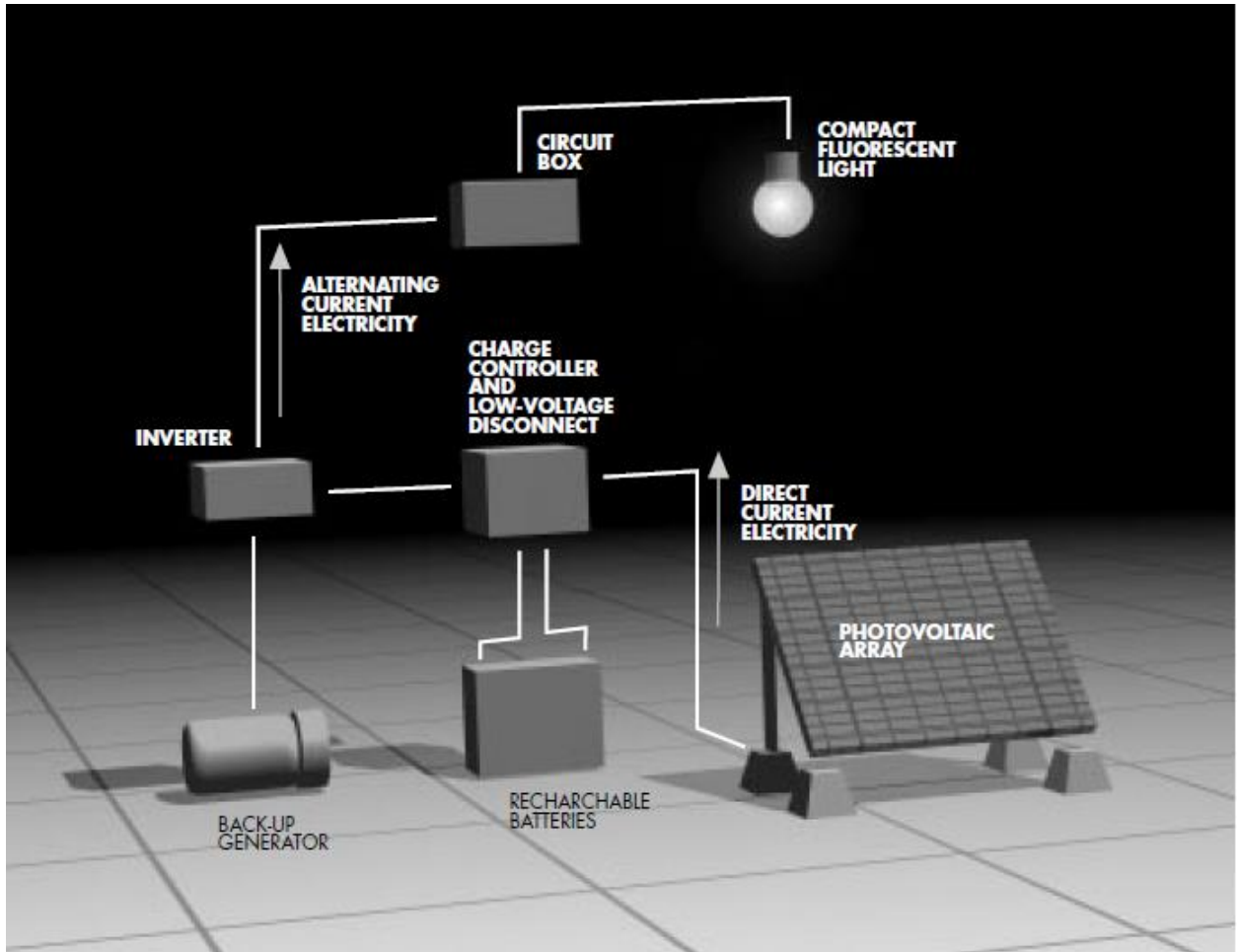


Figure 29: PV Solar Panels System Requirements (Busch, et al., 1998)

In fact, providing a remote PV system to power everything in the building is generally too expensive. For instance, appliances used infrequently, such as a clothes washing machine, may be run more cheaply with a backup generator (Busch, et al., 1998).

***b. Wind turbines***

Wind turbines use the moving wind to produce energy by spinning a generator (see Figure 30). In those areas having good air flow, wind turbines are praised as the cheapest source of power. Most wind turbines are used with batteries to store energy for when the wind is not blowing and it can work without batteries for water pumping and other direct applications (Busch, et al., 1998).

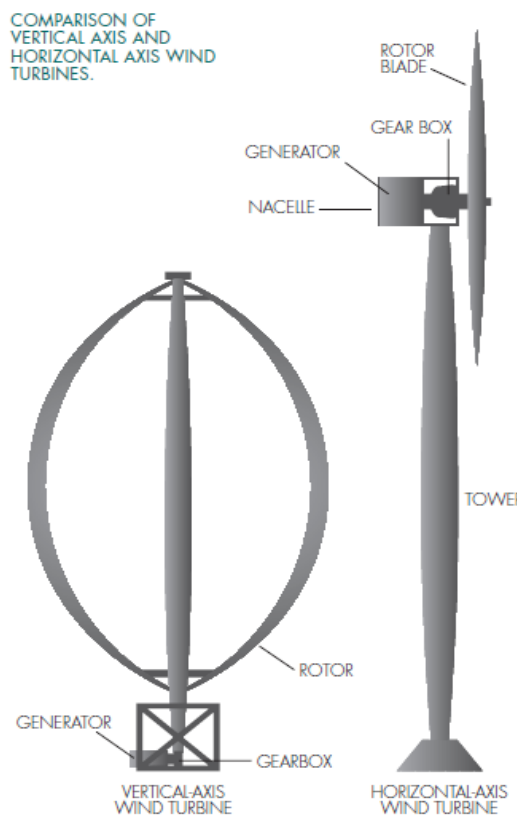


Figure 30: Vertical and Horizontal Axis Wind Turbine (Busch, et al., 1998)

The size of a wind turbine is specified by the ability of the generator, but the actual output of energy depends on the wind speed and diameter of the turbine rotor (Busch, et al., 1998). This system needs a vast area to be installed and work properly, for some countries, like Holland, wind turbines are considered a landmark and tourist attraction.



### *c. Solar water heaters*

Another use for solar panels is solar water heater. It is solar panels that collect heat from the sun and use it to heat up water, which is stored in a hot water cylinder (Energy Saving Trust, 2014).

This system can be operated in all climate types but some are preferred and more efficient in operation process. Basically, solar water heaters are divided into two types: passive (for warm and hot climates) and active (for moderate and cold climates). Active systems use a circulating pump and some type of temperature control. Passive systems do not have any moving parts and rely on the basic physical principle that hot water rises and cold water falls.

Solar water heaters come in many designs, all of them include a collector and storage tank, and all use the sun's thermal energy to heat water (Energy Star, 2014).

Using solar heaters systems instead of electrical ones has many advantages on NZEDs, including the following (Solar Direct, 2014):

- Climate is not forming an obstacle in solar water heater systems any more, the new designs are fitting all climates.
- Using solar water heating system reduces the water heating cost by up to 80%
- Efficient and reliable system has been used widely in USA and Europe and some Middle Eastern countries like Palestine.
- Solar water heaters reduced demand for fossil fuels, which has improved the environment by reducing air and water pollution.

#### *d. Tidal (hydroelectric) power*

Tidal power is a type of renewable energy system that uses the energy of water movement. The greatest predictable energy source that is free and sustainable. Basically, there are two types of tidal energy, dams and ocean flows. The first type is based on using a dam at a bay with a large tidal range. Power is produced during tides movement, much like a “*hydroelectric dam*”. For example; a 240 MW plant has operated at the Ranse estuary in Brittany, France (see Figure 31) since 1966; this is considered as the second largest tidal power construction worldwide. A facility has also been in place since 1984 in Annapolis, Nova Scotia (Martin, 2005). In the Middle East, there is Aswan High Dam in Egypt, which was constructed between 1960 and 1970 and has been used to generate hydroelectricity since that time.



Figure 31: The Rance Tidal Power Station Bridges the Ranse River in Brittany, France (National Geographic, 2014)

The second type of hydroelectric power generation is based on operating the fast-flowing sea currents caused by tidal action. While there are non-tidal based ocean currents, such as the Gulf Stream (like Arabian Gulf in Qatar), the tides cause water to flow inwards from the ocean twice a day during flood tides and outwards during ebb tides. Additional monthly and annual cycles vary the strength

of this current. Narrow and shallow constrictions produce faster and more powerful movements where energy can be captured using underwater turbines. This is still new technology with only a few tested prototypes (Martin, 2005).

Tidal energy is considered the most constant renewable energy because the tidal move is very predictable and follows a daily schedule, depending on the orbits of the earth, moon and sun. Furthermore, tidal energy is carbon free, but on the other hand it is not totally environmentally-friendly. There are some cases that show tidal energy affecting, somehow, the shoreline and aqua-ecosystems (Helston, 2012).

In addition, large tidal barrages have large capital costs and long construction times. This is somewhat balanced out by long plant lives, 100 years for the actual barrage structure and 40 years for the equipment (Helston, 2012).

#### *e. Geothermal power*

The word geothermal has Greek roots, geo (earth) and therme (heat), meaning “earth’s heat”. Thus, thermal energy is energy generated and stored in the earth (Boyer, 2012).

Geothermal energy is heat from the earth used in electricity production, direct thermal use and geothermal heat pumps, which are also called geo-exchange units or ground-coupled heat pumps (Green, 2013).

Historically, geothermal power developed in the twentieth century. The first experiments on geothermal power began in Lardarello, Italy in 1904. Subsequently, the first U.S plant was built at the Yellowstone geysers in the 1920s. However, the first commercial plant was not built until 1960 (Green, 2013).

Geothermal energy falls mainly into three types: direct dry steam, flash and double flash cycle, and binary cycle. In the first type, direct dry steam, the steam comes from the earth and moves directly to a turbine, which drives a generator that produces electricity. While in the second type, flash and double flash cycle, a very high temperature fluid (above 360°F-182°C) is preheated underground

and sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or “flash”. The vapor pressure drives a turbine, which drives a generator. In the third type, energy is extracted from these hot fluids in binary-cycle power plants (State of California Energy Commission, 2014).

A geothermal power production loop is closed, meaning there are no GHG emissions produced or solid wastes added to the environment. Figure 32 shows a 1998 comparison made by the EIA of several energy primary sources and geothermal power.

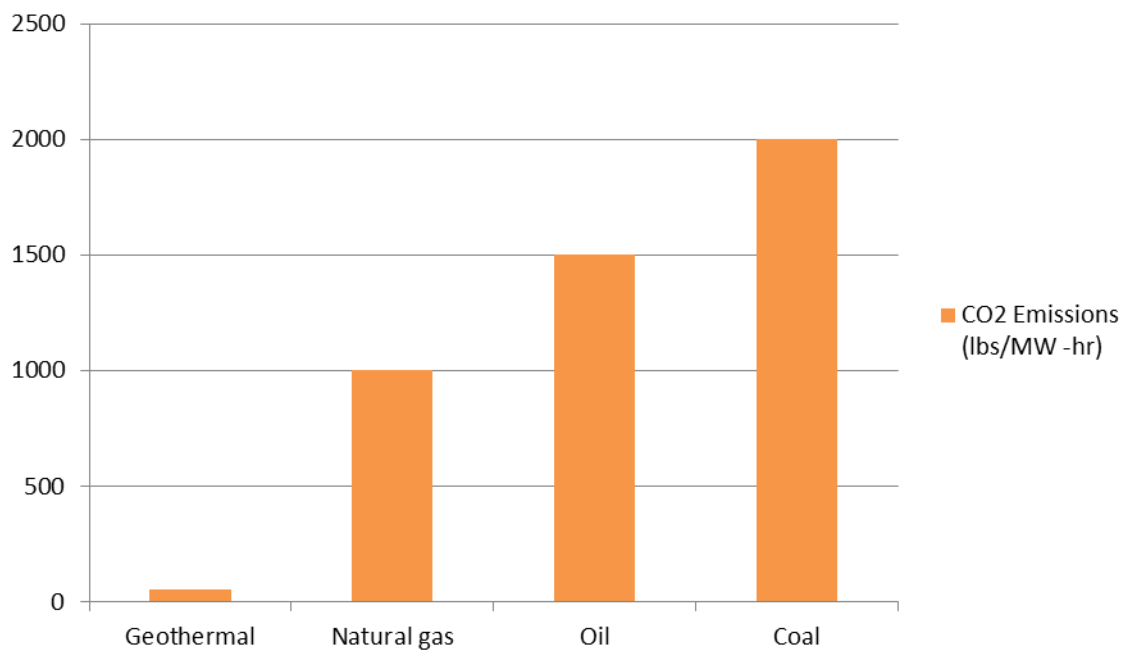


Figure 32: CO<sub>2</sub> Emission Comparison Done by EIA 1998 (Green, 2013)

In NZED, the most important usage of geothermal power is geothermal district heating (GeoDH) and geothermal district cooling (GeoDC). In the Middle East, especially in the Gulf area, the most important factor in energy consumption is cooling. Existing district cooling systems mostly rely on fossil fuel. Even though district cooling systems are reducing energy consumption, they are still using fossil fuels, a non-sustainable resource. District cooling by absorption chillers can be easily operated by geothermal energy with no CO<sub>2</sub> emissions or fossil fuel consumption.

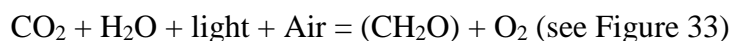
Absorption chiller cooling is the oldest form of air conditioning and refrigeration. “An absorption heat pump or chiller uses a heat source, to evaporate the already-pressurized refrigerant from an absorbent-refrigerant mixture instead of electric compressor. This takes place in a device called the vapor generator. Although absorption coolers still requiring some electricity for pumping the refrigerant, the amount is so small compared to that consumed by a compressor in electric air conditioner or refrigerator. The absorption cycle requires a cooling water supply to enable processes in the absorber and the condenser” (Rogowska, 2003).

In fact, 63% of Qatar’s domestic energy production is totally driven by fossil fuels; this fatal use of energy creates a high CO<sub>2</sub> footprint. Scientists are expecting suitable temperature regimes in Qatar’s geological subsurface, even though, operating geothermal energy in Qatar, for example, requires detailed hydrogeological and geological feasibility studies. If this happens, geothermal power will replace fossil resources and will improve the CO<sub>2</sub> footprint (Kreuter, 2010).

*f. Biomass energy (bio-power)*

Biomass—as is most of the renewable energy sources—is still relatively unknown. Biomass power or waste-to-energy power uses plant and animal waste; it is the oldest source of renewable energy, used since human ancestors learned the secret of fire. Biomass energy systems can supply far more renewable electricity or *bio-power* than wind and solar power combined (Union of Concerned Scientists, 2014). Biomass energy is a renewable, low emissions fuel and its production and use have many environmental and economic benefits if correctly managed (Biomass Energy Centre, 2011).

Biomass process depends on photosynthesis by capturing solar energy and carbon dioxide, carbon dioxide (CO<sub>2</sub>) is converted to organic compounds, and this is the initial step in the growth of virgin biomass and is described by the following equation (the simple equation of photosynthesis):



Carbohydrate or biomass, represented by the block (CH<sub>2</sub>O), is the primary organic product (Klass, 1998).

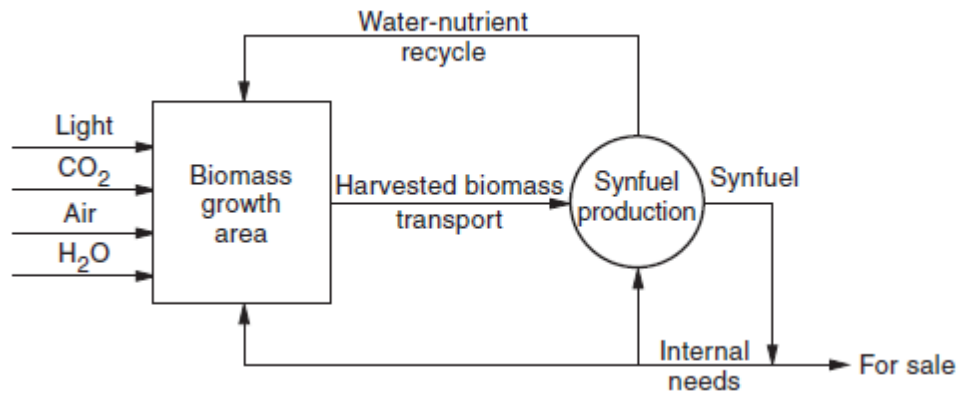


Figure 33: Idealized Biomass Growth and Manufacturing (Klass, 1998)

Biomass power comes from different sources, such as: (Zafar, 2014):

- Wood from forests.
- Agricultural remnants such as dry straw, Stover and green agricultural wastes.
- Agro-industrial wastes, such as sugarcane bagasse and rice husk.
- Animal wastes.
- Industrial wastes, such as black liquor from paper manufacturing.
- Sewage.
- Municipal solid wastes (MSW).
- Food processing wastes.

A waste-to-energy renewable energy source is an important type of bio-power production. In fact, if biomass wastes were left thrown, they will break down over a long period of time, slowly storing energy, but they are releasing carbon dioxide. By burning biomass wastes, this energy is released quickly and in a useful way, and the carbon dioxide can be controlled (Zafar, 2014).

Waste-to-energy production reduces GHG emissions in two ways. First, enough heat and electrical energy will be generated, which reduces the dependence fossil fuels. Second, preventing methane

emissions from escaping landfills significantly reduces the greenhouse gas emissions (Zafar, 2014). On the other hand, biomass power may have environmental risks that need to be mitigated if not used carefully. It can be collected at unsustainable rates, damage ecosystems, produce air pollution, consume extra amounts of water and produce GHG emissions when burning (Union of Concerned Scientists, 2014).

In Qatar, waste is collected and mostly disposed of in landfills. There are three landfills in Qatar: Umm Al-Afai for bulky and domestic waste; Rawda Rashed for construction and demolition waste; and Al-Krana for sewage wastes. This method of waste disposal by landfill is unsustainable action and it harms the environment, yet only 8% of produced waste in Qatar is getting recycled. Actually biomass power project in Qatar will benefit both the environment and energy resources (Suresh, 2014).

### **3.4 Discussion and Conclusion**

This chapter is considered the core of this study. It sets guidelines for districts identification assessment method according to their energy consumption and energy efficiency. These guidelines will be used later to assess the case studies. Considering the four Parameters, some might say why not use the energy cost only as an indicator to assess NZED; energy cost is the simplest calculation and can easily be determined by checking the total energy bills of the project. But, energy prices are sometimes different from country to country. In Qatar, for instance, energy prices are low compared with other countries. Some national buildings are exempt from electricity and water bills. Consequently, these buildings have zero energy cost, but they are not zero energy projects. Likewise, source energy and site energy are different from country to country, and vary according to their primary resources and even residents' lifestyles. Therefore, the suitable NZED Indicator has to be determined by case basis.

Nowadays, energy modeling programs, like DESIGNBUILDER, sum up all calculation steps by creating a similar model of existing buildings, streets, services, etc., it can be filled with all the energy data and parameters to run a simulation of the exact energy usage in and out of the building. The good point in energy modeling programs is that the user can add or remove any energy efficiency indicator (like adding shade elements on the façades of the buildings at the right orientation) and calculate the influence of this change on the total energy consumption. By adding and removing parameters, the designer can reach the best energy practice of the district while still in the design stage.

The EES mentioned in this study are not only available strategies, but these Parameters have been collected from many primary and secondary resources and are meant to fit with Middle East projects. The mentioned renewable energy systems are the most noteworthy systems that use available resources like sun, water and waste. Many more renewable energy systems have not been covered in this research for two reasons. Either they are using unavailable or costly resources (such as ice, which is more available in polar regions), or because they are similar in concept with other mentioned renewable resources and need no additional discussion in this research.

Finally, the energy field is wide and constantly renewing. One research project is not enough to address all its issues. This study attempted to address NZED related issues of energy to create an integrated system for assessing NZEDs in Qatar and in the region.



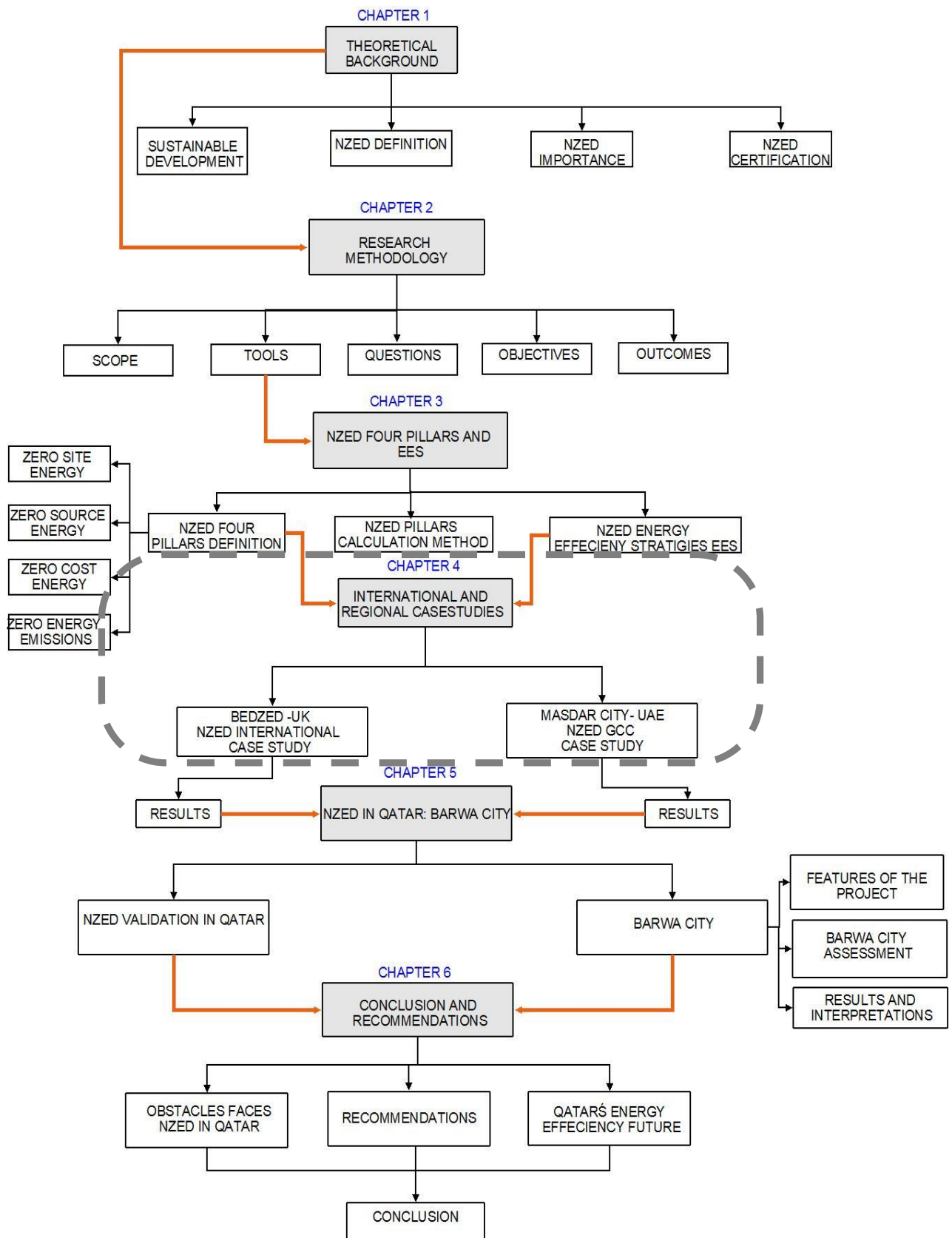


Figure 34: Flowchart of Research Phases – Chapter 4

## Chapter 4. International and Regional Case Studies

There is a new trend of communities adopting districts to make groups of buildings that use Net Zero Energy. According to the global census in 2011, there are a total of 178 zero-energy district initiatives worldwide. Following from an earlier generation of sustainable cities in the 1980s and 1990s, the growth of this new breed of zero-energy districts has been particularly pronounced since the mid-2000s, and especially across Asia (Barry, 2012).

This study will choose two case studies—international and regional—to address if those districts are NZEDs or not according to theoretical work done previously in this study. The data displayed in these two case studies was collected from reports, websites, books and conference papers, accurate information about each case study was investigated as much as possible.

### 4.1 International Case Study: The Beddington Zero Energy Development (BedZED)—Beddington—UK

The first case study is the BedZED project; it was designed to be the UK's largest sustainable community (see Figure 35). It was built in 2002 to provide ordinary people with a high quality of life while living within their share of the earth's resources (Barry, 2012).



Figure 35: The Beddington Zero Energy Development (BedZED) (Chance, 2009)

BedZED's new-build development consists of residential buildings plus 3000 square meters for live/work units, work spaces, commercial and services, established on an urban brownfield site in South London (Twinn, 2003). The project was implemented and operated by Bioregional Development Group with Bill Dunster Architects, Arup, and Gardiner and Theobald as cost consultants (Andrews, 2008).

The development consists of 82 houses, 18 live/work units, and 1,600 square meters of office buildings, retails and services, like shops, café, sport facilities, health center, and nurseries (see Figure 36). BedZED was opened for residents in 2002 and recently the district is home for around 220 residents.



Figure 36: BedZED Layout Plan adapted from (Chance, 2009)

The design concept of BedZED project was initiated to create a free Fossil-Fuel community in London, applying Net Zero Energy District principles to produce renewable energy as much as consuming. Its mission was to use only renewable energy to be the first carbon-neutral development in UK (Hodge, 2008).

#### 4.1.1 Application of EES

BedZED district started as a green project idea, and being a new project gave the opportunity to apply most of the energy efficiency strategies, unlike the revitalization projects, which did not have the opportunity to apply some strategies like orientation and location.

##### a. District location

BedZED District is located in Hackbridge, London, UK. It is in Sutton area (see Figures 37, 38, 39 and 40), 2.0 miles (3 km) northeast of the town of Sutton itself. BedZED’s location in the UK positively affects the desire of making the project a zero-energy district. One of the reasons being that the UK—as per the recent records—has only fifteen years of North Sea natural gas left.

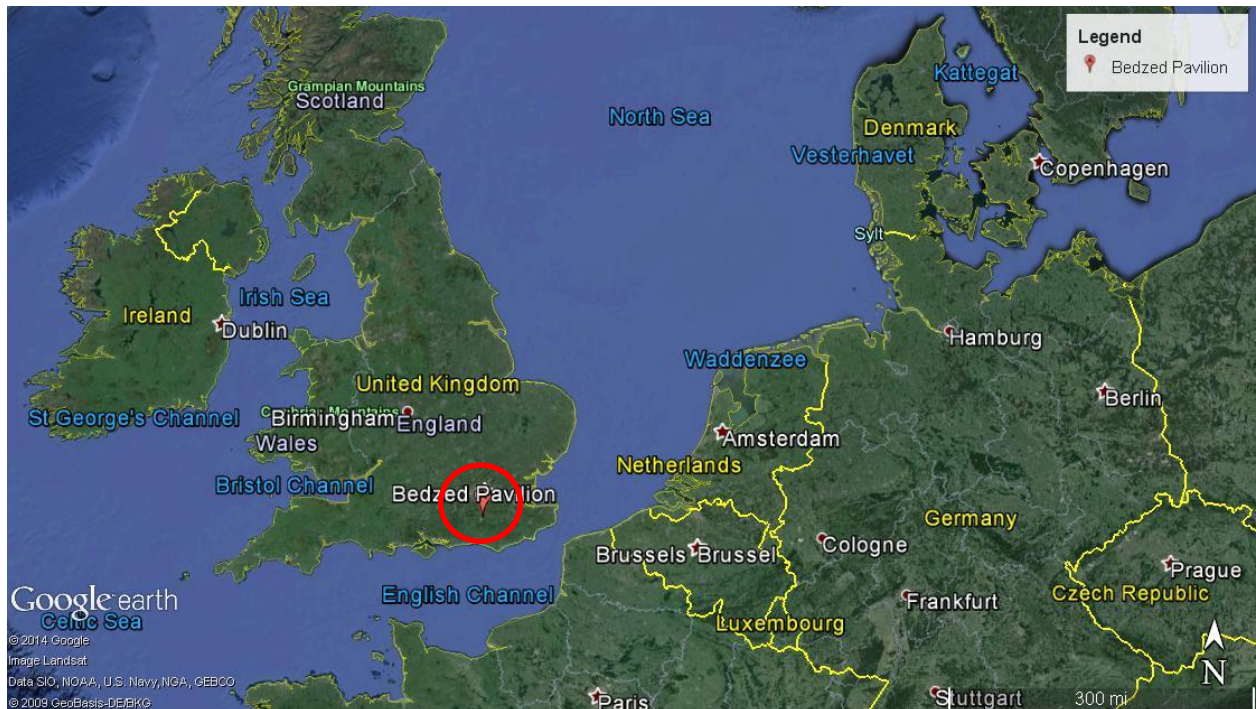


Figure 37: BedZED Location in UK (Google Earth, 2014)

Once this is consumed, the country will be totally depending on fuel reserves from non-renewable sources (Lazarus, 2003).

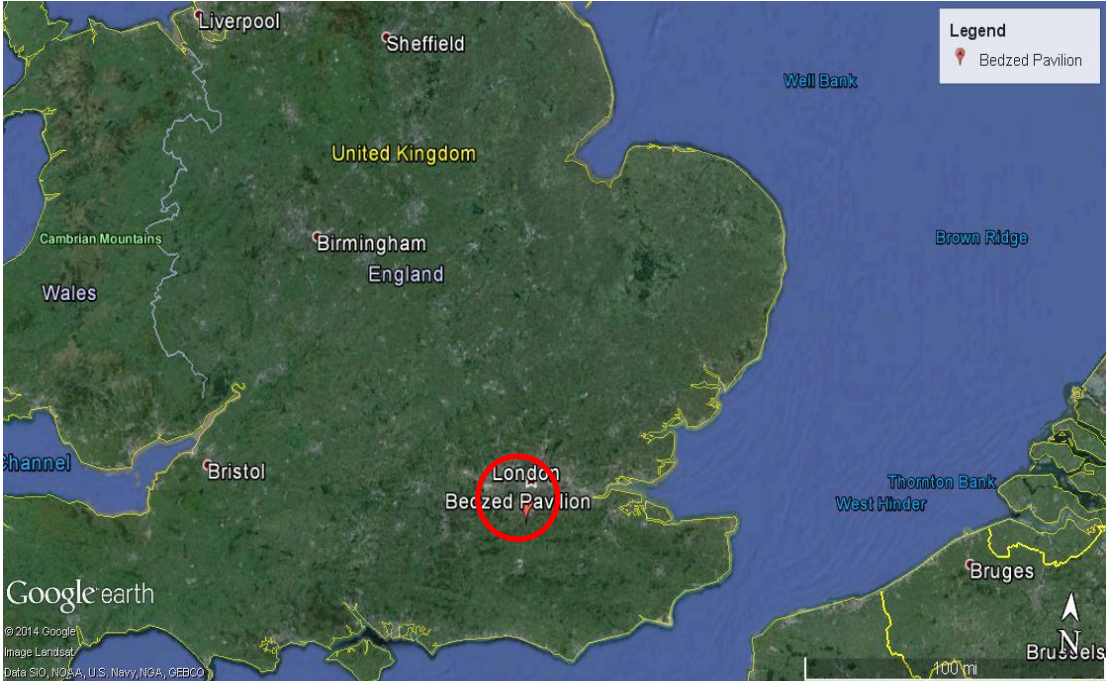


Figure 38: BedZED Location in London adapted from (Google Earth, 2014)



Figure 39: BedZED Location in Beddington (Google Earth, 2014)



Figure 40: BedZED Site adapted from (Google Earth, 2014)

Furthermore, the average CO<sub>2</sub> emissions for each of UK's citizens is 12.3 tons per year. This number is responsible for 80% of the total annual GHG emissions.

The UK's Royal Commission on Environmental Pollution (RCEP) has recommended an urgent reduction of CO<sub>2</sub> pollution by 60% before 2050. This is the motivated target for implementing sustainable projects in the UK (Lazarus, 2003). Since BedZED was established, the UK's government addressed that reducing the countries footprint is not impossible. The government started to revise building regulations to address environmental issues for first time (Twinn, 2003).

Internally, BedZED was built on a brownfield site; it was used initially for sewage mud disposal. Using this site to implement BedZED community has benefited the city by reducing its pollution levels and green footprint (Lazarus, 2002).

The site was originally owned by the municipality of Sutton, the latest welcomed this sustainable development at the possible lowest cost. One more advantage of the site is the good location in the middle of public transport network. Bill Dunster and his group started to put the primary sustainable concept of the project together in 1996, which seemed to be very theoretical at the beginning (Commission for Architecture and the Built Environment, 2011).

***b. District at design and construction stage***

As discussed in the previous chapter, the design and construction stage is very important to set up EES from the early stages.

***c. Orientation***

BedZED's design begins with an energy efficient idea that gives the development the chance to benefit from the best orientation of its buildings. The homes' terraces at BedZED are facing south to have the advantage of passive solar principles that come from the sun's natural light and heat (see Figure 41). At the same time, these homes are triple glazed and are super-insulated to reduce cooling and heating load. On the other hand, office buildings are facing north to reduce air conditioning loads (ZedFactory, 2002).

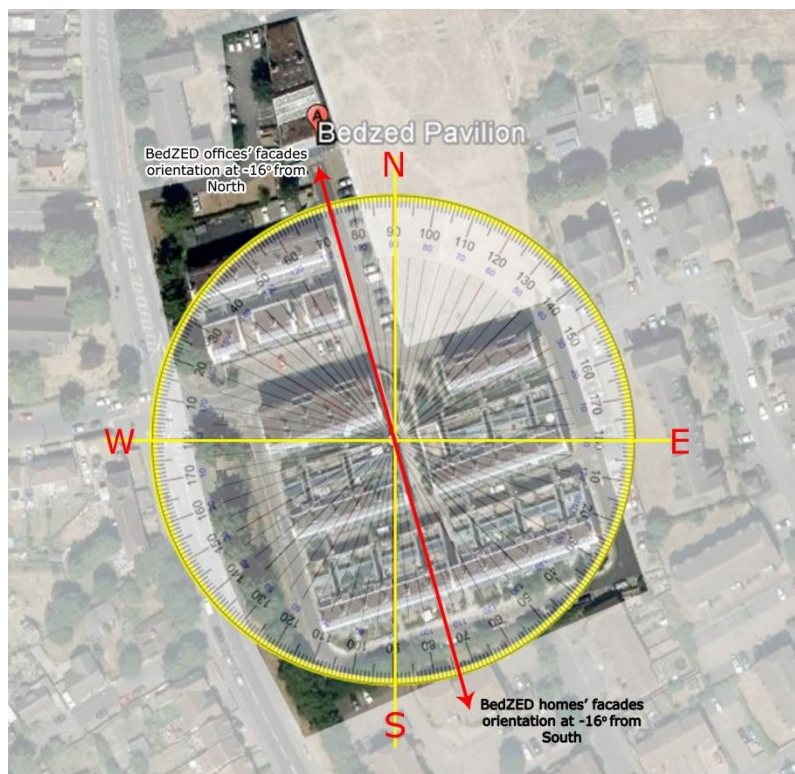


Figure 41: BedZED Buildings' Main Façades Orientation

*d. Integration of the district*

Mixed-use dense development offers a valuable accommodation with no more water and fuel charges. In BedZED, most of the needed facilities are provided inside the community—even organic food, where the residents can grow their own food in the community gardens. Easy to use recycling bins are distributed everywhere in the city: homes, retails, streets, gardens...etc. BedZED encourages a green lifestyle by endorsing pedestrian walkways, cycling and bus and train stops within walking distance from the residential buildings (see Figure 42). Car use is not welcomed in BedZED community (Standley, 2009).

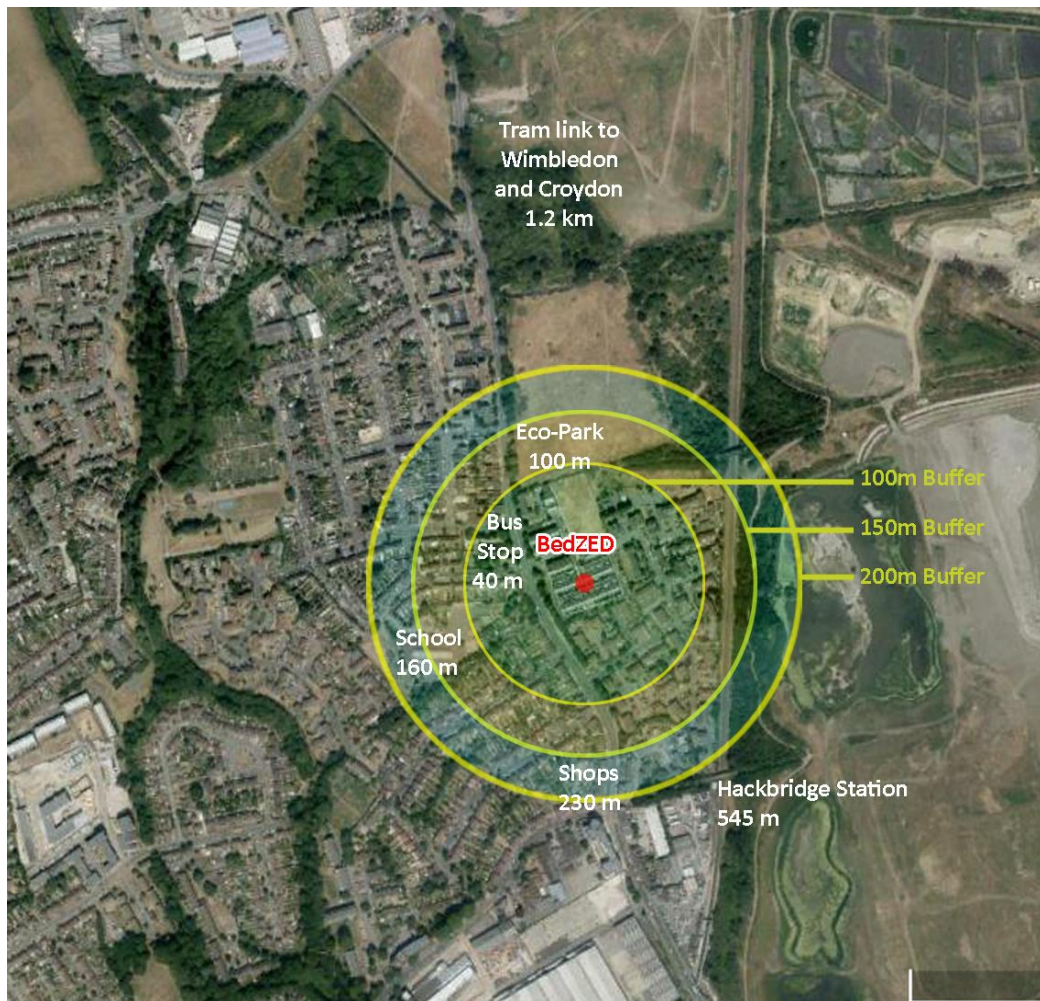


Figure 42: Public Facilities' Distances from BedZED



*e. Urban structure*

BedZED is a high-density settlement with large, green open spaces and gardens, and yet every home has a rooftop garden to maintain the overall view and the residents' well-being (Dauncey, 2004).

BedZED contains 130 homes per hectare; it is higher in density than most of Sutton's settlements (Dauncey, 2004). The district contains residential, commercial, and mixed-use buildings. Some of its public spaces are open to the sky like the village green square and the sports pitch, while others are covered like a sports clubhouse and community center. The district has pedestrian-friendly ways that are not welcoming personal cars when possible (see Figure 43).

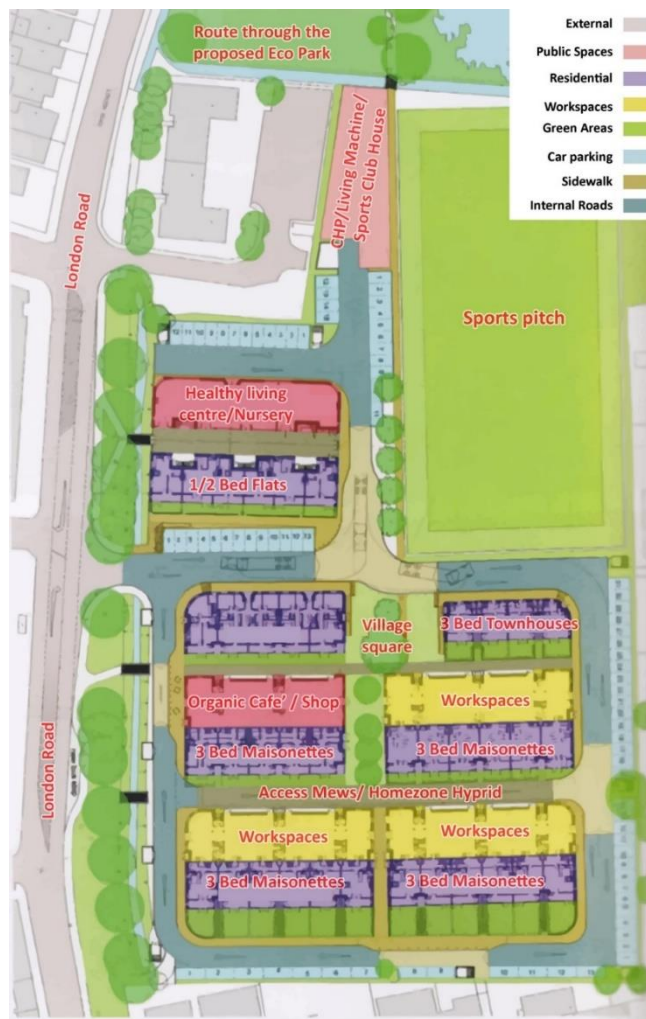


Figure 43: BedZED Zoning Plan by Author adapted from (Rackey, Chatto, & Fouch, 2006)

Bed ZED established a healthy community, which is considered as the biggest achievement of the project. The residents of BedZED named an average of 20 people in their community, which indicates a very strong community, while the average was less than 10 persons in other Sutton communities (Chance, 2009).

The space design and the created public spaces have affected the relations between occupants. The site layout creates more opportunities for neighbors' interaction; all events and residents' meetings are held in the community center managed by the residents themselves (Chance, 2009).

Good environmental awareness helped residents to understand how to cooperate in achieving maximum electrical efficiency; it helped them also in applying some techniques to keep their homes cool in summer. Also, it helps to increase recycling among users (Chance, 2009).

In social terms, Bioregional—the project operator—evaluated residents' satisfaction. This evaluation showed that BedZED seems to be successful, since 84% of residents stated that their quality of life has increased since they moved in (WWF, 2012).

#### *f. Infrastructure (District Energy Networks)*

In London, heating is the biggest concern of the residents. BedZED is supposed to receive heating power from a technology called combined heat and power plant (CHP). The heat from the CHP also can provide needed hot water, which is distributed around the project by a district heating system network of super-insulated pipes (Hodge, 2008).

Practically, BedZED's district-heating power plant was unsuccessful; the scale was too small to run, costly and unpractical (see section 4.1.3). Such service has to be provided by the government on a larger scale to work properly (WWF, 2012).

Another failure in the BedZED District Networks is that residents have no authority to turn off the heated towel rail in their bathrooms, which can lead to overheating and wasting energy. This was an unexpected consequence of the original design, which delivers hot water to the towel rail via the

district heating system. As a suggested solution, the designer has to separate the towel rail to another loop to solve this problem, but it will cost more time and money to update the existing infrastructure (Hodge & Haltrecht, 2009).

*g. Façades*

Selected materials in BedZED façades are affected by London’s thermal requirements. Buildings need to mitigate cold weather and benefit from the sun’s heat using specific materials. Nicole Lazarus—the engineer at Bioregional (BedZED’s designer company)—reviewed using façade materials in BedZED such as:

- Efficient double or triple glazing especially when facing north or west.
- Using heavy materials with high thermal performance that can store heat at day time to radiate it in cool nights.
- Using wind in ventilation.
- Passive solar gain from sunspace buffer zones on south elevations, in addition to efficient zoning design to take advantage of heat gains.
- External walls are a mixture of isolated brick with block cavity construction and timber stud weatherboarding (see Figure 44).



Figure 44: Brick/Weatherboarding Combination (Lazarus, 2002)

- All openings and grooves in the external walls were carefully filled by silicon sealants.

Weatherboarding is a local feature of the area; it keeps the look of local architecture and protects the building against the weather. Local oak was chosen instead of imported wood for environmental benefits.

The main elements in the building façades that affect its energy efficiency performance are windows. In BedZED, all windows are double or triple glazed (see Figure 45) especially in the north and west elevations of the buildings where the cold is most effective (Lazarus, 2002).



Figure 45: BedZED Windows by (Raf Makda, 2002)

Timber frame windows were chosen for environmental impact reasons. Local oak could not be used in the windows' frames as designed because of the large size of BedZED windows, for which it would be costlier to make a custom frame. Therefore, BedZED windows were ordered from a Danish company that produces high performance window frames at all sizes. They offered the best lifetime thermal performance, lowest environmental impact with a good price (Lazarus, 2002). On the other hand, the long delivery journey for this material caused a significant loss in energy counted mainly by the source energy.

### *h. Thermal insulation*

Thermal insulation is one of the biggest factors that affect energy consumption, by affecting cooling and heating loads. Walls in BedZED's buildings are insulated with rock wool (see Figure 46); ground floors are insulated with expanded polystyrene and the roofs with extruded polystyrene. Chosen insulation products offered the best durability for each application (Lazarus, 2002).

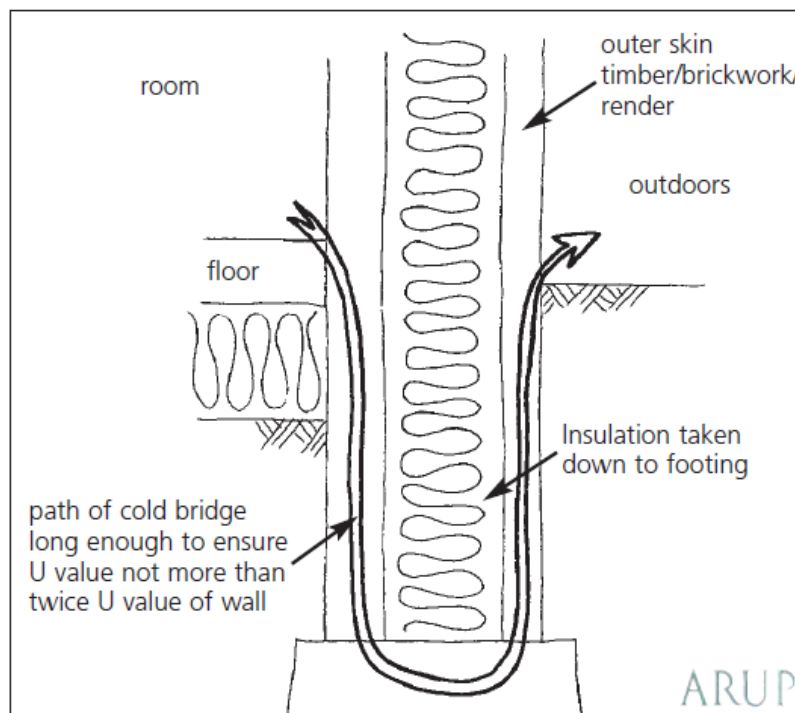


Figure 46: Walls and Floors Thermal Insulation in BedZED to Avoid Cold Bridge (Lazarus, 2003)

## **2- Materials**

BedZED built from natural and recycled materials that reduce consumed energy for extraction, production and transportation. Selected materials were sourced within a 35-mile radius of the site where possible (Hodge, 2008).

The following is a construction material analysis published by Bioregional Development Group (one of the BedZED stakeholders) written by Nicole Lazarus, the Policy and Communications Manager of the group (Lazarus, 2002):

- Bricks and blocks produced locally within 20 miles' distance.
- Pre-stressed concrete floor was used for internal slabs, which save in steel usage.
- Ninety-five percent 95% of used steel frames in BedZED is reclaimed.
- Internal wooden partitions are from reclaimed materials, while 80% of the external studwork is also reclaimed. There are also 150 reclaimed doors used in the project.
- Using interior finishing materials have been avoided where possible, such as using painted brick finish in walls instead of plastering, using nearby clay with sand in flooring instead of flooring tiles. No suspended ceilings were used where possible and very low environmental impact linoleum was used to cover toilets and kitchens floors.
- UPVC was used as little as possible and only where there are no alternatives for it with an affordable price, like wiring, water pipes or cable sleeves.
- Non-toxic paint was used in BedZED buildings; this paint is made from water, chalk, vinegar, salt, powdered marble and other natural materials. Practically, some difficulties were faced to reach a smooth finish of this paint mixture, which lead the contractor to mix it with other regular toxic paint to simplify work with it.

### ***3- Electrical equipment***

The solar passive design of BedZED let the daylight replace the need of artificial lighting during the daytime. In addition to using LED lights, which have reduced the electrical consumption by 80%. The average annual lighting demand for south of England households is 606 kWh; in BedZED it is 94 kWh only (Lazarus, 2003).

Furthermore, energy efficient appliances were used most in BedZED buildings, where Figure 47 shows recorded electricity consumption for 72 BedZED homes. The average BedZED electricity consumption until June 2003 was 3.0 kWh/person/day, and it is low compared with a UK average of 4.0 kWh/person/day (Lazarus, 2003).

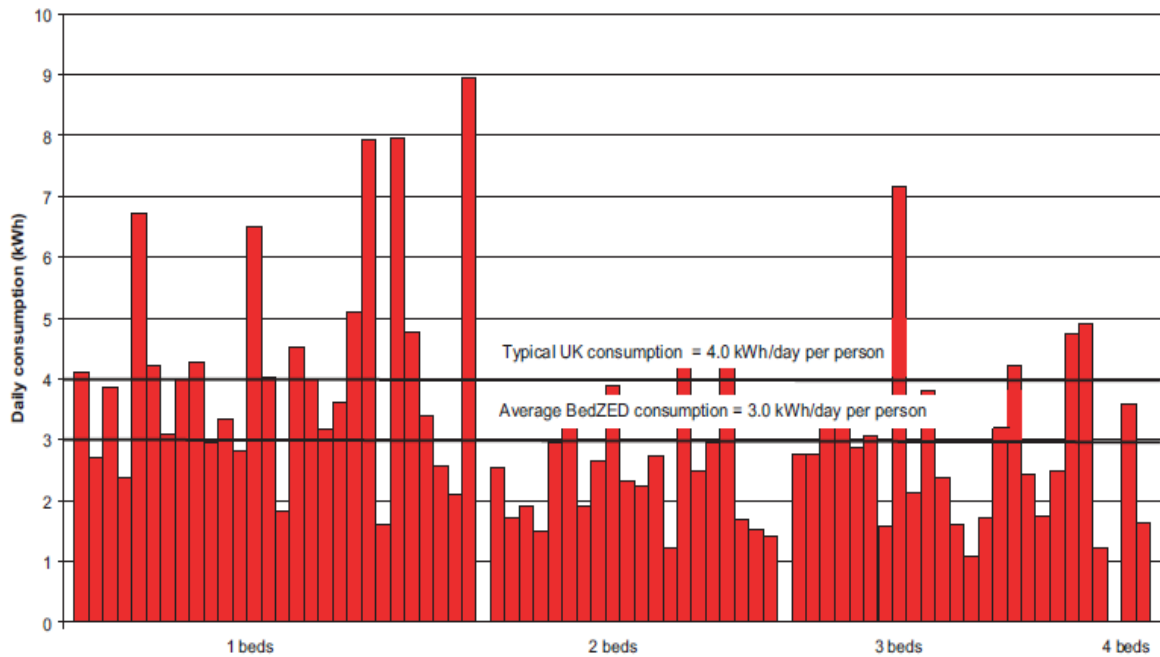


Figure 47: Average Daily Electricity Consumption per Person for 72 BedZED Households (Lazarus, 2003)

#### 4- Landscape

All landscape works used on-site reclaimed materials. Crushed concrete was used instead of fresh aggregate as road sub-base. It was used to cover 30% of landscaping areas, and it is a good technique to absorb rainwater into the natural underground water rather than the sewage water network (Lazarus, 2002).

Crushed green glass was used in paving instead of sand, which is cheaper and has an interesting look (see Figure 48). Native species of plants were used for landscaping, which consumed less water and better supported the local ecological system (Lazarus, 2002).



Figure 48: Landscape in BedZED by (Woodrow, 2010)

### ***5- Water strategy***

There are many strategies used in BedZED to save water resources, such as collecting rainwater and filtering black water into grey water to reuse it for toilet flushing. Also, most water-efficient appliances (at the construction time 2002) were fixed in bathrooms and kitchens, in addition to placing a visible water meter in every kitchen to keep water consumption under surveillance.

These techniques reduced water consumption by 76 liters/day (see Figure 49) (Hodge, 2008).

BedZED residents are charged for “green water” less than fresh water to encourage using green water



and recycling. “Green water” is a mixture of rainwater and recycled, treated wastewater (Lazarus, 2003).

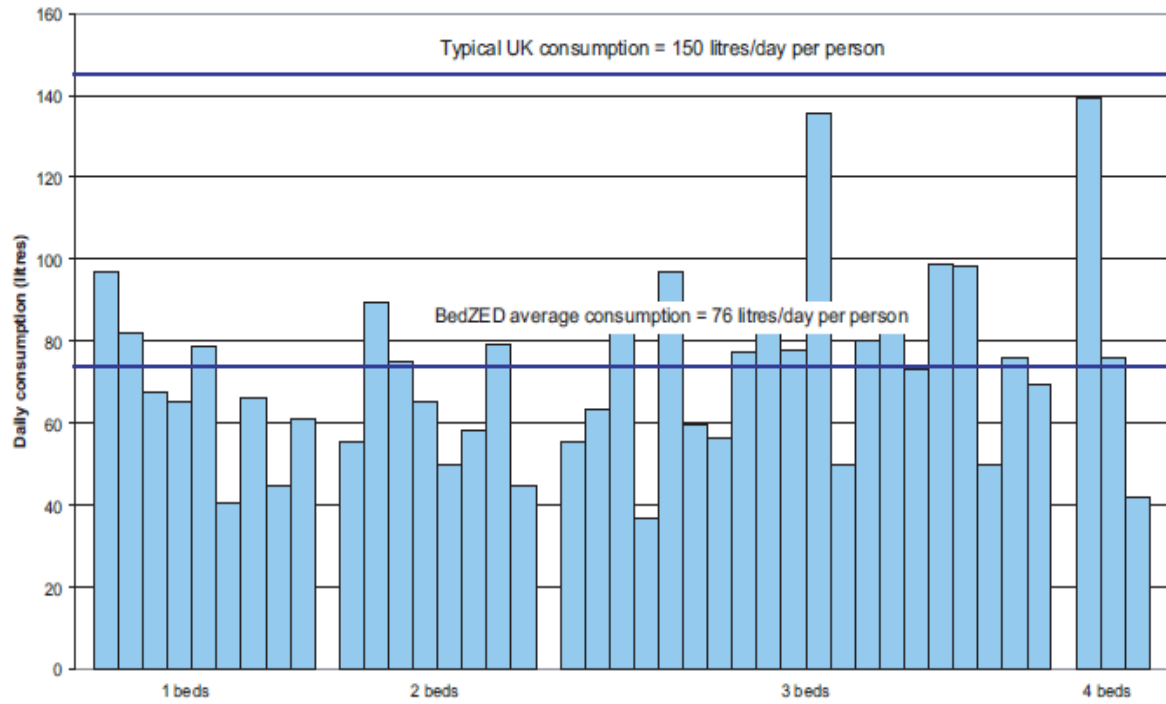


Figure 49: Average Daily Mains Water Consumption/Person for 40 BedZED Households (Lazarus, 2003)

BedZED toilets are provided with 4 liters per flush toilets instead of the ordinary toilets, which consume 9 liters per flush, and saved around 11,000 liters/person/year (Lazarus, 2003).

Water efficient showering fittings were also fitted in BedZED homes in addition to self-regulating flow restrictors added to the water taps; the latter reduces water consumption by around two thirds of the original consumption (Lazarus, 2003).

### ***6- Transportation***

Public transport is a hallmark of London; especially, the red double-decker bus, but the citizens of London like anywhere else like to drive their own cars and the city is full of them (O’Hare, 2010).

In BedZED, a green transportation plan was created that promoted 50% less use of private cars. The project is surrounded by many bus stations and within a walking distance from the metro rail and has many needed services within walking distance inside the district. Only 0.5-car parking is provided per unit and the car owner has to pay for it. There is a car club called ZED cars, which has an internet based booking system, that helps to share the provided electrical cars powered by solar panels (see Figure 50) between tenants instead of having their own fossil-fuel cars (Carmody & Weber, 2009).



Figure 50: Electric Vehicle Charging Points at BedZED Powered by Renewable Energy, picture by (Ashley Cooper, 2007)

In general, alternatives like walking, cycling, ZED cars, and public transport were provided to reduce the need of private cars in BedZED. The owners of BedZED promoted pedestrians' priority by providing Drop-Kerbs for baby strollers and wheelchairs, good lighting and natural observation of paths by the houses. These are all part of walking encouragements and creating lower levels of air and noise pollution (Lazarus, 2003).

BedZED encourages cycling by providing on-site prepare shop and up to 3 bicycle parking spots per unit cycle (see Figure 51) located close to the entrances in the ground floor hallways (Lazarus, 2003).



Figure 51: BedZED Pedestrianized Areas and Cycle Parking, picture by (Tom Chance, 2008)

## *7- Waste management*

BedZED residents are truly educated about the importance of reusing their wastes as much as possible. They are using color-coded recycle bins that segregate their wastes (see Figure 52). BedZED tenants produced 68% less waste than the UK average by weight (Carmody & Weber, 2009). In BedZED, the recycling rate reached 60% of the total produced waste.



Figure 52: Divided Bin in BedZED Kitchen (Hodge & Haltrecht, 2009)

## 4.1.2 Renewable Energy Systems

### a. Wood-fueled combined heat & power (CHP)

Combined heat and power (CHP) is a new renewable energy technology that can produce heat and electricity at the same time with no carbon emissions produced at the side of this operation (see Figure 53). (Speirs, et al., 2010).

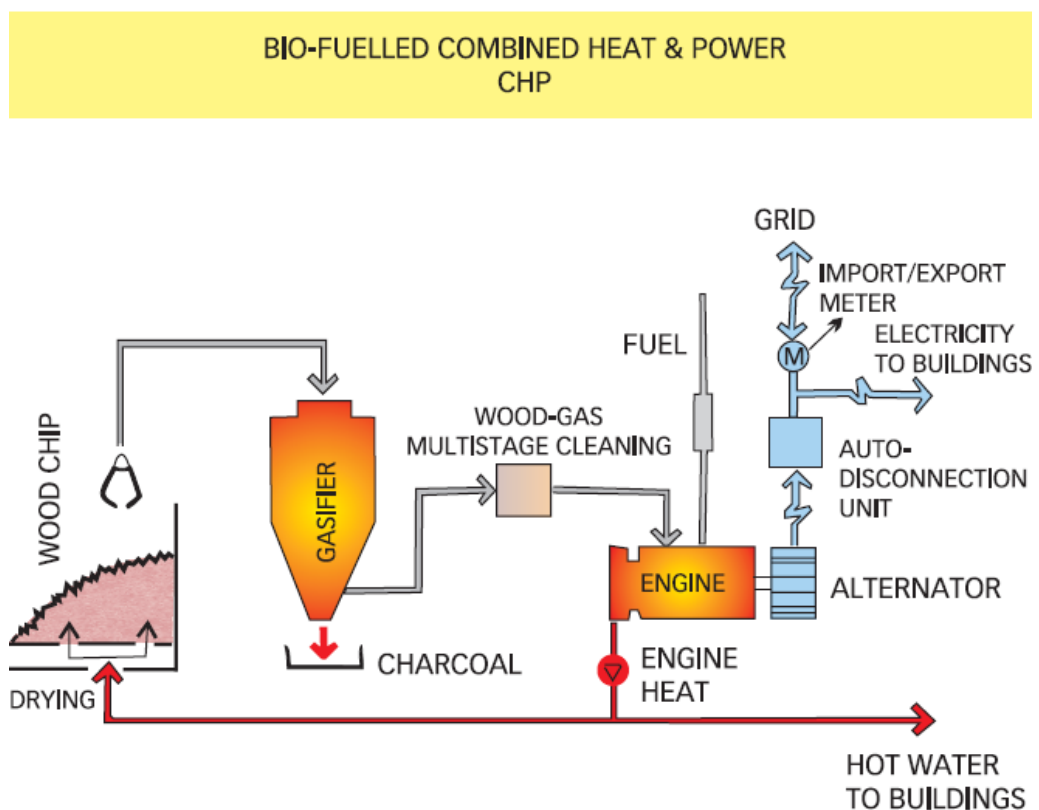


Figure 53: The Bio-fueled Combined Heat and Power Plant Renewable Energy System (Chance, 2009)

This system was designed for use in BedZED to produce energy, homes' heating and water heating. In the CHP system, energy produced from burning woodchips and the waste heat from the burning process is used totally by the engine in water and space heating, then special gas is heated by this process as well and fed into a "spark ignition engine". The engine shaft is connected to a generator, which produces electricity (Hodge & Haltrecht, 2009). Theoretically, this system is supposed to provide 100% of the needed power to BedZED, but in their monitoring report, Bio Regional listed some technical problems with the CHP system as follows (Hodge & Haltrecht, 2009):

- The automatic ash removal didn't work properly.
- Durability of some parts of the machine is not sufficient to operate it constantly.
- Tar condensing from the wood gas gathered up on the machine and increased during cooling of the plant when shut off at night.
- The operating costs are higher than expected including maintenance costs.

***b. Photovoltaics***

At BedZED there are 777 square meters of photovoltaic panels, located on the buildings' rooftops and second-floor windows. Basically, these solar panels are supposed to operate 40 electrical cars on site, but residents did not cooperate in having their own electrical cars for many reasons. Yet, there are only two electrical cars in the project owned by ZED factory and Bio Regional (the project developers). However, the produced energy from the photovoltaic panels is used for other purposes, but there is no electrical power exported to the national grid as designed. Until 2006, CHP was not working; table 7 below shows the imported and exported electricity in six months at 2006. Notice that all of the exported electricity is from PV panels (Corbey, 2005)

*Table 7: Monitored Import and Export Electricity for BedZED adapted from (Corbey, 2005)*

	<b>Electricity imported kWh</b>	<b>Electricity exported kWh</b>	<b>Net grid electricity consumed kWh</b>
May-06	12,312.87	725.95	11,586.92
Jun-06	14,423.06	2,627.71	11,795.35
Jul-06	14,897.27	2,558.72	12,338.55
Aug-06	21,436.51	538.41	20,898.1
Sep-06	22,742.4	273.95	22,468.45
Oct-06	24,115.51	243.04	23,872.47
Nov-06	14,903.52	11.96	14,891.56
<b>Total</b>	<b>124,831.14</b>	<b>6,979.74</b>	<b>117,851.4</b>

### **4.1.3 NZED Four Parameters Application in BedZED**

#### ***a. BedZED source energy consumption***

BedZED is not zero source-energy consumption, the development was designed to use only energy from renewable sources generated on-site (ZedFactory, 2002). However, since 2005, 80% of used electricity is imported from the national grid and hot water comes from ordinary water boilers operated by natural gas (Chance, 2009).

The 777 square meters of solar photovoltaic (PV) panels provide only 20% of needed electricity. The provided CHP unit does not work properly to provide the remaining 80% of needed electricity as planned (Chance, 2009) for several reasons, as mentioned previously in the last section.

#### ***b. BedZED site energy consumption***

Basically, BedZED aimed to reduce site energy demand with a lot of techniques (mentioned in detail in application of energy efficiency strategies section 4.1.1), like choosing the right orientation of the buildings, using efficient appliances, visible electricity meters and selected fittings for showers, taps, toilet flushes.... etc.

The average electricity consumption in Sutton is 5.5 kWh/person/day, while in BedZED it is 3.4 kWh/person/day. These measurements were taken in 2007, which indicates 38% lower than the Sutton average.

In the same context, after the application of all possible strategies of efficiency, BedZED cannot be considered zero site energy because it receives its energy from the national grid and its renewable energy systems are not covering the total consumption.

#### ***c. BedZED energy costs (bills)***

The average UK family spends £256/year on electricity (at 7.36p/unit, including standing charge), with the average London family spending £251/year (at 7.23p/unit, including standing charge).

These are based on national average electricity consumption levels for cooking, lights and appliances (Lazarus, 2003).

In BedZED, the analysis done by Bioregional states that electricity bills were reduced by £959/year while water bills were reduced by £1,872/year. The electricity exported to the national grid equals only 20% of the total consumption and it's deducted from the overall bill. Anyway, the output bills are not reaching zero since renewable energy is not covering the whole of consumption (Elling, Penney, & Carlisle, 2008).

#### *d. BedZED energy emissions*

Based on monitoring, BedZED was successful in GHG emission reduction. If the rest of UK residents lived like the ordinary BedZED resident, that could reduce the UK's carbon dioxide emissions by 90% without sacrificing quality of urban life. The energy efficient design and the output from the solar PV panels reduced BedZED's carbon dioxide emissions by 56% compared to the average UK home. Reducing the need of car travel in the BedZED development also affected GHG emissions by an additional reduction of 23%; this percentage was supposed to be higher, if the electrical cars idea was applied as planned (Chance, 2009).

#### **4.1.4 After Operation Audit**

BedZED's evaluation shows that most of the residents are satisfied with the new life experience in the development; commercially, the project gained high profits at the first year of construction. After seven years of operation, most of the carbon-neutral goals were achieved as per Bio Regional's assessment. The overall water heating has been reduced by 57%, while the need for space heating has been reduced by 88%, the electricity consumption reduced by 25%, and water consumption reduced by 33% compared to an average UK home (Hodge, 2008).



On the other hand, the total cost of the project exceeded €17 million while it was supposed to be €14 million only, which means that the costs were 30% higher than expected. This caused the average home price in BedZED to be 20% higher than other developments in the same area (Hodge, 2008). In fact, most of the succeeding factors are dependent on the residents themselves and their awareness and cooperation. Even though there are some failure points related to infrastructure and renewable energy systems as will be discussed later (Hodge, 2008).

#### **4.1.5 Results and Discussion**

BedZED has achieved some energy efficiency strategies and it has failed in others. Table 8 shows a summary of achieved strategies along with the percentage of each one of them that are dependent on 2003 monitoring done by Bioregional and residents' reviews collected from reports and websites. The percentage taken is compared with average UK residents in the surrounding areas at the same time.

Table 8: Summary of Energy Efficiency Strategies in BedZED

Indicator	Percentage of Achievement	Notes
<b>District Location</b>	NA	Chosen location has more benefits and advantages than failures (see BedZED location section).
<b>District Orientation</b>	NA	The design oriented from the beginning to gain solar benefits and reduce cooling and heating emissions.
<b>Integration</b>	NA	All the buildings are integrated with facilities, pedestrian ways, and public spaces.
<b>Urban Structure</b>	84% of residents are satisfied with urban structure	Vibrant urban structure created and helped to change people's lifestyles.
<b>Infrastructure (District Energy Networks)</b>	NA	District cooling and heating system has not been working properly for several years.
<b>Façades</b>	80%	Used local material (except in windows). Insulated to protect the internal spaces from cold and hot climate, and glass areas oriented to gain solar benefits.
<b>Thermal Insulation</b>	100%	Thermal insulation used and cold bridges prevented.
<b>Materials</b>	NA	Local energy efficient and reclaimed materials used in most of the construction parts; on the other hand, economical restrictions in choosing materials has been taken into account.
<b>Electrical Equipment</b>	Low-energy light bulbs reduce energy used for lighting by 80%. High efficiency appliances reduce energy used for them by 25%.	Energy efficient appliances and other electrical equipment used.
<b>Landscape</b>	NA	Landscape used to reduce thermal effects, solar reflection and to conserve water. Irrigation depends mainly on rain and recycled water.
<b>Water Strategy</b>	Water usage reduced by 58%.	High water efficiency equipment used, recycle water activated and there is an efficient system for rainwater collection and recycling.
<b>Energy Consumption</b>	-Total water heating reduced by 57%, -Space heating reduced by 88%, -Total electricity consumption reduced by 25%	Good thermal isolation causes higher energy efficiency and lower energy consumption.

<b>Transportation</b>	-Fossil-fuel car miles become 50% less than the average. -The vehicle miles traveled per person per year is reduced by 65%.	Strategies used to reduce need of travel, public transportation activated and electric cars were used as an alternative.
<b>Waste Management</b>	-Produces 68% less waste than the UK average by weight. -Recycling rate 60% by weight of waste.	Complement plan for waste management has been accomplished.
<b>Greenhouse Gas Emission (GHG)</b>	-CO <sup>2</sup> emissions reduced 56% by using PV panels. -CO <sup>2</sup> emissions reduced by 23% using new transportation strategies.	GHG emissions reduced by around two thirds comparing with regular UK district.
<b>Renewable Energy Systems</b>	PV panels produced 20% of used energy.	Designed to be 100% at peak but the design faced complications with CHP system.

In general, surveys are insuring that more than 70% of BedZED residents are happy with their choice of green lifestyle and happier with the reduced bills and extra benefits. On the other hand, some of them declare that most people who come to BedZED haven't given up their cars, and they aren't eating local food, it's not the buildings that aren't working, it's the profligacy of a modern consumer society (Slavin, 2006).

On the NZED scale, despite the effort to create a model for a zero energy district in Sutton City, BedZED doesn't achieve any of the four Parameters as a district. Some homes have full dependency on the renewable energy and they are producing energy in the same amount of their consumption, but for the whole district at the end of the year it is not net zero for source energy, site energy, energy cost or energy emissions.

BedZED applied most of the energy efficiency strategies but some of them were not successful in reaching the desired results to be NZED. In addition to the challenges that appear after operation, the renewable energy covered only 20% of the energy consumption, district heating did not work properly, and shared electrical cars have a relatively expensive rate.

On the other hand, people at BedZED learned how to reduce their waste production and how to control their lifestyle to serve the environment (see figure 54). The district used local materials to enhance the local economy and reduce the used energy in materials transportation. Strategies used in the city reduced the water consumption by half and energy consumption by a quarter. People in BedZED know each other and are ready to cooperate to save their small community resources.



Figure 54: Awareness day about Recycling in BedZED (Carmody & Weber, 2009)

Finally, even if it is not NZED, BedZED was aiming to answer the demand for housing in the twenty-first century with no more damaging of our planet. In this researcher's opinion, it is a good example of creative use of brownfield land to create a mixed-use development: BedZED has most facilities on-site, which significantly reduced the need to travel. The development took into account high and low incomes to create a mixed healthy community with different life styles. This is more than implementing a new development to experiment with the sustainability rules. Despite if it was successful or not, it shows that an eco-friendly lifestyle can be done, affordable and attractive.

## 4.2 Regional Case Study: Masdar City—Abu Dhabi—UAE

Masdar City is the first model of a proposed Net Zero Energy District in the GCC area (Gulf Cooperation Council area) (see Figure 55). According to the operators of the city, the project achieved its goals in increasing the energy efficiency and decreasing the demand, as well as producing energy from renewable resources, then exporting the extra energy to the national grid. This section presents a comprehensive study of the city, and addresses its main features of conserving energy and reducing carbon foot print, and then studies the advantages and disadvantages of implementing this project.



Figure 55: Masdar City Birds-eye View (Ferris, 2010)

Even though it has a wealth of energy resources, Abu Dhabi has taken its responsibilities seriously in climate change, GHG emissions, developing renewable energy and reducing demand for power (Btebbia & Beriatos, 2011).

Masdar City was implemented to support this concept by development, commercialization and adoption of renewable energy and clean-tech systems. The city, owned by Mubadala Development Company, was established in Abu Dhabi in 2006 as an example of the ability of green living in the Middle East region (Masdar, 2013).

#### **4.2.1 Application of EES and NZED Parameters.**

Masdar City planners reduced energy consumption by enactment of building energy efficiency guidelines, which include and are not limited to propitiate thermal insulation, LED lighting, low glazing external elevations, passive solar designing, importing high-efficiency appliances, smart meters and smart audit systems (Masdar, 2013).

Masdar City, in covering 100% of its energy consumption with renewable sources, buildings were designed to be energy efficient as much as possible without ignoring residents' satisfaction. Masdar Energy Design Guidelines (MEDG) have been created especially for Masdar City to draw an integrated plan for an energy efficient city (Masdar, 2013).

The goals of Masdar City as the first Net Zero Energy District in the Middle East are:

- Provide renewable energy to cover the full amount of consumption.
- Waste management to reach net zero waste.
- Mitigate GHG emissions to be zero carbon emissions.
- Being a fossil fuel free zone.

To address how Masdar City's owner achieved previous goals, this study analyzes some applied EES in the project as follows:

### *a- Project location*

The Masdar City project was established on Masdar City Security Zone Area at Abu Dhabi (see Figure 56), United Arab Emirates; the project has a new six-square kilometer city for 40,000 residents and 50,000 commuting, located 17 kilometers southeast of Abu Dhabi (Masdar, 2011).



Figure 56: Masdar City Location, map by (Google Earth, 2014)

The city is 5 minutes driving distance from Abu Dhabi International Airport, 20 minutes from downtown Abu Dhabi, and 45 minutes from Dubai (see Figure 57).

Masdar City this prime location has attracted global companies such as the National Bank of Abu Dhabi, Siemens, and technology and research companies (Dadd, 2014).

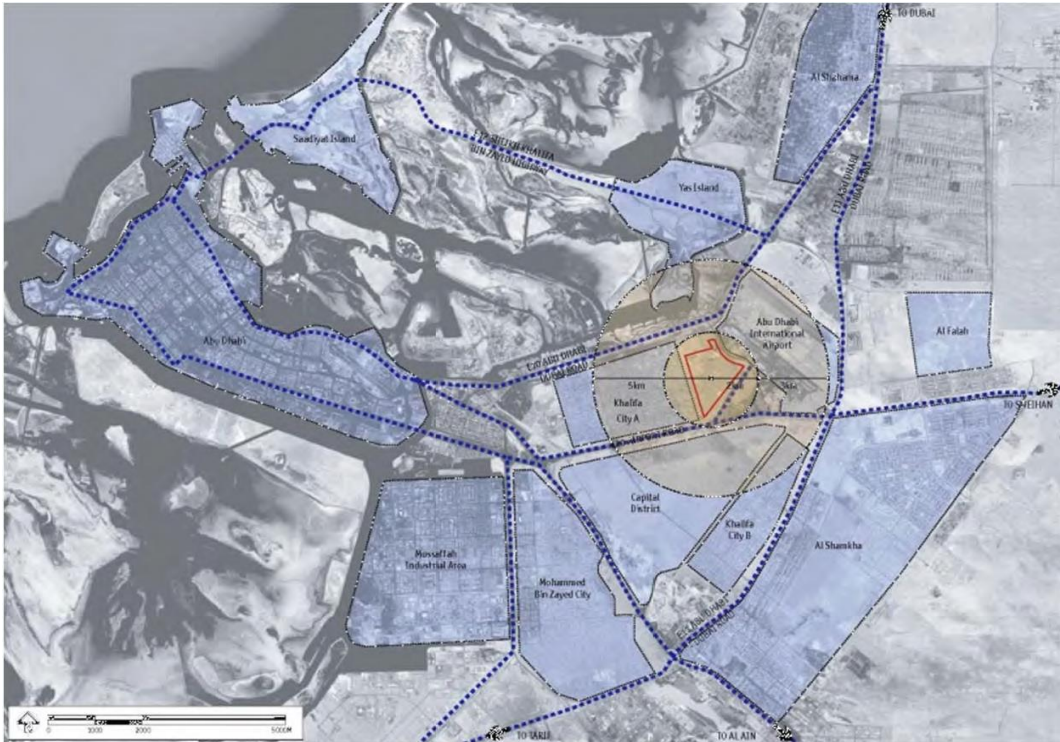


Figure 57: Masdar City Site Plan (Wagle, 2014)

At the national scale, the existence of Masdar City in the UAE is considered an opportunity (see Figure 58); where UAE government has its own vision in sustainable development in economic, social and environmental aspects.



Figure 58: UAE Location, map by (Google Earth, 2014)



In the UAE Vision 2021 National Agenda, the sustainable development focuses on improving air quality, preserving water resources, increasing the clean energy production, implementing green growth plans and green infrastructure (UAE Vision 2021, 2014).

Masdar City is a good opportunity for Abu Dhabi; it provides it with a modern, energy-efficient and healthy society located between the Abu Dhabi city center and the Abu Dhabi International Airport. In addition, its public transportation network is complementary, working with Abu Dhabi public services and transit systems.

***b- Design and concept***

Masdar City is owned by the Mubadala Development Company, and the concept of the city was established in 2006 and accomplished in 2008, then the master plan was created in 2011, and the city construction was accomplished in 2013 (see Masdar City Master Plan Figure 59). The project was established as a high density community—140 people per hectare—to be one of the most sustainable districts in the world as the owner company claimed that Masdar City is the place where you can live the sustainable development and test it (Masdar City, 2011). The project has a mixed-use urban plan consisting of multi-modal residential houses, offices, retails, hotels, schools, *masjids*, light industries, parks and open spaces, and Masdar Institute educational colleges all collaborated and developed new technologies and solutions (Masdar City, 2011).

**c. The city's orientation**

The climate for UAE has a very hot, dry summer and relatively warm winter; the big concern in UAE is to mitigate the solar radiation and solar heat gain on building walls and streets.



Figure 59: Masdar City Master Plan (Masdar, 2014)

This mitigation was applied effectively in Masdar City at the lowest possible cost by angling the city grid and buildings in a perpendicular direction within the sun’s track during the day (see Figures 60 and 61).

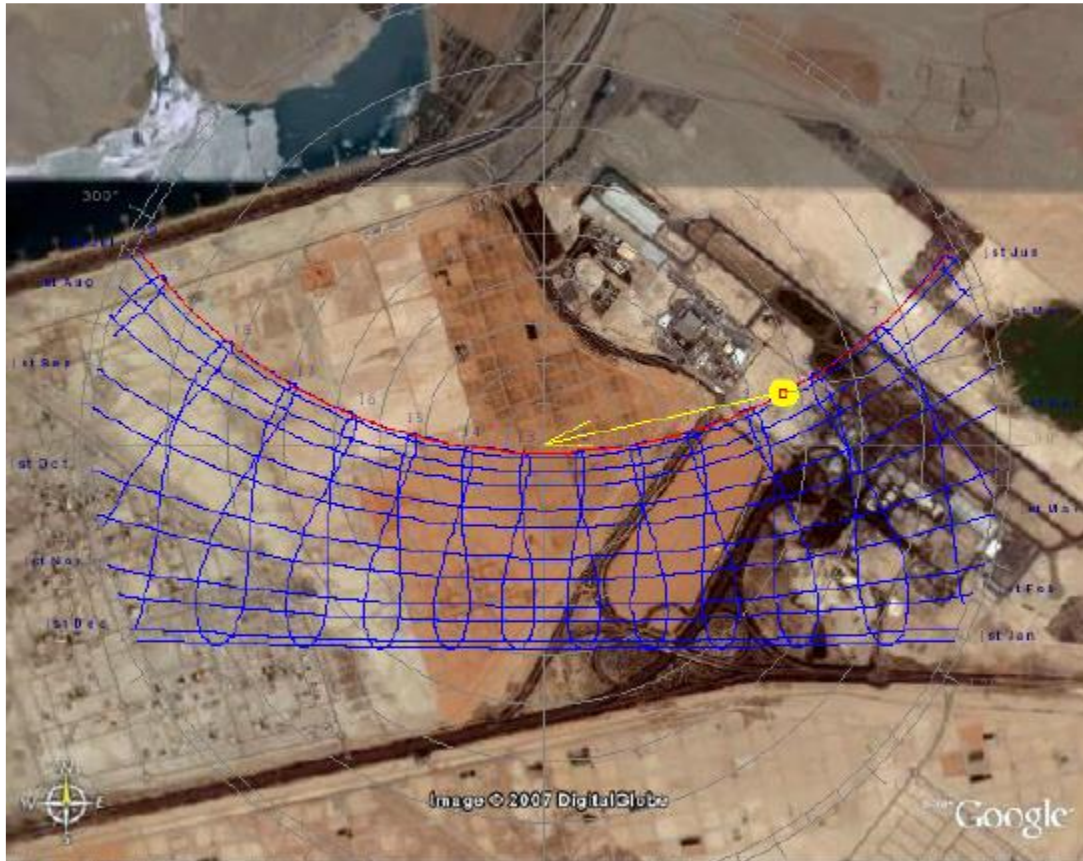


Figure 60: Annual Sun Path Around the City by (Foster and Partners Architects, 2007)

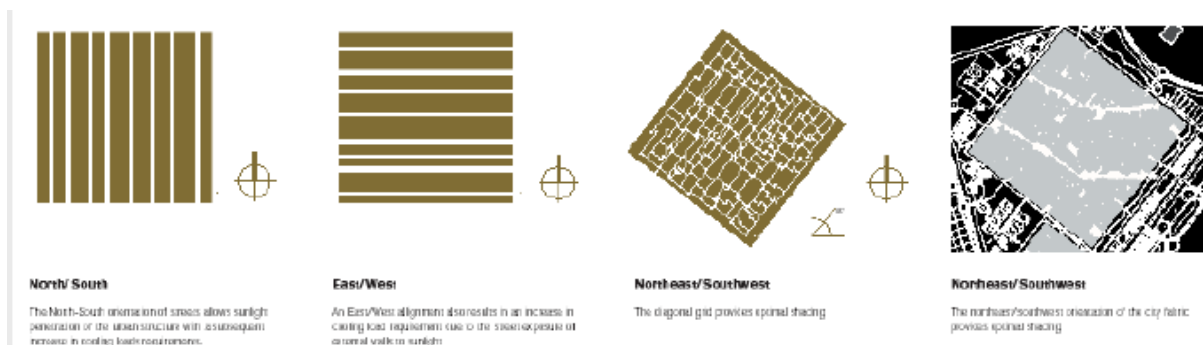


Figure 61: Masdar City Orientation Northeast, Southwest in a Diagonal Grid by (Foster and Partners Architects, 2007)

Masdar City buildings' orientations provide shaded *Sikkas* and corridors and reduces the outdoor temperature (see Figure 62).



Figure 62: Masdar City Shaded Streets by (Foster and Partners Architects, 2007)

This is surely affecting the indoor temperature and the outside thermal comfort and conserving the huge amount of energy used for cooling (see Figure 63).

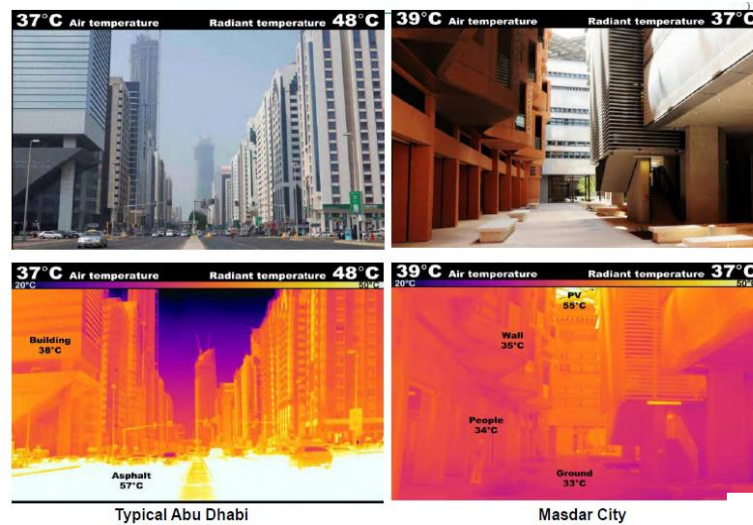


Figure 63: Comparison in Thermal Comfort Between Masdar City and Abu Dhabi Rest Typical Areas (Wagle, 2014)

In addition, the city's orientation benefits from the solar panels distributed all over the city, knowing the exact map of the city's annual sun bath is very important to put these solar panels in the sunniest areas in the city during the year (see Figure 64).



Figure 64: Rooftop Solar Panels Oriented to the Sun (Whittier, 2010)

Regarding the winds, the city orientation cools hot winds over linear parks and provides refreshing street ventilation while maximizing cooling nighttime breezes (see Figures 65 and 66).

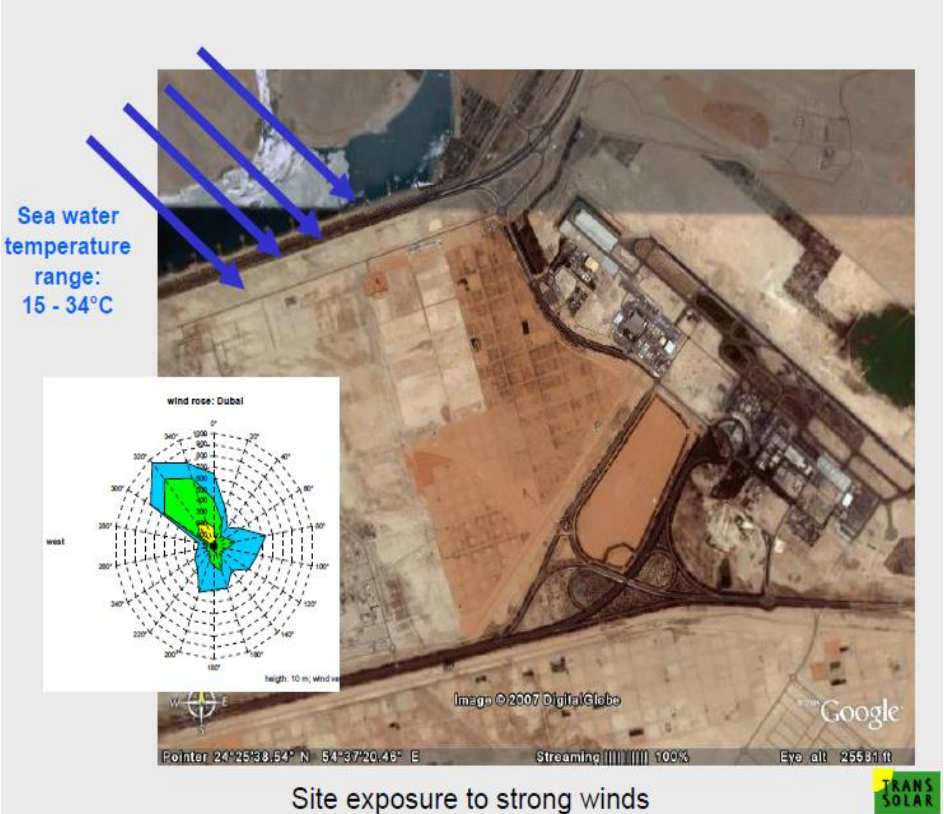


Figure 65: Wind Direction by (Foster and Partners Architects, 2007)

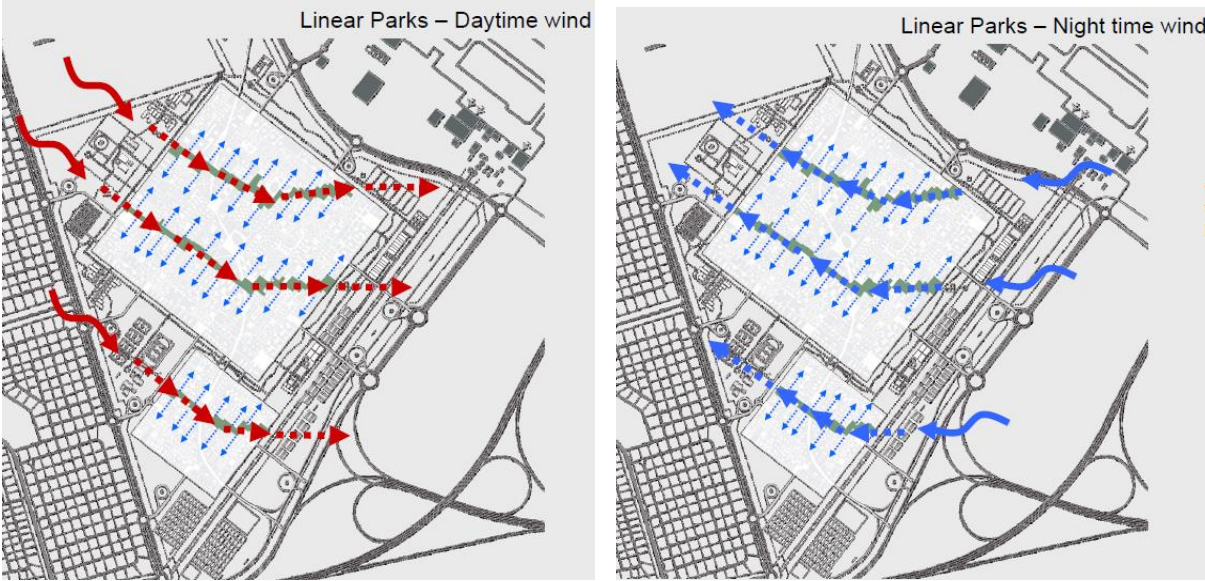


Figure 66: Day and Night Wind by (Foster and Partners Architects, 2007)

In addition, there is a reinterpretation of wind towers distributed all over the city. It is an old tradition in the Arabic city; they make wind protection and controlled street ventilation, and thus they reduce energy use in cooling and increase the efficiency of cooling systems (see Figures 67 and 68).

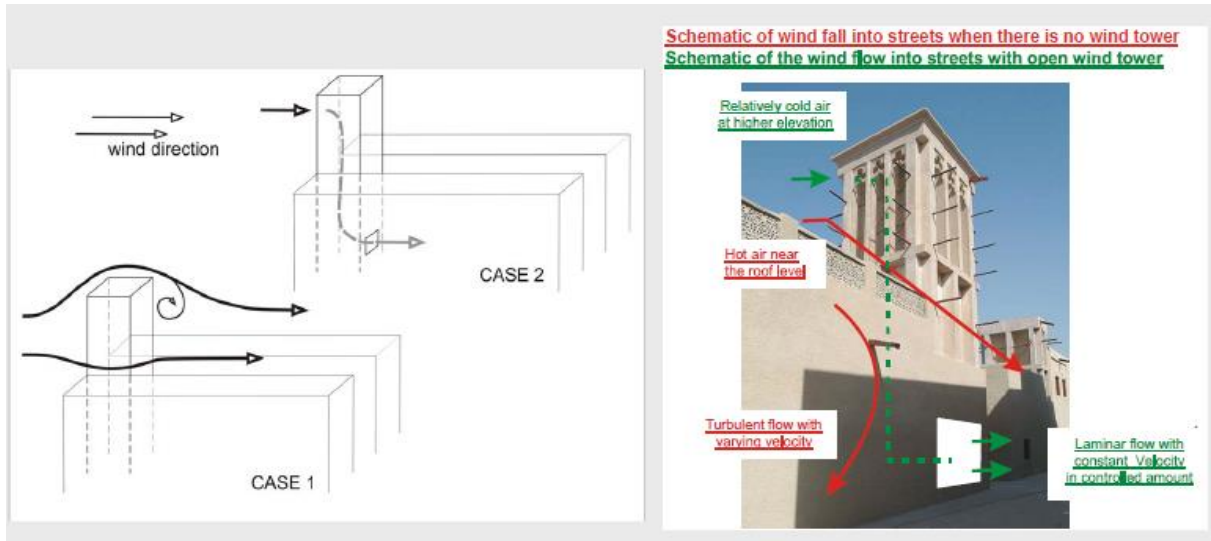


Figure 67: Wind Towers Help in Street Cooling by (Foster and Partners Architects, 2007)



Figure 68: Wind Towers – Open, Cooling the Streets at Night by (Foster and Partners Architects, 2007)

#### ***d. City integration***

All components of the city seem to be integrated; commercial, residential, recreation areas are all close to each other and the transportation hubs (will review transportation in a separate point later). The city is offering the highest level of working and living experience with the lowest footprint. Multi-use streets are providing many services such as food, retails, sitting areas, health clubs, travel agencies and an organic supermarket, which received its products from the city gardens. Wind towers are working as urban squares and landmarks as well as cooling towers; it is activated by cafés and shaded by the adjacent buildings and trees. The square offers a public space of recreation and social interaction. In addition, Masdar Institute campus's social and public spaces are reachable by Masdar City residents; its facilities are serving Masdar City's walkable, car-free corridors or *Sikkas* (Masdar, 2013).

#### ***e. Urban structure***

Masdar City area is approximately 600 hectares, while the gross floor area of 3.7 million square meters consists of 52% residential, 26% commercial, 10% community facilities, and 12% light industrial (Al-Ramahi, 2014). The urban fabric of the city is characterized by many factors like: High-density, low-rise structures: most buildings are no more than five stories (see Figure 69). Actually, a low rise building is recommended when relying on renewable energy, usually the rooftop area (used to install PV panels) is distributed equally on the number of flats; therefore, a fewer number of stories is better (Sahyoum, 2014).





Figure 69: Low-rise, High-density Urban Structure in Masdar City (Wagle, 2014)

Vibrant urban realm: public spaces are the crown jewel in Masdar City. Thus, squares and streets seem very welcoming for people to enjoy the outdoor environment; people from all of the community segments are interacting there (see Figure 70).



Figure 70: Internal Courtyards and Open Space Network – Facilitating the Phases & Neighborhoods (Wagle, 2014)

In addition to the large urban squares at the base of each wind tower as mentioned previously (see Figure 71), developed landscapes will provide them by view and shade, in addition to all other available services like a gym, prayer room, supermarkets...etc. (Masdar, 2011).

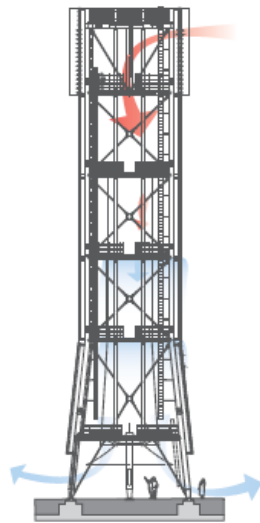


Figure 71: Urban Squares Under Wind Towers Provide Vibrant Public Spaces (Masdar, 2011)

Masdar City is pedestrian friendly: meaning narrow, shaded walkways and *Sikkas* that encourage walking. The integrated city means that all needed facilities are within walking distance from the hubs (see Figure 72); other facilities can be reached by cycling. Encouraging the use of alternative transportation modes is saving energy, natural resources and the environment.

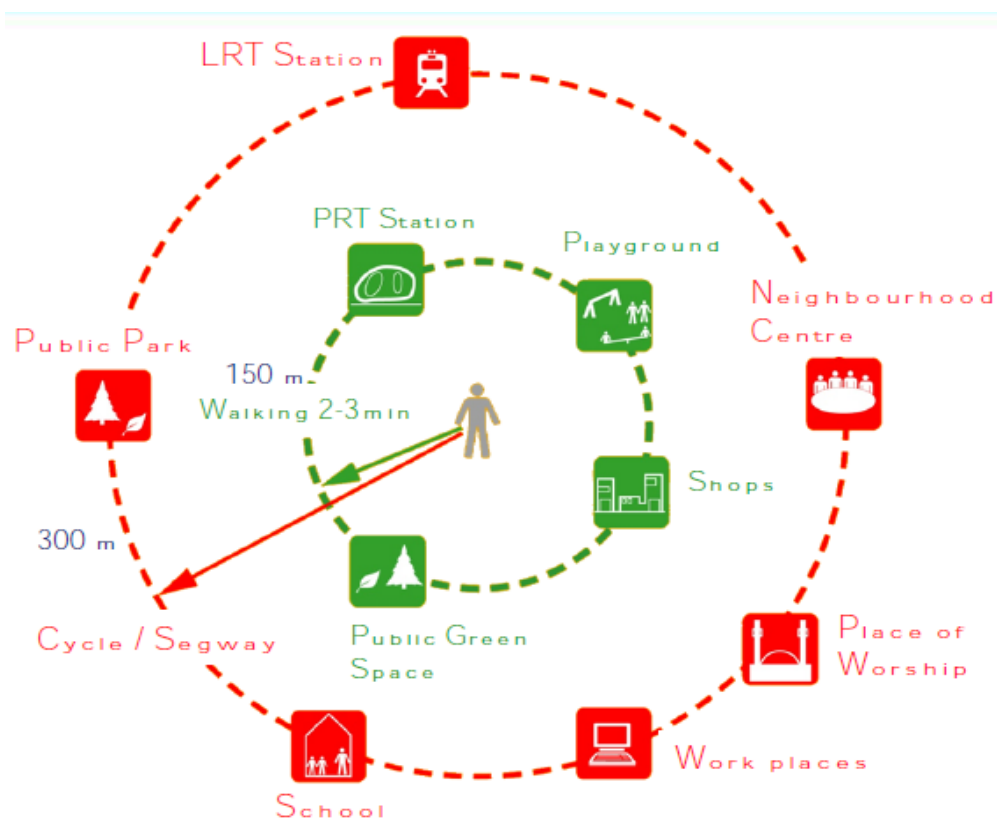


Figure 72: Close Distances in the City Encouraging Walkability (Masdar, 2010)

Improvement of the natural and artificial landscape: The origin for Masdar City's landscaping concept is the history of open spaces in the traditional Arab city, in addition to the desire of maintaining view and micro climate with the consideration of limited water resources (Masdar, 2013).

Masdar City's distinguished by urban squares, open field landscapes, linear green parks (see Figure 73), public plazas and laneways. The linear green parks are oriented to the direction of wind to benefit from seasonal cool breezes; these linear green parks are connecting public spaces with semi-public spaces gradually, as an example of the pedestrian-friendly planning in Masdar City (Masdar, 2011).



Figure 73: Landscape and Linear Parks in Masdar City (Wagle, 2014)

Desert climate is a big challenge when planning a new city. Landscape and water features usually help to mitigate the arid climate as in Masdar City (see Figure 74); landscape provides the shade for the streets and public spaces in the high temperature days, which can reduce the temperature by 20 degrees Celsius in the best cases. Water features help to soften the micro climate (Masdar, 2013).



Figure 74: Landscape and Public Spaces in the Project (Masdar, 2011)

#### *f. The district infrastructure*

Masdar City consists of many layers, consisting of upper buildings, transportation networks and amenities (see Figures 75). It has a huge sustainable infrastructure designed to serve many generations.

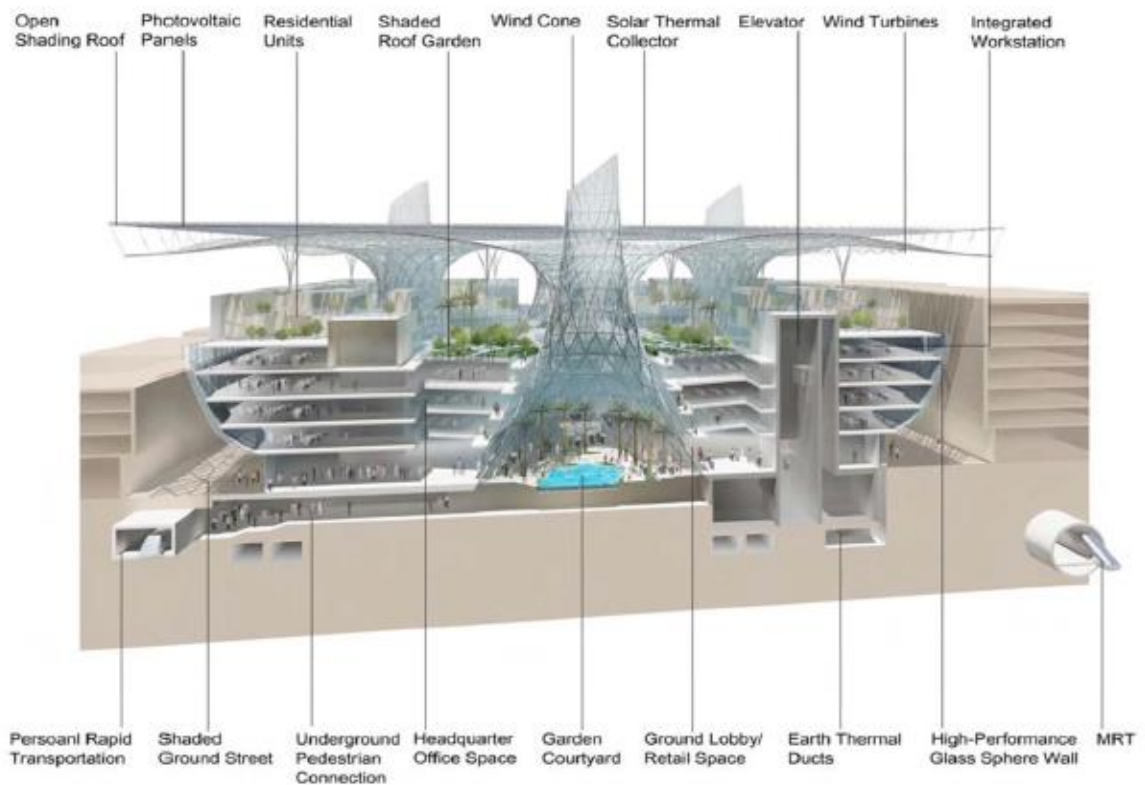


Figure 75: Layers of Masdar City (Whittier, 2010)

district cooling used in Masdar City in 2010 is the first low-enthalpy geothermal project in the Middle East (see Figures 76) (Reykjavik Geothermal, 2012).



Figure 76: Masdar City Layers and Infra-structure by (Foster and Partners Architects)

There was some effort in Masdar City to use the geothermal heat to feed the district cooling system, but after experiments, the Masdar City operator and his partner reported that geothermal drilling gave only 95° centigrade, which was not hot enough for power generation (Under, 2010).

***g. Building façades***

Mitigating the solar gain on the external façades is one of the biggest challenges in the Gulf area. Masdar City designers applied a variety of sustainable design technologies and materials to address this issue. For example, in the laboratory buildings, the designers used air-filled cushions that ensure almost no solar gain on the structures and limit the heat re-radiated to the street. Followed by a layer of foil cladding to reflect light and send some of it back to the pedestrian street below. Another layer of highly sealed paneling was added behind the foil (Masdar, 2011).

Most of the windows are shaded by adjacent buildings as a desirable result of narrow streets and *Sikkas*; for those not shaded, they provided vertical or horizontal louvers (depending on the sun's radiation angles on them). Red, sand-colored façades define the residential buildings, added GRC screens gave the look and function of old *Mashrabiya* (see Figure 77).



Figure 77: Wall Insulation on Building Façades Provides Shade for the Building and the Street, as well as a Renewable Energy Source (Masdar, 2011)

*Mashrabiya*s used to provide shade and privacy for the building's interior space, in addition they let breezes crawl inside balconies. In general, all Masdar City façades are highly sealed, insulated and wrapped in 90% recycled aluminum sheeting given the same rose-red color as the GRC screens (Masdar, 2011).

#### ***h. Materials***

Material used in Masdar City construction was chosen from local and regional resources for two reasons: the first one is to support the national economy and the country mission in sustainability. The second reason is to reduce transportation side effects like GHG emissions.

All used materials are certified as green materials; some of them are even recycled from previous construction wastes (Masdar, 2013). Product lifecycle assessments were conducted to help in choosing more sustainable materials (Masdar, 2011).

#### ***i. Water strategy***

As an increasingly precious resource—especially in the Gulf area—water strategy is one of the most important plans discussed in the design stage. The main goal of the water strategy was to reduce the water demand by 50% and use all available recycling methods to reuse grey water, and resupply it for domestic use and irrigation.

Environmental awareness needed to be distributed among the residents about efficient use of water resources. A wide variety of new technologies were used to reduce the water demand: including high-efficiency appliances, low-flow showers, high-efficiency laundry machines, smart water meters that inform consumers of their consumption, high-efficiency irrigation and native species of plants in landscaping that can adapt better with climate and consume less water. In addition, grey and black recycled water were being used for landscaping and irrigation.

#### *j. Waste management*

The waste strategy for Masdar City was subject to a classification system starting with the most desired action, which is waste prevention then minimization, followed by a reusing and recycling strategy, then using it in energy generation, and the last option is disposal as an un-preferred solution. Masdar City plans to eliminate around 50% of its produced waste to the landfills by the completion of first phase and 90% of total construction waste during the development period.

Each resident in Masdar City has learned to classify waste into three categories: paper and plastic, organic wastes and residuals. Paper and plastics are to be recycled at a Material Recycling Facility (MRF). Organic waste is to be reused as an organic fertilizer for landscaping. All the previous operations are to be managed by the Resource Recovery Centre, which has been developed by Masdar City (Masdar, 2013).

Approximately 96% of the construction waste at Masdar City has been managed and recycled via an on-site Materials Recycling Centre (MRC). Waste storage areas were separated even if it was concrete, wood, metal...etc. to reuse it easily on-site and off-site (Masdar, 2013).

#### *k. Transportation*

Masdar City has a Transport Master Plan known as Surface Transport Master Plan (STMP). STMP was developed to be a unique transportation experience that was created in Masdar City for the first time in the Middle East (Department of Transport, 2009). It is based on an Integrated Transport mode to include the Metro and PRT systems working in Masdar City internally and reaching into Abu Dhabi city center (Masdar, 2013). Fossil-fuel automated cars are not allowed for use in Masdar City as planned. Instead, the integrated city was designed to encourage a pedestrian lifestyle beside sustainable transportation modes. The Personal Rapid Transit (PRT) system is a network that contains single cabin cars powered by electricity generated from renewable energy plants. The vehicle-applied technology used lithium phosphate batteries, which need to charge only 1.5 hours to



travel 60 kilometers. This system has provided 3000 cars, which are supposed to make 130,000 trips daily (see Figures 78 and 79) (Green Cities Campaign, 2015).



Figure 78: Personal Rapid Transit System (PRT) Electric Cars (Graaf, 2014)



Figure 79: PRT Electric Cars Station in Masdar City by (Walsh, 2011)

## 4.2.2 Renewable Energy Systems

Masdar City's energy strategy consists of three principles: first, reduce energy demand; second, cover energy needs with renewable energy resources 100%; and third, efficient distribution of the energy on the demanded sectors. As mentioned before, Masdar City is designed to be entirely powered by renewable energy generated on-site and off-site (see Figure 80).

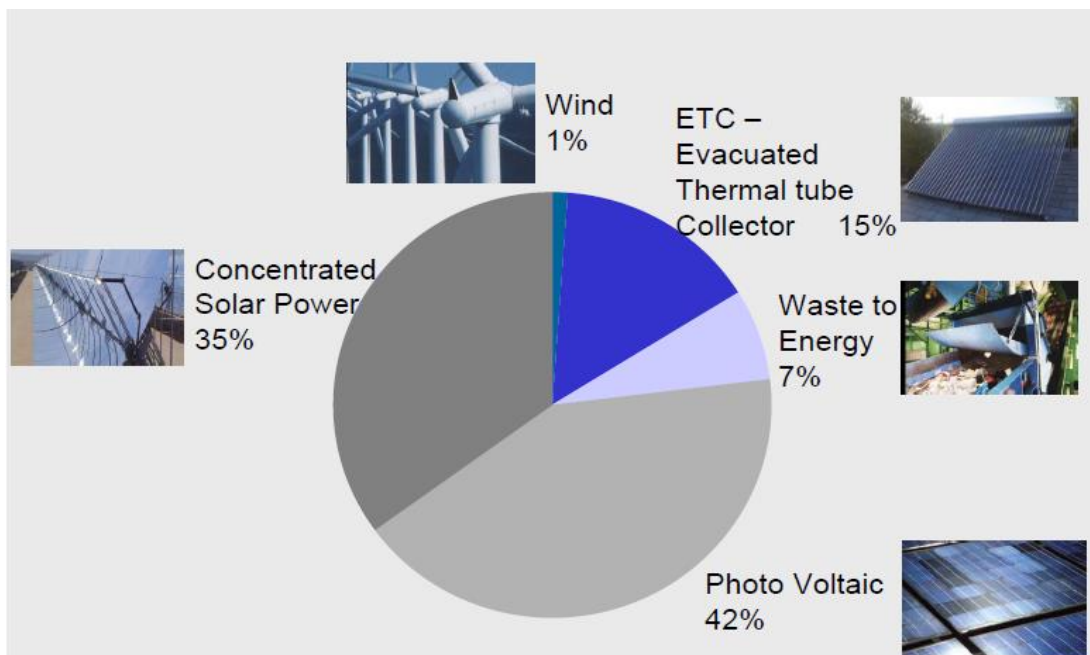


Figure 80: 100% Renewable Energy Resources in Masdar City by (Foster and Partners Architects, 2007)

Proposed solar power plants were supposed to cover most of the city's energy requirements; 22 hectares of the adjacent lands of Masdar City was occupied by 10 MW solar power plants to form the largest number of connected solar plants in the Middle East. This system connected to the Abu Dhabi national power grid in April 2009.

Roof-mounted solar panels were installed on Masdar Institute's laboratories and residential buildings to generate clean electricity as well as provide additional shading to the corridors and courtyards. In addition, Masdar City is studying other renewable energy resources like geothermal and solar thermal cooling technologies that use heat to run the district cooling system (see district infrastructure section of this case study). In addition, 101 LED solar lights have been installed with

all their accessories; these lights are self-recharging by solar energy with limited maintenance needed.

Masdar City’s buildings were designed to efficiently use minimum amounts of energy, which made the mission of covering all the city’s energy needs by renewable resources achievable (Masdar, 2013).

### 4.2.3 After Operation Audit and Results

Masdar City—as a brand name city—tried to apply most of the known energy efficiency strategies, including saving critical resources, GHG reduction, pollution control, waste management as well as gaining ESTIDAMA certification in both Communities and Buildings categories.

Masdar City got an ESTIDAMA one pearl certificate as a community, and achieved three and four pearls on some individual buildings like Siemens institutions, which got three pearls in the ESTIDAMA rating system and LEED platinum (see Figure 81); ARENA HQ, as well, achieved four pearls in the ESTIDAMA rating system.



Figure 81: Masdar Certificate by LEED

Each category of energy efficiency strategies was assessed individually to be more accurate as per Masdar City’s 2014 annual report in Table 9 below.

*Table 9: Used Rating Systems for Each Energy Efficiency Indicator in Masdar City (Masdar by Mubadala Company, 2014)*

No.	Design Criteria	Mandatory Design Requirement	Reference Baseline / Remarks
1	Energy Consumption	<ul style="list-style-type: none"> <li>40% reduction from ASHRAE 90.1: 2007.</li> <li>Compliance with Masdar Energy Design Guidelines 3.0.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System – Improved Energy Performance.</li> </ul>
2	Renewable Energy Provision	<ul style="list-style-type: none"> <li>75% of hot water heated by solar energy.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System – Renewable Energy.</li> </ul>
3	Interior Water Use	<ul style="list-style-type: none"> <li>40% reduction of interior water demand.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System Water Calculator.</li> </ul>
4	Exterior Water Use For Landscaping	<ul style="list-style-type: none"> <li>Average landscape irrigation demand to be less than 2 litres/m<sup>2</sup>/day.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System Water Calculator.</li> </ul>
5	Construction Waste Management	<ul style="list-style-type: none"> <li>Not less than 70% of demolition and construction waste (by weight or volume) to be recycled or salvaged.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System – Improved Construction Waste Management.</li> </ul>
6	Operation Waste Management	<ul style="list-style-type: none"> <li>Not less than 60% of total operational waste (by weight or volume) to be diverted from landfills and incineration. This is reduced to 50% for Multi-Residential Buildings.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System – Improved Operational Waste Management.</li> </ul>
7	Embodied Carbon in Materials	<ul style="list-style-type: none"> <li>0% reduction in the overall construction for steel structured buildings.</li> <li>15% reduction in the overall construction for concrete structure buildings.</li> </ul>	<ul style="list-style-type: none"> <li>650Kg of CO<sub>2</sub>/m<sup>2</sup></li> </ul>
8	Sustainability Rating System	<ul style="list-style-type: none"> <li>Minimum 3 Pearl under Estidama Pearl Building Rating System.</li> <li>Minimum LEED Gold.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System.</li> <li>LEED Rating System.</li> </ul>
9	Building Performance Monitoring	<ul style="list-style-type: none"> <li>Design and implement monitoring strategy for major energy and water uses at building level and tenant level.</li> <li>All meters to be connected with Masdar’s Central Monitoring System.</li> </ul>	<ul style="list-style-type: none"> <li>Estidama Pearl Building Rating System – Energy Monitoring and Reporting + Water Monitoring and Leak Detection.</li> <li>MEDG V3.0.</li> </ul>

After operation, Masdar City has hired a number of providers of data collection and management tools that support after-operation audits with information collection, tracking, analytics and reporting of sustainability performance data. This research will list two of these tools as an example to how Net Zero Energy Districts’ performance can be tackled and calculated:

The first tool used at Masdar City is *C3 Energy*, which is a GHG tracking tool. Masdar City operators relied on C3 Energy to collect all kinds of information related to GHG emissions released from energy use, waste management, on-site and off-site energy production, transportation and even GHG caused by water purchasing, water treatment and water consumption (Masdar, 2012).

The second tool is called *SoFi*, it is a Construction Carbon tracking tool. This tool was designed to collect all the information related to released carbon emissions at the construction stage by transporting materials, energy production, construction waste management...etc.

To sum up the results of performance assessment in Masdar City, Table 10 below shows the city's performance after six years of operation in 2012. Masdar City covered 75% of the demanded energy with renewable energy and the rest was imported from the national grid.

Table 10: Performance Assessment Results for Masdar City adapted from (Masdar, 2012), (Masdar City, 2011)

Performance Criteria	Percentage
Energy: energy demand reduction by increasing energy efficiency (against Abu Dhabi)	50%
Electrical demand reduction compared with UAE average	51%
Reduction in cooling demand compared with UAE average	55%
Covered energy demand with Renewable Energy	75%
Water Demand Reduction compared with Abu Dhabi average	54%
Reuse of processed wastewater for irrigation to help reduce overall potable water consumption on campus	100%
Materials embodied Carbon Reduction	30%
ESTIDAMA certificate achievement	The whole city (1 pearl) Siemens (3 pearls) ARENA HQ (4 pearls)
Certified timber that came from sustainably managed forests or other sources	100% FSC or PEFC
Recycled aluminum used for the inner façade	90%
Green concrete used to replace cement	campus's carbon footprint reduced by 50,000 tons of CO <sub>2</sub> .
Reinforcing bars	100% recycled steel
Waste generated on campus is reused, recycled or composted	60%
Construction waste generated in building the city diverted from landfill through an on-site Waste Recycling Centre that separates waste for reuse in the construction process or transfer to nearby recycling facilities	96%

When designed, Masdar City was supposed to cover its energy needs and export energy to the national grid by using renewable energy systems; it was designed to be more than an NZED (a Plus Energy District in the ideal case), but the real operation faced complications regarding the high demand for energy for cooling in the summer. Meeting 75% of the energy needs makes Masdar City a near-zero energy district and not Net Zero.

Masdar City is already satisfying its strategic goal to become a center for the application and testing of new green technologies. Masdar City is a new experience in the Middle East that gives an opportunity of exploring new technologies like alternative solutions of transport, cooling systems

such as wind towers, and new potential sources of power that fit with the hard climate of the Gulf region, like solar thermal cooling. Even though Masdar City got only one pearl in the ESTIDAMA rating system, it is considered as a first Net Zero Energy District in the Gulf area and maybe in the world.

Masdar City reduced its energy demand, cooling demand and water demand by half, and then covered 75% (in some buildings 100% like Siemens and ARENA HQ) of these requirements with renewable energy systems to comprise the first livable, sustainable community.

#### **4.2.4 Conclusion**

In this chapter, two case studies were presented; the first one does not achieve any of the four Parameters despite applying most of the EES and using renewable energy; in this case it cannot be considered as an NZED. But there are many lessons learned by discovering this case study, first of all the design stage is the most important stage in the NZED implementing, energy efficiency strategies like district location, orientation, urban structure.... etc. can be only controlled in the design stage. The second important stage is the construction stage, NZED has to be energy efficient through the construction as well, many of claimed green projects are harming their environment by throwing the construction waste in landfills and using unplanned fossil fuel to cover the construction machines need, in addition to providing many materials from abroad which enlarge the project footprint before its start. The third important stage in NZED life is after operation stage, after operation audit can tell if the project is achieving its goals or not. Many systems are not working as supposed to be when they face the real pressure after operation, therefore, the regular audit after operation for any NZED project is necessary to address the project's performance. Some projects are witnessing a failure in their systems after working properly for a certain time; so, NZED assessment has to be done yearly at least to supervise the EES application on it, and to be sure that the district is still achieving one of the four Parameters at least.

. In the second case study, Masdar City achieved a zero bill for its energy consumption; furthermore, it is exporting extra energy to the national grid in some days of the year when there is no need for air cooling and when the energy consumption is below the average consumption of the city.

Suitable renewable energy systems for each case study is determined based on the surrounding circumstances or factors such as weather, cost, area, distances...etc.; these factors are drawing the guidelines of choosing a renewable energy system in any NZED project.

When applying the lessons learned from international and regional case studies on any project in Qatar, the planner has to consider all the particulars of Qatar like climate, stakeholders, economics, energy sources...etc.



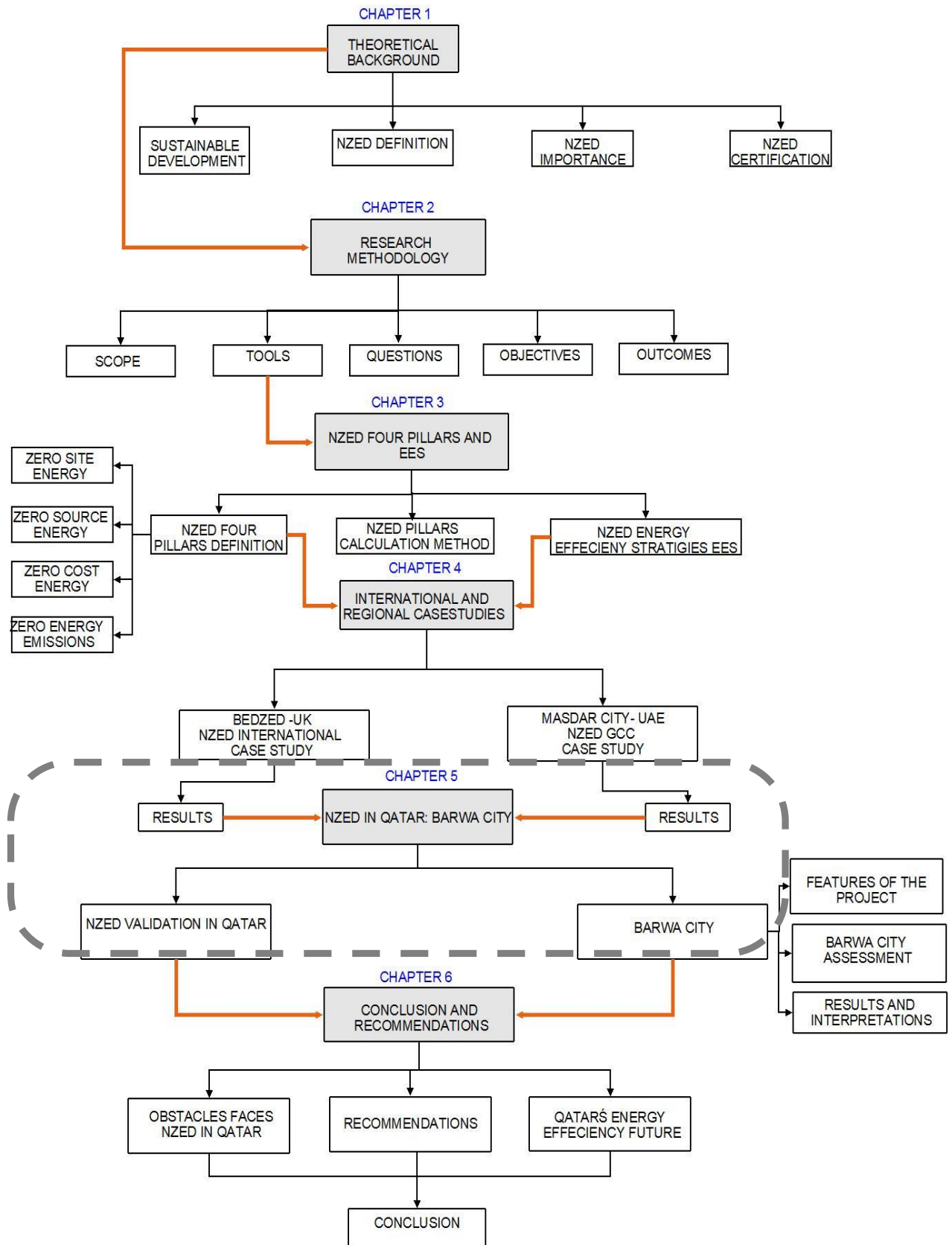


Figure 82: Flowchart of Research Phases – Chapter 5

## **Chapter 5. NZEDs in Qatar: Case Study of Barwa City**

Qatar's environmental impact per capita is very high compared with other countries. The excessive use of oil and gas in Qatar for transportation, water desalination and air cooling makes the ecological footprint of Qatar the second highest in the world as per some recent research (Adema, 2015). To address and solve this This chapter presents a case study from Qatar by reviewing its main features, and assessing its energy status using NZED Parameters and EES.

### **5.1 NZED Validation in Qatar**

Qatar has established its own system for environmental assessment called GSAS or QSAS, Qatar Sustainability Assessment System. This system was created and developed in 2010 by the Gulf Organization for Research and Development (GORD) in cooperation with the T.C. Chan Center at the University of Pennsylvania. GSAS aims to create a sustainable urban environment, reducing environmental impact while satisfying the needs of the local community (Zafar, 2015).

GSAS is designed for hot regions like Qatar; it takes into consideration economic, environmental and cultural factors. GSAS also takes into account the particularity of the Gulf area in some factors such as scarcity of water and hot climate. The GSAS system was discussed in greater detail in the third chapter, section 3.2.12.

Qatar has merged GSAS rules into the 2010 Qatar Construction Standards (QCS), and obtaining GSAS certification is now mandatory for most of new mega projects in both the private and public sectors (Suresh, 2014).

The crucial objective of the green buildings trend in Qatar is to reduce the impact of the built environment on human health and the natural environment by reducing used water and energy. This aim is translated by NZED energy efficiency strategies. Implementing NZED projects in Qatar has

social, economic and environmental benefits for Qatar's residents. However, some of Qatar's organizations move towards green projects to achieve the Qatar 2030 National Vision.

### **5.1.1 Qatari Organizations' Influence on NZED Projects in Qatar**

#### ***a. ASHGHAL***

The Public Works Authority (ASHGHAL) was indiscriminate in its implementation of projects in Qatar. The Authority has no clear, environment-friendly standards for new local projects. Recently, ASHGHAL adopted Qatar Sustainable Assessment System (QSAS) as a green sustainable framework for its public projects. ASHGHAL signed a Memorandum of Understanding (MOU) with the Barwa and Qatari Diar Research Institute (BQDRI) agreeing to the provision of measures to develop sustainable buildings and create a better living environment for natives and residents (Bawaba, 2010).

The MOU contract aims to confirm the commitment of both organizations to preserve the environment and apply the concept of sustainability to ensure a healthy environment and better living standards for future generations. This will be achieved through:

- QSAS principles to insure better saving of the environment and better living for the residents.
- Cooperation in researches and developments that serve environmental issues (Bawaba, 2010).

#### ***b. Ministry of Environment***

The Ministry of Environment recently added a new section to the latest version of the 2010 Qatar Construction Specifications (QCS) contain a section entitled "Green Construction", which has maintained saving environmental resources in the construction stage and has recommended minimum scores in QSAS rating system at least (Shaka, 2013).

### *c. Qatar Green Building Council*

The Qatar Green Building Council (QGBC) was established in 2009 to support green and sustainable development in Qatar. The QGBC is one of the 30 members of the LEED roundtable and has a great role in supporting energy and water efficiency programs in Qatar, and it suggests strategies that reduce the pollution (Suresh, 2014).

### *d. Universities*

Universities and institutions in Qatar are heavily engaged in energy efficiency research such as (Global Economy and Development at Brookings, 2013):

- *Education City*: Qatar's Education City is a cluster of eight international university campuses in Doha. Energy-related research has been conducted at most of them, such as Texas A&M University in Qatar (TAMUQ), which operates the new Smart Grid Center.
- *Qatar Science & Technology Park (QSTP)*: QSTP conducts research on applied energy, environmental and water issues.
- *Qatar Energy and Environment Research Institute (QEERI)*: QEERI is a member of the Qatar Foundation founded in 2011; it conducts and cooperates in research that discusses national concerns like:

Assessment of solar resources to address its available technologies and applications, mitigation of GHG emissions, water scarcity and water desalination and Green Buildings.

QEERI has its authority to work with the main stakeholders related to water and environmental issues; it has been funded by Qatar National Research Fund (QNRS).

### 5.1.2 Qatar’s Climate Influence on NZED Projects

The weather in Qatar remains relatively unchanged throughout the year except in the few winter months. The country suffers in summer from temperatures reaching 50°C in July and August and 90% humidity (Qatar Tourism Authority, 2013). During the short winter, from December to February, the weather in Qatar is pleasant. Temperatures remain in an endurable range and there is a little rainfall during the winter season (see Figure 83). In other seasons, there is almost no rain (National Geographic, 2014).

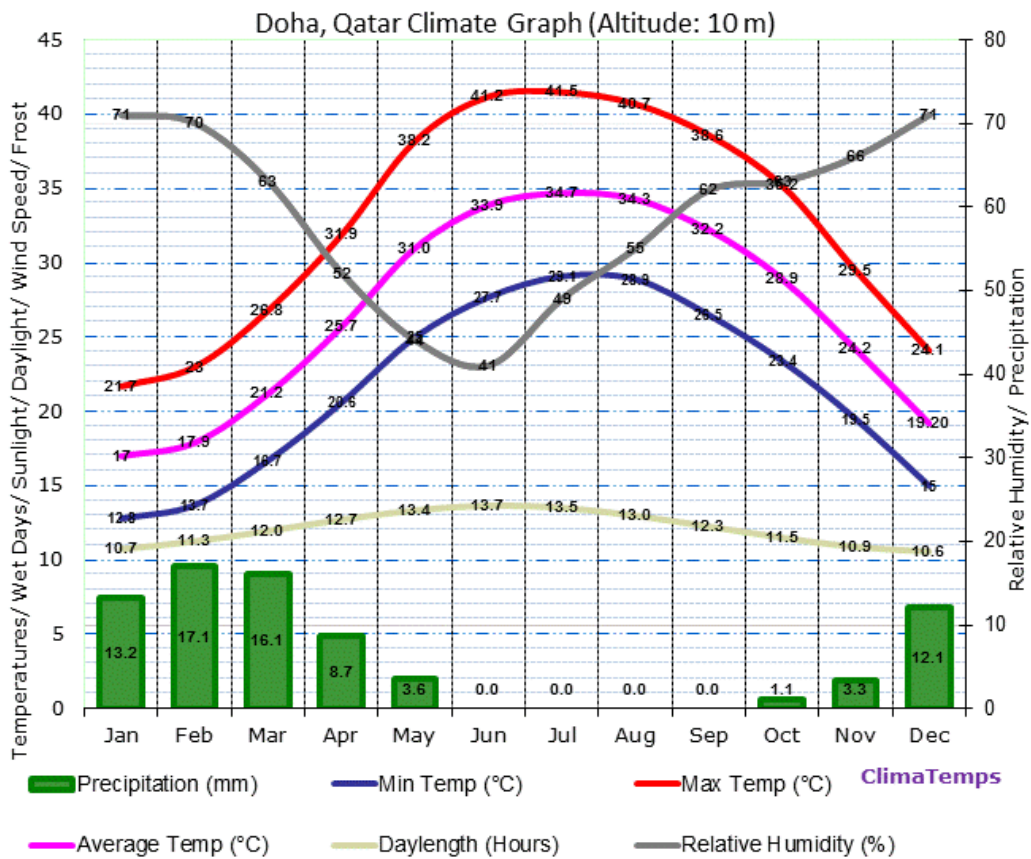


Figure 83: Average Qatar – Doha Climate Graph (Darwish, 2013)

According to reports from the Qatari Civil Aviation Authority, over the last 30 years the mean air temperature in Qatar has been between 17°C and 35.1°C. The highest recorded temperature was 50°C while the lowest recorded temperature was 3.8°C. The mean relative humidity was between 42% and 72% but reached highs of 90%. The mean wind speed in Qatar was between 7kt and 9kt.

In addition, the highest recorded rainfall in a 45-year period was 155.4mm since December 1964. The average rainfall is much lower than this. Hence, Qatar has one of the smallest supplies of fresh water reserves in the world. The mean daily sunshine is between 7.8 and 11.6 hours, while the mean daily solar radiation is between 347.9 and 646.3 MWh/sq.cm. The effect of the sun on buildings differs according to the orientation of their façades (Civil Aviation Authority, 2013).

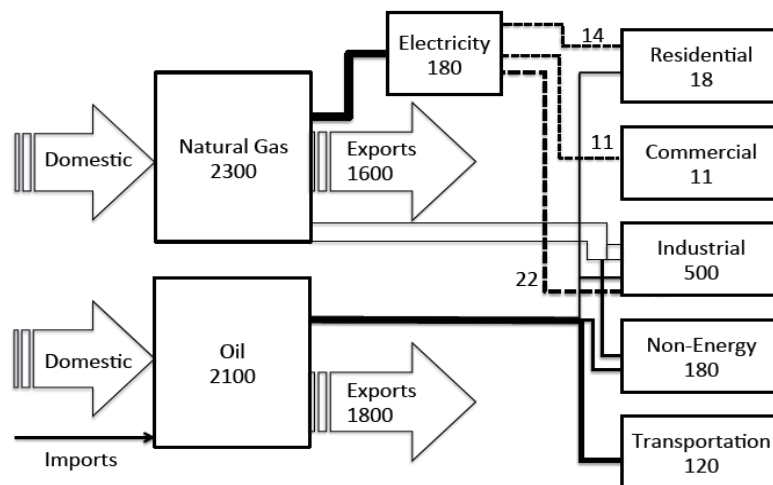


Figure 84: Qatar's Energy Flow, 2007. Values are in PJ/year. Adapted from Smith, Belles, and Simon (2011) (Meier, Darwish, & Sabeeh, 2013)

In Qatar, virtually every building has an air-conditioning system and these are responsible for 70-80% of most buildings' energy bills. It is common practice for a commercial building to operate its air-conditioning system 24 hours a day, 365 days a year (and in many residences, too). Some of the larger, new developments are served by district cooling systems. The remaining electricity consumption mostly grows from lighting and refrigeration (Meier, Darwish, & Sabeeh, 2013).

### 5.1.3 Energy Sources in Qatar

With the exception of transportation, Qatar's electricity supply runs entirely on natural gas. Figure 84 shows Qatar's energy flow in 2007. Present consumption is roughly 50% greater but the distributions are still generally the same. Although, while gas production has increased, oil production has decreased (Meier, Darwish, & Sabeeh, 2013).

## **5.2 Case Study: Barwa City**

Barwa City is the local case study for this research. It is a regular district chosen for study as a potential GSAS-certified district. This research will consider the validity of net zero energy systems for Doha and why there have been no attempts to create Net Zero Energy Districts (NZED) in Doha until now. It will also address some of the obstacles to the implementation of NZED projects in Qatar.

To achieve the previous goals, this chapter will use the following strategies:

- Interview some of the stakeholders responsible for deciding whether to implement a Barwa City NZED project (the owner of Barwa City, Barwa CEO, key operations personnel...etc.).
- Visit the city and determine its energy and carbon emissions by reviewing its bills and statistics.
- Conduct a comprehensive study of the buildings, streets and facilities.
- Suggest some solutions and recommended measures required to implement the net zero energy model in the city.
- Address the main constraints preventing a zero carbon and energy transformation in Barwa City.
- Address the main recommendations for the application of NZED systems to Qatari project

### **5.2.1 Features of the Project**

#### ***a- Reasons for choosing Barwa City as a case study***

Barwa City is a convenient place to start applying Net Zero Energy Districts in Qatar for several reasons:

- 1- The Barwa Housing Company has a constant module for its projects that would make it easy to apply the results to other existing Barwa housing projects and to its future projects.

- 2- Barwa projects are far from the center of Doha, so there is plenty of external space for solar panel installation, storage batteries and other renewable energy systems.
- 3- The size of these projects is suitable for applying NZED systems and testing the results.
- 4- Low-rise buildings, such as those in Barwa City (one to five stories), are recommended for net zero energy projects; in which building roofs, in such buildings, acting as centers of solar systems serve fewer number of apartments, keeping energy consumption under control.
- 5- The city has most of the facilities required that make it an integrated district for the project, such as residential buildings, commercial buildings, *masjids*, schools, nurseries, markets, multipurpose hall, green areas ...etc.
- 6- Some parts of the project are already certified by GSAS like Newton International School.
- 7- The city has an independent electrical station, which makes the calculations for production and consumption easier. It is also easier to switch into renewable energy resources.

#### ***b- Barwa City history***

Some may wonder why large national projects like Barwa City did not start out as green, or at least carbon-free, districts. This question was raised in an interview (conducted on September 1, 2014) with Barwa City's Senior Technical Specialist. He replied:

The city was built in 2006 before the idea of Passive House in 2012 [Barwa Passive House is in the same location]. We have a great experience with net zero energy homes through the Passive House project, but Barwa City was implemented a long time before this experience. Anyway, we got one star according to the QSAS assessment tool, but this happened many years later, after the city construction stage, so the plans and designs of the city didn't consider the environment initially. Comparing with Lusail City, the latter has guidelines started in the design stage related to environmental systems. Furthermore, at that time, applying green rules was not mandatory and was adding an extra cost on the project. Maybe this cost is returnable in some stages and cases, but as a



commercial project, we always try to reduce the cost as much as we can. Some points of net zero energy district are achieved by the design, even if we meant it or not, such as being near to the facilities and schools, public transit network, bike stations... etc. But other technical things, related to insulation and LV panels, for example, were not in the Barwa City company scope. As a commercial project, we calculate everything related to the project, like the electricity bills, which is usually paid by the tenants, not by the owner. So reducing consumption of electricity is not within our scope, for example. Rules related to the energy and carbon footprint should be enactment by the government. The latter should have strict rules related to insulation and energy consumption and production systems. If this happened one day, all investors and companies will put green systems in their scope while implanting new projects.

Barwa City's Senior Technical Specialist added that Passive House is a good starting point for the implementation of green systems by the Barwa Real Estate Company. In an experiment to test these systems and their validity in Qatar, the two villas, Passive House and the ordinary villa, will provide a good comparison. This will serve Barwa investors as well as other investors in Qatar. For Passive House, Barwa Real Estate used green materials and systems and green design to achieve the maximum reduction in energy consumption and maximum energy efficiency. Barwa City was built on reclaimed swampland and an old landfill site. Transforming this land from its polluted state into a green living environment has benefited both the investors and the 2500 residents. This is one of the greatest achievements of Barwa City, of which they are proud (Al-Safi, 2014). The maps from

Google Earth in Figures 85 to 88 show the progression of the area from swamp and landfill to Barwa City.



Figure 85: A Satellite Picture Taken in August 2004 Shows Swamp and Landfill in the Area that is Now Barwa City (Google Earth, 2015)



Figure 86: The start of the Barwa City Project in May 2009 (Google Earth, 2015)



Figure 87: Barwa City During the Construction Stage in July 2011 (Google Earth, 2015)



Figure 88: The Completion of Barwa City's Construction in December 2014 (Google Earth, 2015)

**c- GSAS certification**

Barwa City's Phase-I Residential Buildings' Design was assessed by Qatar Sustainability Assessment System (QSAS). And it received a total score of one, as per the GORD official website; each of Barwa City's apartments received the same score as well (see appendix B for Barwa City's score calculations done by GORD).

### **5.2.2 Barwa City Assessment According to NZED Parameters and EES**

As per the other two case studies in this study, the identification method for NZED based on the existing of one of the four Parameters and most of EES in this district. Barwa City is not designed to be an NZED, and according to the city bills (see section 5.2.4), it is not achieving any of the four Parameters. But assessment is needed to address the missing EES to achieve one of these four Parameters in the future; this study can be useful for Barwa City and similar projects in the country by setting up the recommendation to transfer these projects from normal commercial development to a Net Zero Energy District.

It is easy to know that Barwa City is not an NZED project by testing the city's electricity bills, which are not equal or near to zero; therefore, Barwa City is not achieving any of the four Parameters. To test the level of application of EES, this study will analyze each of them as follows:

*a. Location of Barwa City*

Barwa City is located in Doha, Qatar, to the south of Muntazah Street, between Mesaimmer and the industrial area. It has a built-up area of 945,537 m<sup>2</sup> (see Figure 89).

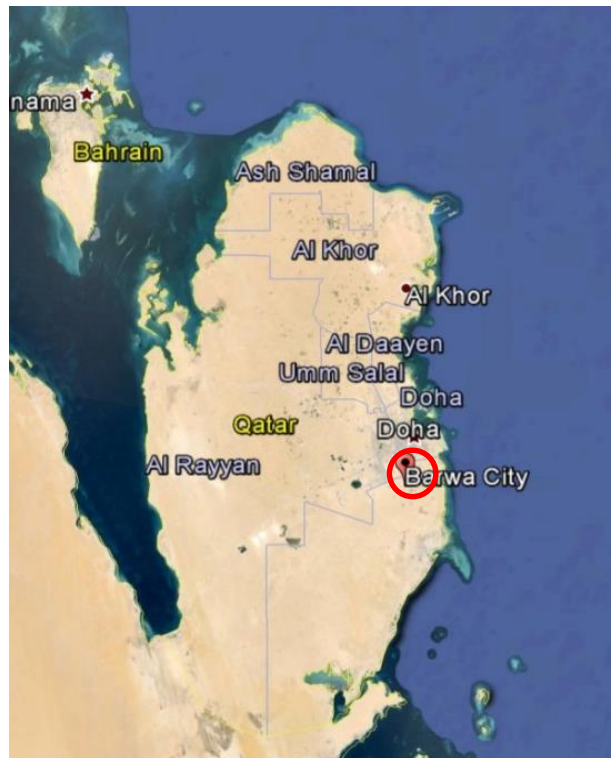


Figure 89: Map Showing Barwa City's Location in Qatar (Google Earth, 2015)

The city is built on a landfill area, which was polluting the site. There was also a polluted swamp in the same location (see Figures 90 and 91).

Qatar is a small peninsula jutting into the Arabian Gulf. The country is built entirely on desert land. Almost 2 million people live in Qatar, nearly all of them in Doha, the capital.

Being in Qatar affects Barwa City's energy consumption in a number of ways. The first of these is the hot weather, which causes high energy costs due to the widespread use of air conditioning and transportation in those months of the year when it is too hot to walk or cycle to one's destination.

The second feature of the Qatar location that affects energy consumption is water scarcity. This

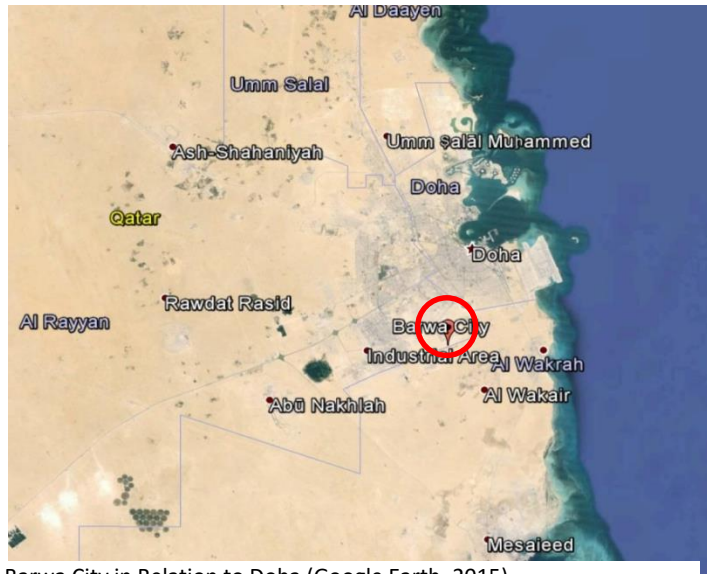


Figure 90: Location of Barwa City in Relation to Doha (Google Earth, 2015)



Figure 91: Barwa City Site Plan (Google Earth, 2015)

leads to energy consumption used for sea water desalination. The rare and irregular rain increases energy spent on irrigation and recycling grey water.

In addition, Barwa City is located in the Abu Hamour area, which is some distance from Doha. As a result, more energy is spent on transportation. However, to control this, the city planners tried to supply most of the facilities required to reduce the number of trips to Doha.

On the other hand, Barwa City was established on reclaimed swampland and a landfill site, which saved the environment in that area and reduced overall pollution rates in Qatar long-term.

***b. Orientation of Barwa City***

Barwa City is oriented  $25^\circ$  to the west from the north (see Figure 92).

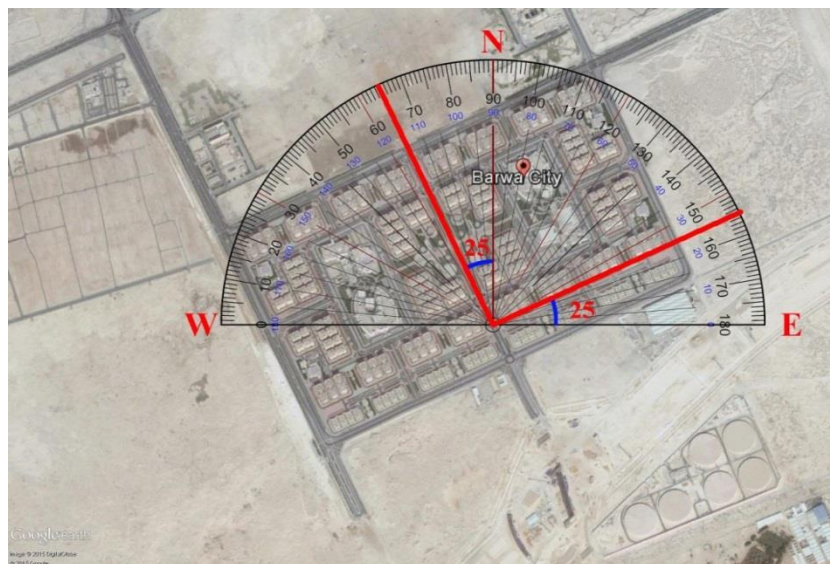


Figure 92: Barwa City is Oriented  $25^\circ$  From the North, adapted from (Google Earth, 2015)

This orientation affects energy consumption and efficiency due to the amount of sun that falls on the city’s buildings (see Figure 93).

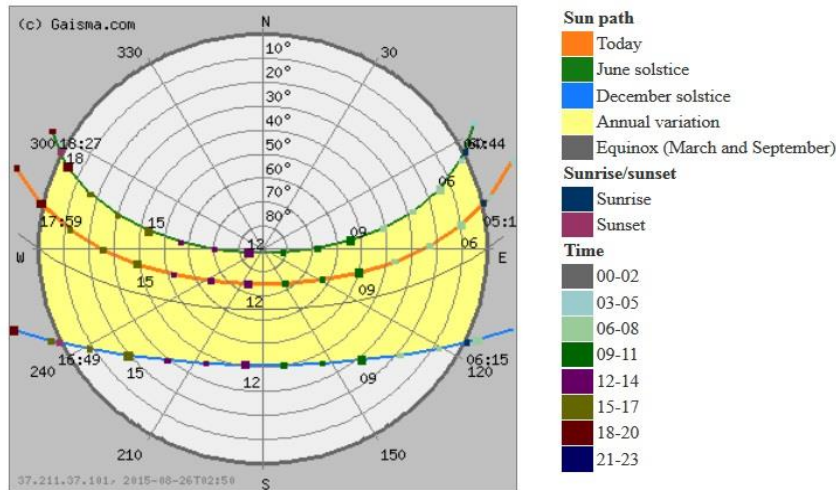


Figure 93: The Sun’s Path over Qatar (Qatar Meteorology Department, 2015)

In Qatar, the preferred orientation of buildings is to have the largest façades facing north-west, which is the direction with the most wanted wind and the least sun. In Barwa City, the buildings are oriented in this manner, which indicates that there was some environmental analysis during the design stage.

*c. Barwa City urban structures*

Barwa City was designed to contain most of the required facilities. The design of the project consisted of two phases. In the first phase, the city streets and residential buildings were distributed on a regular grid with school and kindergarten in the middle (see Figure 94).





Figure 94: Newton Kindergarten in the Center of Barwa City

In the second phase, the streets were distributed radially around a semi-circle with a plaza in the middle (see Figure 95). Barwa City was designed to be a self-contained community composed of 128 residential buildings, offering tenants 5,968 apartment units with diverse interior layouts to satisfy the different needs of its tenants, including studios, 2-bedroom and 3-bedroom apartments. These buildings accommodate up to 25,000 residents (Waseef, 2013).

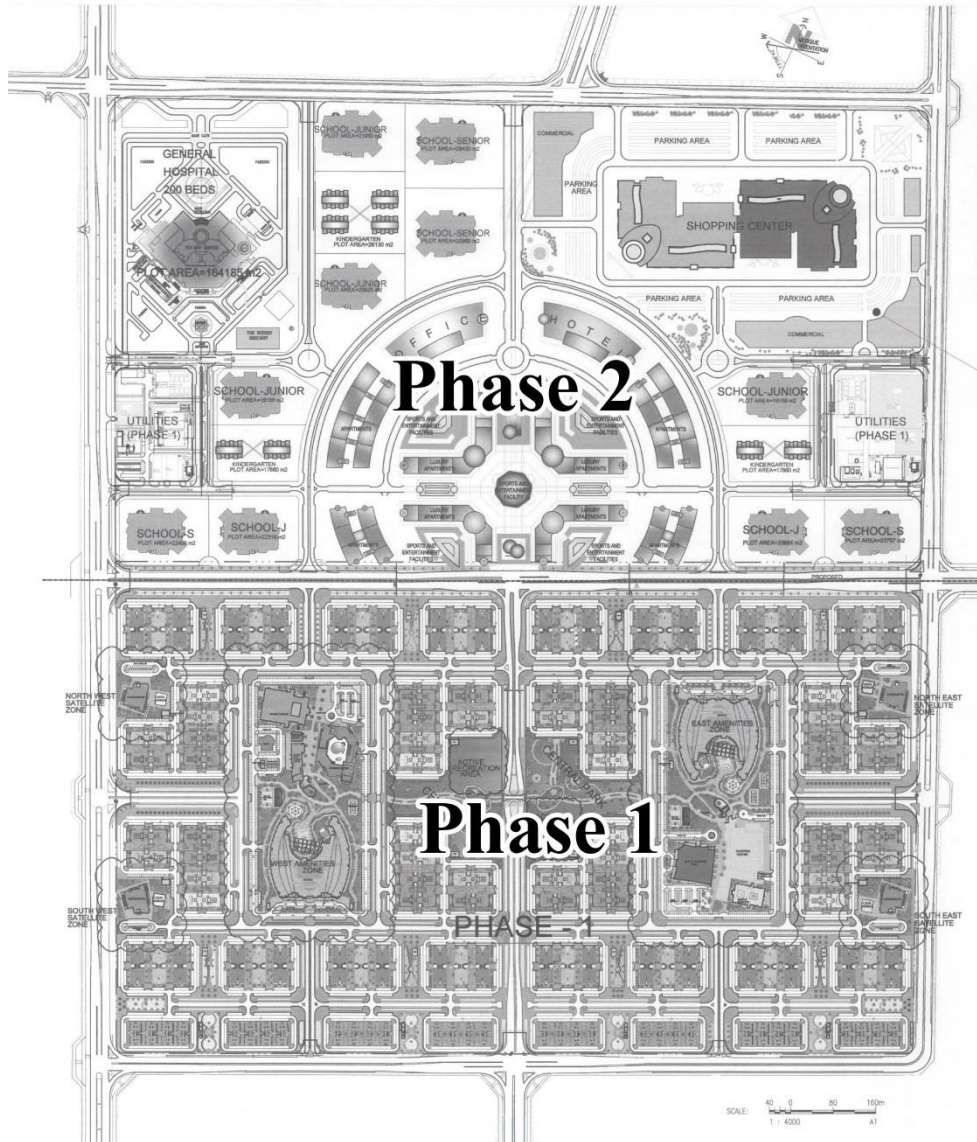


Figure 95: Barwa City: Two Phases (Crisme, Barwa City, 2015)

The first phase offers quality apartments and amenities including a classical-style shopping center (see Figure 96) and a number of retail outlets in a commercial center. There are two international schools in the center of the city and four kindergartens (see Figure 97). The center of this phase contains numerous facilities, including two big *masjids*, a multi-purpose hall, a health center, a sports field, and a bank. There are two big playgrounds, one on the eastern side and the other on the western side of the city. Many green areas are distributed between the residential buildings.



Figure 96: Shopping Center in Barwa City, First Phase



Figure 97: The Schools in the Center of Barwa City, First Phase

The project's second phase was designed to be mainly commercial. It contains a luxury shopping center, more schools, kindergartens, luxury apartments, a hospital, offices, and hotels.

The residential area (phase 1) has a higher building density and narrower streets than the commercial area (phase 2). The buildings in phase one are distributed in blocks or communities, each containing two to four buildings with their own parking and green area.

Phase one is now almost finished and fully occupied by residents and some markets opened like LuLu Hypermarket (see Figure 98) but, for commercial reasons, phase two has not yet been started, even though it was planned for completion by May 2014.



Figure 98: Lulu Hypermarket in Barwa City

In an interview about energy efficiency with a tenant of the residential buildings in Barwa City, the resident stated that the quality of life in Barwa City is good. She praised the district cooling system and stated that it works properly; Waseef company teams are making maintenance yearly just before the summer time for the whole cooling system. The resident added that:

*“The best thing has been done in the city is the markets and other facilities, which are reachable by walking; they are amazing, especially in the winter months”* (Nour, 2015).

Other residents praised the green areas and internal corridors; one of them said,

*“It’s safe place for children to run and play without fear of car accidents, unlike other many places in Doha”* (Bahdour, 2015).

One of the workers there said that it is a nice place to use his bicycle safely. On the other hand, there are some Barwa City residents on social media websites claiming the high utility bills for everybody, even for small families. Some of the residents claimed that when they were on vacation and out of the country they received the same bill in the same amount of other months. They claimed that the overall bill is distributed between the residents dismissing the case of each of them; others requested big and visible electricity, water and gas meters to control their consumption by themselves (Scott, 2014).

*d. Infrastructure (District Networks)*

Barwa City utilizes district cooling system plants (DCS) to provide air conditioning, and other district networks are providing a central gas network, and a central TV channel system (GORD, 2014).

The district cooling system (DCS) is durable and energy efficient; in addition, there is an individual control unit in each space, which reduces energy waste by not cooling unused spaces like offices in the evening.

The Maintenance Department Director at Waseef, Barwa City's operator company, has stated that the water used in the district cooling chillers is all recycled, further enhancing the energy and water efficiency of this system. On the other hand, the energy used by the DCS comes from natural gas, which is a non-renewable resource. However, district cooling consumes 47% less energy and produces 51% less greenhouse gas emission than individual chiller units (Poeuf, Senejean, & Ladaurade, 2010). To increase the energy efficiency of the project, an alternative to natural gas could be used for cooling, such as geothermal energy and solar panels.

### *e. Façades*

The façades of Barwa City's buildings are normal, uncured, precast concrete panels covered with plaster and normal paint. They have no thermal insulation (Crisme, 2015).



Figure 99: Small Windows Are Used on the Façades of Residential Buildings

The buildings' windows are designed to cover small areas (see Figure 99), especially in the residential buildings, as this reduces the amount of heat and sun that enters the buildings through windows. There are shades over the windows to reduce the effect of the sun inside the buildings, but, in some cases, these shades are not on the façade that receives the most sunlight.

Façade shades may be on the north, south, east or west side, depending on the shape of the building rather than their function (see Figure 100).



Figure 100: Shading Elements and Louvers on Building Façades: The Shopping Mall

This issue could still be rectified by adding external shades such as horizontal or vertical louvers based on calculations of the angles of the sun's rays (see Figure 101).



Figure 101: Shades over the Residential Buildings

#### *f. Thermal insulation*

The Maintenance Engineer at Waseef in Barwa City stated that there is no thermal insulation installed in the building façades or building roofs. This is to reduce the building costs and because there are no mandatory rules about thermal insulation (Crisme, 2015).

### *g. Electrical equipment*

Some of the residential units are furnished and others not. The supplied appliances in the furnished apartments have been chosen according to their cost and durability. Electrical efficiency and water efficiency are not listed in the owner's main goals. (Crisme, 2015).

### *h. Landscape*

Barwa City is covered with green areas. This makes the city a spectacular sight, but the green areas consume a lot of water and energy in the irrigation process. These plants are for decoration only and cannot be used for other purposes, such as food. Waseef, Barwa City's property management service, claimed that treated grey water has been used for the irrigation process, but sometimes there is not enough grey water, forcing them to use the fresh, municipal water for irrigation. Some of the energy consumed in irrigation is produced by solar panels on the site but, unfortunately, many of these units no longer work and the irrigation is powering recently from the national grid.

The plants in Barwa City comprise many species. Some of them are native plants and can easily adapt with Qatar's climate, like palm trees, which reduce their need for irrigation, while other species are foreign species and need a lot of irrigation water to stay alive. Most of the green area is covered with grass, which is known as a big consumer of irrigation water (see Figure 102).



Figure 102: Grass Consumed a lot of Water During Irrigation



Bougainvillea flowers are a native species of South America used mostly in green areas, which also consume a lot of irrigation water (see Figure 103).



Figure 103: Most Plants in Barwa City are Ornamental Plants

*i. Water consumption*

Water demand in Qatar is expected to double from 1.1 million m<sup>3</sup>/day in 2011 to 2.1 million m<sup>3</sup>/day in 2020 (Nezar, 2014). All of the fresh water in Qatar is coming from the desalination process, which costs the country 40% of its gas production. In other words, desalination adds at least one kWh for every 200 liters of water consumed. A Qatari home uses 2,000 liters of water per day, requiring over 3,000 kWh/year in power at the desalination plant. Consequently, saving in water consumption is directly translated to saving in energy (Meier, Darwish, & Sabeeh, 2013).

In Barwa City, recycled water is used partially for irrigation; there is no rain water collection because the average annual rain in Qatar is below 155.4mm (Civil Aviation Authority, 2013). Some of the irrigation water is using municipality fresh water as mentioned before, which consumes more energy for desalination (see Figure 104).



**Figure 104: Green Areas Around Barwa City Consume a lot of Irrigation Water**

As per Waseef, there has been no water management strategy for decreasing the water consumption until now, except the awareness campaign done by KAHRAMAA itself. Water efficient fittings (like water taps, toilets, water heaters.... etc.) were not considered in the finishing stage of the buildings; all internal fittings have been chosen according to their cost and durability only.

#### ***j. Transportation***

Cars are unwelcomed in Barwa City. Roads are narrow compared to those in other Doha projects like Pearl or other Barwa projects, and there are no petrol stations in the city. The city planners have tried to encourage the use of alternative transportation modes, such as walking and cycling (see Figure 105).



Figure 105: Bicycle Parking in Barwa City

Most of the city's facilities are within walking distance of the residential buildings, and bicycle lanes and bicycle parking points are provided all over the city. Furthermore, the city is on the route map of KARWA Buses and has five bus stations distributed across the public areas.

The transportation obstacle in Barwa City is that it is some distance from downtown Doha, which increases the consumption of energy by those making regular trips to Doha, especially by those who work or study there and are not using public transit.

Furthermore, Barwa City is not on any of the three new metro lines until now but there is a chance for making a station on alSunaeiih Road serving Barwa 8Klm Market and Barwa City, if not the nearest station will be in al-Wakra, 20 km from the city (see Figure 106).



a great deal in transportation energy and harms the environment. Waste ought, instead, to be used to produce energy (see section 3.3.2).

#### *l. GHG Emissions*

According to the Head of Sustainability in Qatar's Green Building Council, the built environment in Qatar is significantly affected by carbon pollution, in terms of energy and water consumption. So mitigating these impacts, and thereby reducing CO<sub>2</sub> outputs, is of the utmost importance.

A clear system is required to measure the value of CO<sub>2</sub> remaining in the atmosphere, carbon-saving needs to be given a value in terms of tax breaks or carbon credit trading (Amato, 2013).

There was no initial planning in the design of Barwa City to make it a low carbon city. The senior technical specialist at Barwa Real Estate Group indicated that this goal was not within the city planner's scope for several reasons. These included financial issues and time limitations. In addition, at the time Barwa City was designed (2006 to 2008), the country was not really on the sustainability track and sustainability was a moral choice only, rather than a mandatory regulation.

#### *m. Operational Processes*

Barwa City seems to be a perfect place to live. It is well-organized, with plenty of schools, green areas and facilities. Such large projects enhance urban development in Qatar. On the other hand, several residents of Barwa City have told an electronic newspaper that they are disputing unexpectedly high utility bills for gas and chilled water with Waseef. The bills remain consistently high, even for periods when residents are on vacation and not using electricity, gas and water for the whole month. The DCS and gas board have individual control units for each apartment, but some of the tenants claim that there are no individual electricity meters in each unit to notify tenants of their power and water consumption. In those instances, where there is a meter, it is not accessible to the tenant (Scott, 2014).

There is no real waste management in the city, which causes problems for the environment. The landscape plants in Barwa City do not support food security in Qatar and their irrigation accounts for 40% of municipal water usage.

In addition, phase two of Barwa City has not yet been accomplished and will take much longer than planned. This phase incorporates many of the facilities required to reduce the number of trips to Doha by residents. The absence of these facilities affects fossil fuel consumption and CO<sub>2</sub> emissions.

#### *n. Renewable Energy Systems*

Barwa City has some solar panels, which are used to generate power for recycling water used in irrigation, and others fixed on the top of Newton School but these are not sufficient to power the whole recycling process.

More solar panels could easily be installed if Barwa City were to become a Net Zero Energy District. The roofs of Barwa City buildings are suitable for the installation of LV panels and the city has low-rise buildings, which are more efficient when using renewable energy.

Furthermore, it is easier to convert DCS from fossil fuel to renewable energy consumption than individual AC units. Solar panels, geothermal systems, wind turbines, etc. could be installed to supply the entire district cooling system.

### **5.2.3 Results and Interpretations**

Although Barwa City has been assessed by GSAS, only the part of Newton School was certified as a green project (see Figure 107) because of the following features (GORD, 2014).

- Utilize passive shading by constructed elements.
- Use district cooling system.
- Utilize generators for energy recovery system.
- Use water efficient fittings.
- Use water efficient irrigation system.

- Collect and recycle grey and storm water.
- Installed materials are imported from regional countries.
- Implement strategies to eliminate indoor toxic materials.
- Provide sufficient acoustic materials insulation to meet minimum requirements for indoor acoustic quality.
- Provide energy sub-metering.
- Provide intelligent building control system.

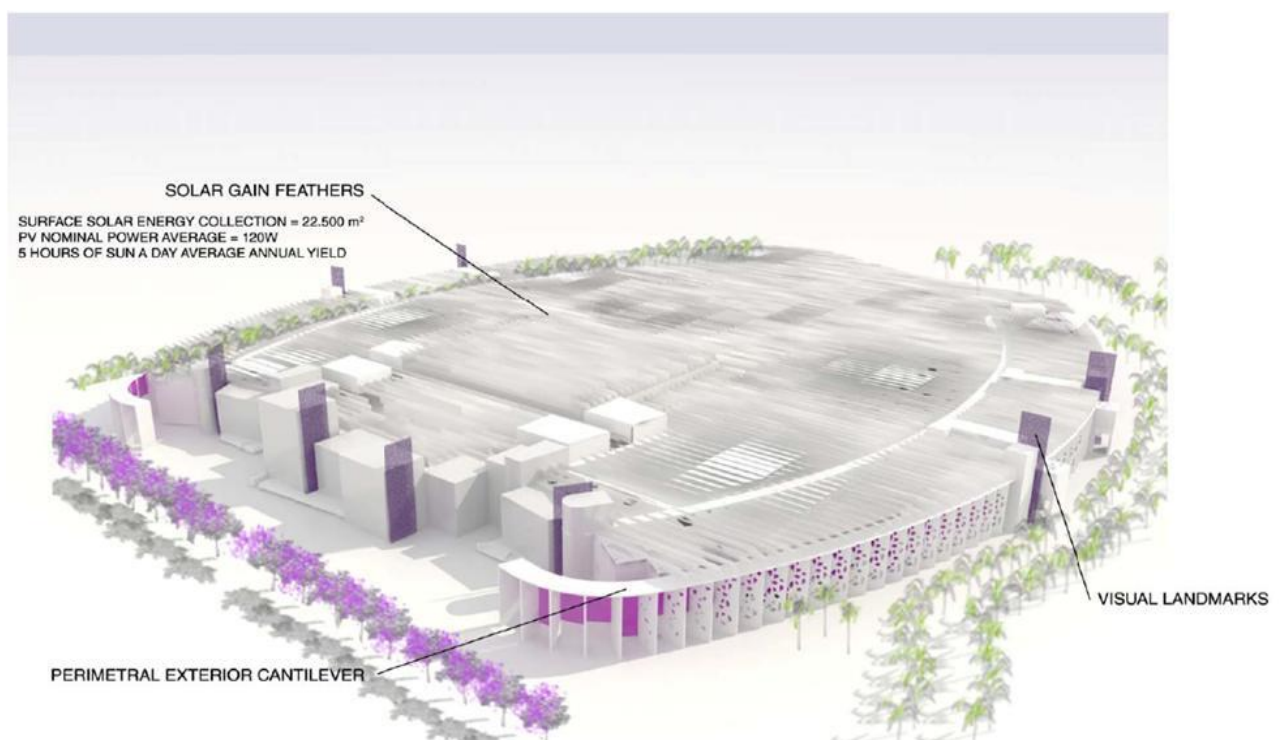


Figure 107: Some Sustainable Features at Newton School in Barwa City (GORD, 2014)

Even though, the whole city is not considered as a Net Zero Energy District or a green district. Undeniably, some principles of sustainability were considered when implementing Barwa City, but they were insufficient to make Barwa City a sustainable district. An NZED needs a fully sustainable system that takes into account all energy efficiency strategies and environmental and social principles.

The city is fully reliant on electricity from the national grid as well as gas for cooking and gasoline for transportation. However, the average annual consumption for electricity and water are estimated to be 6000MW and 420MIGD respectively (Crisme, 2014). When was asked about this consumption, an energy expert in Siemens Global company in KSA stated (see Figure 108).

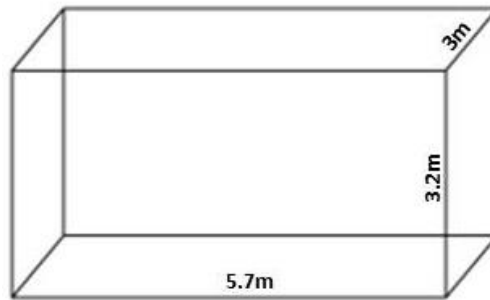


Figure 108: The Daily Petrol Usage to Operate Barwa City

*“These numbers are really high as well as most of the projects in the gulf Area, it means that the city needs 40,000 liter of petrol per day, in other words it consumes an amount of petrol enough to fill a room with size of 3m width X 5.7m length X 3.2 meters high every day” (Yousef, 2015).*

Most of the planned services are not yet available to city residents, which results in more trips to Doha and more energy consumption.

The city designers, AECOM, considered the orientation of the sun and wind during the first stage of design, but there were coordination problems when the external elevations were designed. First, the external materials chosen are commercial materials without thermal insulation. Second, the external shades have been distributed randomly over building façades to serve the external shape rather than their function. Third, the glass used in the windows is a single layer of commercial glass.

Evidence of some consideration of minor environmental issues gave Barwa City one star in the GSAS, but the city has a long way to go to become a Net Zero Energy District.



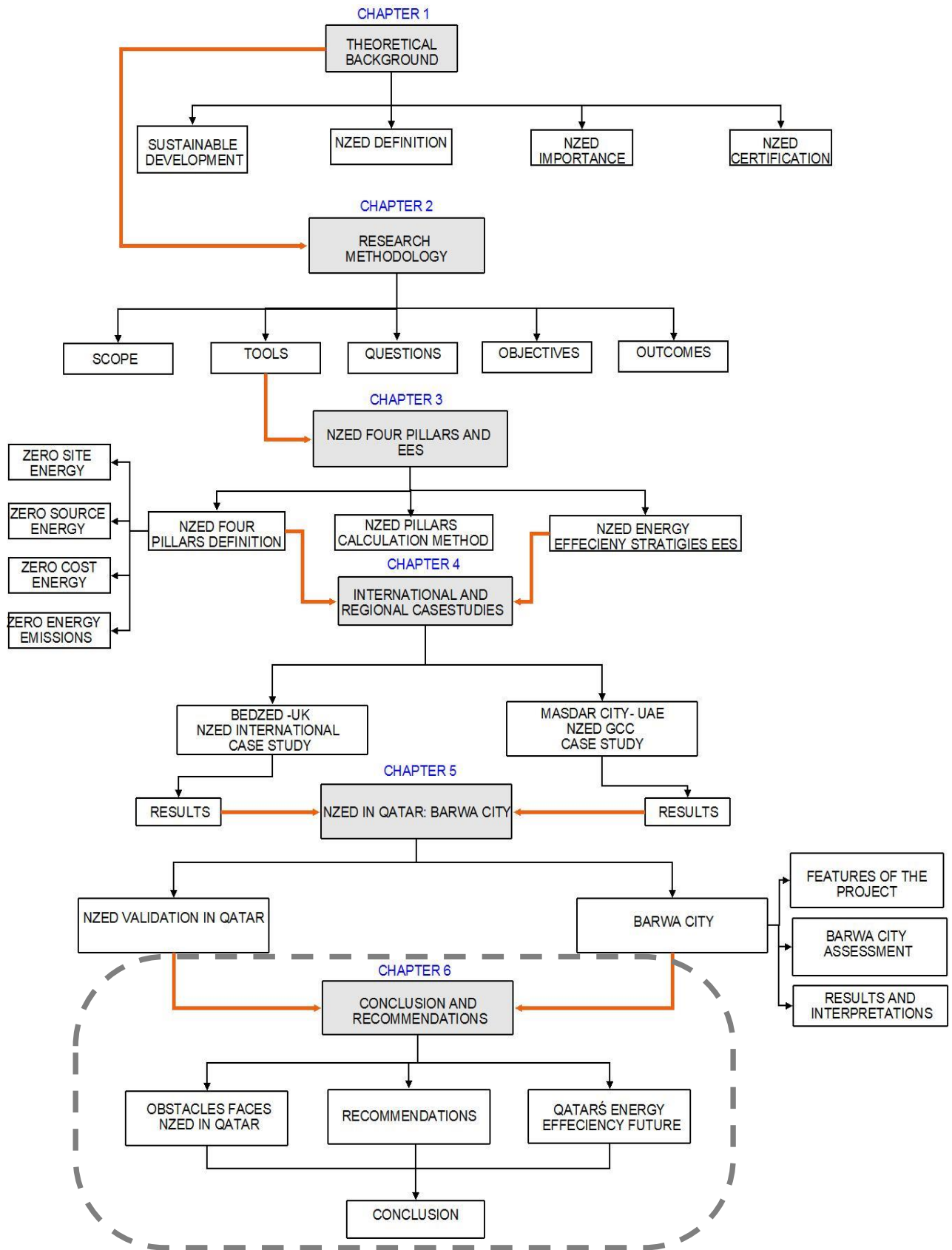


Figure 109: Flowchart of Research Phases – Chapter 6

## Chapter 6. Conclusion and Recommendations

Known that Qatar is an energy-rich country. This is one of the main reasons that Qatar faces problems with energy conservation. These problems are caused by high per capita incomes and very low energy prices (Electricity is free for Qatari citizens.).

A large number of residents are workers disinclined to invest in higher efficiency equipment because they expect to leave in a few years.

In addition, a shortage of experts, such as skilled engineers, and a shortage of materials and energy-saving products make it harder for building owners to implement even a simple measure (Meier, Darwish, & Sabeeh, 2013).

In 2012, Qatar announced plans to gradually phase out the use of incandescent bulbs. It also announced plans to make the installation of photovoltaic systems compulsory. This would displace 2% of electricity demand. There are similar plans to make solar thermal systems compulsory to reduce energy consumption used on water heating. Unfortunately, these measures are yet to be applied (Meier, Darwish, & Sabeeh, 2013).

A green building code is a key element of Qatar's strategy to reduce energy use in buildings. The code is presently voluntary; however, the goal is to make it mandatory once architects and builders have become more familiar with its requirements. Another element of Qatar's strategy is the Global Sustainability Assessment System (GSAS), which seeks to create a means of benchmarking green building developments throughout the Gulf region (GORD, 2014).

Apart from certain light fixtures, no minimum efficiency standards for appliances have been established. Qatar has no domestic production of appliances, and it is costly for large projects to identify and purchase the world's most efficient products. In practice, haste to complete projects, private reluctance to invest in efficiency, and the presence of suppliers of low-efficiency products in the Middle East, results in relatively low product efficiency. This is especially true for air

conditioners, which consume the greatest amount of energy inside buildings (Meier, Darwish, & Sabeeh, 2013).

This Research applied an adapted identification method of NZED on Barwa City as a local project, and concluded that Barwa city –as many of the country residential projects – is a very big consumer of energy where there is no minimum consideration of application of Energy Efficiency strategies. The city’s energy and water bills are slightly high as mentioned before. In general, there are still no net zero energy projects in Qatar, especially at districts scale. The following recommendation can be applied on such projects to reduce energy consumption of them at the minimum. Once these project designed to use one or more renewable energy systems; they can reach net zero energy point to be NZED. Also these systems have to be tested after operation as shown in the two presented case studies. Some systems are working properly at the beginning of the project then could be face some complications after certain time of operation.

## **6.1 Recommendations and Guidelines Towards NZED in Qatar**

To answer the main question of this research; How NZED projects can be implemented in Qatar, the following recommendation can help to reduce energy consumption in district projects in Qatar and renewable energy can supply needed energy to achieve NZED concept.

### **6.1.1 Energy Efficient Electrical Equipment:**

First of all; there is a real need for minimum efficiency standards - code- for appliances in Qatar. This goal would not be difficult to achieve. For instance; in the first case study BedZED in addition to the daylight which replaced the need of artificial lighting during the daytime, it was mandatory to use LED lights, which have reduced the electrical consumption by 80%. Energy efficient appliances were used most in BedZED buildings which reduced energy consumed by these appliances by 25%. In Barwa City; energy efficient appliances and other equipment have the potential to reduce electricity consumption and the resultant GHG emissions by 10% long-life while they will increase

the initial cost by 5% for one time only. Provision of smart meters to allow users to monitor resource usage would be useful after teaching people how to reduce their energy consumption. Energy efficiency awareness has to be distributed among the city residents. Recently, KAHRAMAA began to do this through two awareness campaigns; the first one called “It’s Simple”, which was designed to teach the public basic energy-saving principles, the most recent campaign branded by “*Consume Today Risk Tomorrow*” and its implemented for the same purpose.

### **6.1.2 Water Management:**

Recycling wastewater reduces water use and saves energy. Presently, about 25% of Qatari water is recycled, which is above average in the Gulf, but the country still needs an infrastructure to deliver recycled water to every user. Recycled water is currently used solely to irrigate plants and for industrial processes. Increasing the rate of water recycling (and reducing distribution losses) appears to have considerable potential (Meier, Darwish, & Sabeeh, 2013). Also, the government should reduce the demand for irrigation of open spaces, which consumes more than 65% of the desalted water in Qatar. Using native species of plants that are more suited to the local weather and consume less water is another possible measure.

Qatar is one of those countries with the lowest levels of annual rainfall in the world, so rain is not among the water sources considered. Therefore, installing rainwater collecting systems is not recommended and would be a waste of time and money.

Barwa city need to develop its water recycling system to cover all the irrigation process in the city, this recycling system should be operated totally by solar system.

### **6.1.3 Renewable Energy Systems:**

Renewable energy sources are rarely used in Qatar because of its abundance of oil and natural gas. Such technologies are not considered by investors and designers because of their relatively high initial cost, running cost of energy is not considered especially if it will be paid by residents.

Solar power is available nine months yearly in Qatar and it's one of the biggest alternative power sources in the world, solar power has to be considered and has to be used as renewable energy system, such system needs to be regulated by the government at least to be mandatory for the new projects. Recently; Qatar Solar Energy Institute QSE has been lunched to support Qatar's plans of using solar power, but relatively the institute productivity still very low and inconsiderable.

Projects like Barwa City need to reduce their energy consumption by at least 50-60%. Solar water heaters and photovoltaic cells should be fixed to each home and solar lighting should be used in public open spaces.

In Barwa City, there are a few solar panels to provide energy for water recycling (for irrigation purposes) but this system is covering less than 20% of needed recycled water. This solar system has to be improved to serve the whole irrigation system energy usage.

#### **6.1.4 Waste Management:**

Some progress in recycling construction material was made, but it is still behind many other countries. In November 2014, for the first time in Qatar, a road was constructed using reclaimed and recycled stones from a construction site and landfill (see Figure 110) as part of a research initiative by the Ministry of the Environment and other parties (Walker, 2015).



Figure 110: The First Road Made from Recycled Construction Materials in Qatar (Walker, 2015)

### **6.1.5 Efficient Transportation System:**

Projects like Barwa City far from the center of Doha are a good way to expand the area of the city and relieve pressure on the downtown area. On the other hand, they double the energy consumed in transportation if they do not provide all the facilities required by residents. Good public transport needs to be investigated and provided for all of the scattered cities in Qatar. The transportation system needs to serve all segments of society and to consider the culture and mentality of Qatar residents. Karwa bus stations are distributed across Barwa City but those residents who use Karwa buses are a limited segment of society. The metro lines should serve Barwa City and some other scattered cities. Therefore, it is recommended that lines are built to connect all parts of the country. This could replace 40-60% of private car usage, according to national plans (Al-Enzy, 2011).

In the community, planners need to ensure all households are within a 200-meter radius of a public open space and all other necessary facilities. This will encourage walking in good weather. In shared-use zones, the planners should establish the priority of pedestrians and cyclists. Cycle lanes are provided all over Barwa City, but they are not fully utilized even in good weather. Residents' lifestyles and habits need to be investigated, and residents need to be taught the benefits of using alternative transportation rather than private cars.

### **6.1.6 Energy Efficient Materials:**

New policies are needed to force building designers to apply sustainable building design measures. This should include the use of building materials selected for energy efficiency to maximize each building's lifespan. This will save energy used in construction. The building materials used must also reduce the accumulation of solar heat inside buildings—consequently reducing energy consumption used to cool buildings (This is of particular concern in the Gulf region.).

### **6.1.7 Regular Energy Audit:**

The government should introduce mandatory rules and regulations to put investors on the green track when implementing new projects. These rules would ensure energy and water saving both during construction and after completion.

Energy audits should be conducted during and after construction of new buildings. Inspection, surveillance and analysis of energy flow would help to identify ways to conserve energy in a building, process or system.

## **6.2 Research Limitations**

This research faced many challenges in its various stages including but not limited to:

- Time limit affected several parts of the research.
- The difficulty of collecting information from Governmental institutions in Qatar as a primary resource of information affected the collected information availability and accuracy.
- There is a very limited updated information about Qatar and its facilities in secondary resources which affected the choice of the local case study where most of other case studies are lack of information.
- There are some parts of the research that need to be investigated technically and need some calculations to be done by an electro mechanical specialist.
- The available information about case studies are not equal since they are from different resources and have different locations.
- There is no much available information about Barwa city and some collected information is not allowed to be published.
- The remote location of the local case study imposed extra difficulties on paying site visits, getting appointments and conducting interviews.

- Due to the relatively pioneering nature of the topic, especially in Doha, information was scarce.

### **6.3 Future Researches**

What has been done in this research only sheds light on the possibility of implementing NZED projects in Qatar. This topic is still open and requires conducting further investigation and obtaining deeper information about Barwa City, it also needs life cycle analysis LCA that could be conducted to deeper understand of its energy situation and help to redesign the city systems to include all EES and renewable energy systems. Future research can apply all findings and recommendations of this study in order to record the change in the project energy consumption and the change in its LCA calculations.

### **6.4 Qatar's NZED Future**

In general; there are compelling national motives to reduce energy use and adopt renewable sources which are the main principles of implementing NZED projects.

For example; the government recognizes the environmental impact of high energy use recently. Natural gas is a relatively clean fuel but carbon emissions have climbed sharply and local air quality in Qatar is declining.

A promising development toward the solid waste management sector in recent years was establishing the Domestic Solid Waste Management Centre (DSWMC) at Mesaieed. This center is designed to maximize the recovery of resources and energy from waste by installing new technology for the waste separation, pre-processing, and composting of waste, mechanical and organic recycling, and waste-to-energy conversion. It is expected to treat 1550 tons of waste per day and to generate electrical power supplying around 34.4MW to the national grid (Suresh, 2014).



The output from desalination plants is saltier water than the Persian Gulf surrounding Qatar. Water circulates poorly in the Gulf and increasing salinities have been observed around Qatar (and other Gulf states). Desalination will require even more energy as the salinity rates rise and will, eventually, be technically constrained (Elimelech and Phillip, 2011).

Energy not consumed in Qatar can be profitably exported. Thus, there is an economic incentive to reduce Qatar's energy consumption. In neighboring Saudi Arabia, projections show that rising internal consumption will eliminate all exports and it will be forced to import oil. Qatari policymakers want to avoid this scenario in Qatar's future.

The electricity and water utility, KAHRAMAA, has announced plans to reduce electricity consumption by 20% and water consumption by 35% over the next five years (The Peninsula, 2012).

A 2008 regulation, Conservation Law 26, lists responsibilities, regulations, violations and fines for wasting water and electricity. The law requires KAHRAMAA and other relevant authorities to:

- Develop the technical specifications for thermal insulation and power-saving measures in residential buildings as well as commercial, industrial and investment facilities;
- Update the technical specifications for internal electricity and water installations;
- Upgrade audit methods to reduce power and water loss in premises with high consumption;
- Develop and update technical specifications and standards for instruments, tools and equipment used in electricity and water installations and link them to the specifications for granting building permits;
- Provide technical consultancy on usage of the modern instruments, tools and equipment that will help ration the use of electricity and water;
- Employ the media to establish and disseminate a culture of rationed consumption of electricity and water;

- Work with relevant authorities to incorporate electricity and water rationing values into school curriculums and religious propaganda, preaching and guidance programs;
- Forbid the use of potable water for washing cars or other equipment, or cleaning up the yards of buildings or constructions using a hose or any other water flow tool;
- Forbid the leaving on of outdoor lights, fixed on public or private buildings, and construction fences or façades between 7 am and 4:30 pm;
- Forbid leaving damaged or broken down parts of the internal water network without repair that would cause water leakage after the owners and tenants have been notified by the corporation (Meier, Darwish, & Sabeeh, 2013).

Qatar could improve the efficiency of new equipment by adopting regulations already established by bodies such as KAHRAMAA or by hired European partners. However, Qatar must still develop its own strategy for buildings to deal with the unique problems of construction and operation in an extremely hot climate with an extreme scarcity of water. It must also confront the pricing policies that result in free energy and water for Qataris and exceptionally low prices for all residents.

## **6.5 Conclusion**

Being a Net Zero Energy District is not just a brand name with some solar panels on buildings' rooftops. Implementing Net Zero Energy District anywhere is implementing a new lifestyle of the district residents; that changes people's ways of thinking; it is a change in every single detail around them. NZED implementation is a sense of responsibility towards future generations.

Some investors claimed that NZED projects are a luxury, costly, an optional choice of buildings, but from this study's point of view it's a mandatory action that should be taken by responsible authorities to avoid continuous harming of both the depleted resources and environment.

Qatar is located in an energetically inhospitable climate, hard climate and abundance of resources caused wasteful use of energy. In the last decade, economic growth and construction has been

prioritized over reducing energy use. This situation has to change. Attitudes are gradually shifting with the increasing use of renewable energy and energy conservation. The gradual completion of major infrastructure projects over the next decade may translate into a sharp reduction in energy growth rates and possibly even a decline.

Implementing the first Net Zero Energy District in Qatar will be the most difficult one, but the responsible team will learn from their first experience, and they will create a more developed model of NZEDs.

The previous recommendations are based on one local and two international and regional case studies. These recommendations can be used as a starting point to transform existing neighborhoods that meet certain criteria into energy efficient developments toward NZED.

The four Parameters discussed here are just used to assess if the district is achieving its goals or not. It is not necessary to reach the zero value, and it is not so important as much as applying that collection of strategies (EES) to conserve natural resources, stop harming the environment and afford a better quality of urban life.

Although the government has the greatest responsibility for the enactment of laws, individuals also have their responsibilities to change their lifestyles and levels of energy consumption. Increasing public awareness about the importance of energy and water and methods of reducing their consumption is a huge task. KAHRAMAA in Qatar has begun two awareness campaign to teach its residents the most efficient ways of consuming power and water, the first one called *It's Easy* and the other one branded by *waste today danger tomorrow*. These campaigns still new and there are no predictable results for them.

Finally, this research confirms that NZED is not an impossible mean. As discussed in the research chapters, most of the EES are applicable and can be planned with the first stages of any project. In fact, making all new neighborhoods NZEDs seems affordable—especially in Qatar where financial cost is not the first concern for many mega projects. Additionally, it is increasingly necessary to

face upcoming power and water shortages worldwide and to create a secure future for generations to come, which is the real meaning of sustainability.

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## Appendix A: Dubai Municipality Law about using solar heaters in new buildings



بلدية دبي  
DUBAI MUNICIPALITY



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06/12/2011

تعميم إلى جميع المكاتب الاستشارية وشركات المقاولات العاملة في إمارة دبي

رقم (183)

بشأن " استخدام نظام السخانات الشمسية لتوفير المياه الساخنة في المباني بإمارة دبي "

تنفيذا لقرار صاحب السمو الشيخ محمد بن راشد آل مكتوم نائب رئيس الدولة رئيس مجلس الوزراء حاكم دبي بالبدء بتطبيق معايير "المباني الخضراء" على كافة المباني والمنشآت في إمارة دبي والحفاظ على الموارد الطبيعية والعناصر البيئية في الإمارة و إلى التعميم رقم 161 الصادر بتاريخ 2008/4/3 بشأن تطبيق معايير المباني الخضراء في إمارة دبي، وإلى القرار الإداري رقم ( 344 ) لسنة 2011 بشأن اعتماد وتطبيق لائحة شروط ومواصفات المباني الخضراء في إمارة دبي ، فإن بلدية دبي تهيب بجميع المكاتب الاستشارية وشركات المقاولات العاملة بإمارة دبي العمل على استخدام نظام السخانات الشمسية لتوفير المياه الساخنة في الفيلات السكنية ومسكن العمال وكذلك في المباني والفنادق والشقق الفندقية والمراكز التجارية والأماكن العامة والمنشآت التعليمية والصناعية حيثما أمكن وطبقاً للتالي :

- أن تكون وفقاً للمعايير والمواصفات الفنية المرفقة بهذا التعميم.
  - أن يقوم الاستشاري المشرف على المشروع بعمل حسابات التصميم لنظام السخانات الشمسية مع تقديم مخططات توضح أماكن وسعة السخانات الشمسية من خلال المخططات الميكانيكية المقدمة للترخيص.
  - أن يكون نظام السخانات الشمسية حاصل على شهادة اعتماد من مختبر دبي المركزي مع الاحتفاظ بنسخة من شهادات المطابقة في موقع العمل.
  - أن يكون نظام السخانات الشمسية مزود بنظام تسخين كهربائي احتياطي يعمل في حال عدم توفر الطاقة الشمسية اللازمة
  - أن يوفر النظام الشمسي المستخدم على الأقل 75% من الاحتياجات الكلية من المياه الساخنة في المبنى.
  - في حال وجود أحواض للسباحة يجب توفير نظام تسخين مياه خاص بها بسعة لا تقل عن 50% من السعة الكلية المطلوبة لتسخين هذه الأحواض.
  - أن يتم التركيب والتشغيل والصيانة لنظام التسخين الشمسي من قبل شركة مسجلة ومرخصة في دائرة التنمية الاقتصادية ومعتمدة من بلدية دبي.
  - يجب تنظيف المعدات وصيانتها بشكل دوري لضمان استمرارية التشغيل بكفاءة .
- علماً بأنه سيتم البدء اعتباراً من تاريخ 2012/3/4 بالتدقيق على هذه المعايير لجميع المخططات الجديدة المقدمة لقسم تراخيص المباني بغرض الترخيص .

أملين من الجميع الالتزام بما جاء في هذا التعميم لضمان سلامة وصحة عمالنا

خالد محمد صالح  
المهندس  
إدارة المباني



Our Vision - To create an excellent city that provides the essence of success and comfort of living.



## المواصفات الفنية لنظام السخانات الشمسية في إمارة دبي

### 1. مقدمة

نظرا لما تمتع به دبي من جو مشمس في معظم أيام السنة و طاقة شمسية عالية جدا فإن استخدام نظام السخانات الشمسية لإنتاج المياه الساخنة (SHW) تعتبر وسيلة ذات جدوى اقتصادية عالية وخاصة للمباني التي لها استهلاك عالي من المياه الساخنة وذات ملكية فردية واحدة مثل الفلل وسكن العمال والفنادق. وحيث أن الفلل وسكن العمال لها نسبة سطح كبيرة مقارنة مع المساحة الإجمالية للمبنى فإنها تعتبر من أكثر الأنواع ملائمة لتطبيق هذه التكنولوجيا.

### 2. المجال

يقدم هذا الدليل الإرشادات الفنية لتصميم واستخدام نظام السخانات الشمسية في إمارة دبي لإنتاج المياه الساخنة للاستخدام المنزلي في المنازل وسكن العمال وكذلك إرشادات التركيب والتشغيل والصيانة والحماية ولا يغطي هذا الدليل استخدام السخانات الشمسية لإنتاج المياه الساخنة لأغراض التكييف أو الأغراض الصناعية

### 3. معاملات التصميم

لتصميم وحساب حجم وكفاءة نظام السخانات الشمسية في دبي يتم استخدام المعاملات التالية :

موقع مدينة دبي على خط العرض : 25 درجة شمالا

التصنيف المناخي لدبي : 1 (A&B) حسب تصنيف الجمعية الأمريكية لمهندسي التدفئة والتبريد وتكييف الهواء (ASHRAE)

زاوية الميل للألواح الشمسية المسطحة : لالتقاط أكبر قدر ممكن من الإشعاع الشمسي على مدار العام توضع الألواح الشمسية المسطحة باتجاه الجنوب بزاوية ميل تساوي تقريبا خط العرض أي بزاوية 25 درجة (المصدر : المختبر الوطني للطاقة المتجددة في الولايات المتحدة برنامج تقييم الموارد)

درجة تخزين المياه الساخنة : 60 درجة مئوية حسب متطلبات الدليل الإرشادي للسيطرة على اللوجانيلا في المياه الصادرة عن إدارة الصحة والسلامة العامة في بلدية دبي

معدل درجة حرارة الجو الجافة خارجيا (صيفا) : 42 درجة مئوية سيليزية

معدل درجة حرارة الجو الجافة خارجيا (شتاء) : 14 درجة مئوية سيليزية

رؤيتنا: بناء مدينة متميزة تتوسط فيها رفاهية العيش ومفومات النجاح  
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درجة الحرارة التصميمية للمياه المغذية	20 درجة مئوية سيليزية
للسخان الشمسي	معدل عدد ساعات الشمس سنويا في دبي : 3570 ساعة
معدل عدد ساعات التسخين الشمسي الفعال	في دبي لغرض التصميم : 6 ساعات يوميا
معدل الاستهلاك اليومي للمياه الساخنة	: 50 لتر للحمام الكامل
القلل	: 30 لتر للحمام بدون دش
	: 80 لتر للمطبخ
سكن العمال	: 20 لتر لكل عامل
	: 1000 لتر للمطبخ المركزي
	: 600 لتر للوضوء
المباني والمنشآت الأخرى	: حسب متطلبات الجمعية الأمريكية لمهندسي التدفئة والتبريد وتكييف الهواء (ASHRAE HVAC Application 2011) أو أية مواصفات فنية أخرى معتمدة من بلدية دبي
الحد الأدنى لسعة تخزين المياه الساخنة	: 75% من الاستهلاك الإجمالي اليومي من المياه الساخنة
أحواض السباحة	: يجب توفير نظام خاص لتسخين مياه أحواض السباحة بسعة لا تقل عن 50% من السعة الكلية المطلوبة للتسخين
النظام الاحتياطي الكهربائي (الإضافي)	: تركيب شمعة تسخين كهربائية داخل خزان المياه الساخنة بسعة : 1.5 - 1.8 كيلوات/ساعة للخزان سعة 150 لتر : 1.8 - 2.4 كيلوات/ساعة للخزان سعة 300 لتر
نظام التحكم	: يجب تركيب نظام تحكم في نظام تسخين المياه الإضافي بطريقة تضمن الاستفادة القصوى من نظام السخان الشمسي أولاً

#### 4. متطلبات التصميم

- يجب وضع السخان الشمسي باتجاه يضمن الحصول على أشعة الشمس في جميع أيام السنة والوضع الأنسب لدبي هو باتجاه الجنوب وبزاوية 25 درجة مئوية



- يجب أن التأكد من أن موضع سخان يحصل على قدر كافي من أشعة الشمس وأنه لا يوجد أي عائق يحجب أشعة الشمس عن السخان مثل البنايات المجاورة والأجهزة على السطح والأشجار إن وجدت وذلك عن طريق عمل مسح كامل للموقع لتحديد المكان الأنسب لموضع السخان الشمسي
- في الأماكن التي تكون المسافة طويلة نسبياً بين خزان نظام التسخين الشمسي ونقاط الاستهلاك يجب تركيب نظام تدوير للمياه الساخنة مع عزل جميع أنابيب المياه الساخنة عزلاً جيداً.

#### 5. متطلبات التركيب والتشغيل والصيانة

يجب أن تكون المعدات والتركيب والتشغيل والصيانة لنظام السخانات الشمسية :

- تم اختبارها في المصنع
- معتمدة من بلدية دبي
- مصممة ومركبة من قبل شركة معتمدة من بلدية دبي.
- تتظف دورياً وتوفر لها الصيانة لضمان استمرار التشغيل بكفاءة.
- يجب أن يشمل النظام على اللواقي وخزان المياه وشبكة الأنابيب والتوصيلات والعزل الحراري والمضخات (إن وجد) وأجهزة الحماية والقياس
- يجب أن تكون جميع مواد نظام السخانات الشمسية من مواد غير قابلة للصدأ تتناسب مع الظروف الجوية لدبي

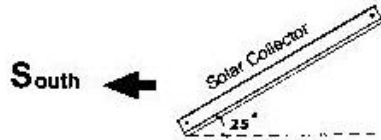
#### 6. متطلبات الأمان والسلامة

يجب أن يحتوي نظام السخانات الشمسية على جميع متطلبات الأمان والسلامة عند التركيب والتشغيل وأن تحتوي على نظام حماية من التسخين الزائد مثل تركيب صمام تخفيف الضغط

#### 7. الضمان

يجب أن يكون العمر الافتراضي لنظام السخانات الشمسية لا يقل عن 15 سنة مع توفير ضمان لا يقل عن 5 سنوات

**Solar Water Heater Scheme :**



The size and performance of the solar system must be calculated using actual design and installation conditions taking into consideration all the effecting parameters including the collector slope angle and direction. Any changes that are incorporated into the system during construction shall be considered.

**Average Daily Hot Water Consumption:**

Average Daily Hot Water Consumption per Villa =

No. of Toilets / Bathrooms	<input type="text"/>	x 50 L =	<input type="text"/>
+ No. of WCs	<input type="text"/>	x 30 L =	<input type="text"/>
+ No. of Kitchens	<input type="text"/>	x 80 L =	<input type="text"/>
			<input type="text"/> L / day / villa

**Design Parameters and Requirements:**

Design parameters and requirements shall be according to circular No. **183/2011** and International Best Practices, with emphasis on the following:

- 1- Hot water storage temp. = 60 C.
- 2- Average dry ambient temp. (Summer): 42 C.
- 3- Average dry ambient temp. (Winter): 14 C.
- 4- The minimum hot water storage tank capacity equal to seventy five percent (75%) of the total daily consumption of hot water.
- 5- Back-up electrical immersion heater to be provided.
- 6- The solar water heater system shall be installed, operated and maintained by a registered and licensed company by the Department of Economic Development and approved by Dubai Municipality.
- 7- The solar water heater system shall be approved by Dubai Central Laboratory.

**Undertaking:**

I/we hereby commit to meet the full requirements of Circular No. **183/2011** issued by Dubai Municipality regarding Solar Water Heaters. This commitment without exception applies to the design, installation and commissioning of the Solar Water Heaters. The solar water heater system shall be installed, operated and maintained by a registered and licensed company by the Department of Economic Development and approved by Dubai Municipality. The solar water heater system shall be approved by Dubai Central Laboratory. It is understood that failure to comply with the regulations may also result in a fine or other penalty.

**Notes:**

- 1- This sheet shall be attached to the roof plan of water supply drawings, and uploaded with sewerage drawings in the plumbing folder.
- 2- No separate electric water heater shall be used.
- 3- In case more than one type of typical villas (with different Average Daily Hot Water Consumption) is available, then additional sheet(s) for each type to be attached.

Applicant: .....



## Technical Report

26<sup>th</sup> Jan. 2013

SUBJECT : Technical Report for Electrical Water Heater System  
CONSULTANT : ARC International Engineering Consultant  
CONTRACTOR : Gamma Contracting L.L.C  
Tel. 04-222 2155 Fax: 04-262 5131  
Attn : Engr. Shaji  
PROJECT : Dubai Municipality Accomodation

### The Electrical consumption for the accommodations:

- Total Hot water required = 10000 liters
- We need 5 units, each unit 2000 liters capacity.

In case of Electrical water heater using

- Calculating the amount of electricity consumed to heat water (Pt):  
$$Pt = (4.2 * L * \Delta T) / 3600$$

Where:

**Pt** is the power used in k Wh

**L** is the number of liters of water heated

$\Delta T$  is the Temperature difference between the hot water ended up with and the cold water started with in °C.

$$\gggg Pt = 4.2 \times 50 \times (60 - 20) / 3600$$

$$= 2.33 \text{ kwh}$$

- The time need to heat 50 Ltr. Is:  $2.33 / 2.0 = 1.2$  hrs.
- We need 65 Electrical water heater 50 Liters capacity for 3,250 Liters
- The cost of the electrical heaters is  $65 \times 400 = 26,000$  Dhs

In winter time :

- The **Daily** consumption for one electrical heater is:  $2.0 \times 4 = 8.0 \text{ kw/day}$
- The **Monthly** consumption for one electrical heater is:  $8 \times 30 = 240 \text{ kw/month}$

- The **Monthly** consumption for 65 electrical heater is:  $65 \times 240 = 15,600 \text{kw/month}$
- For **6 Months** the consumption for 65 electrical heater is:  $15,600 \times 6 = 93,600 \text{kw}$

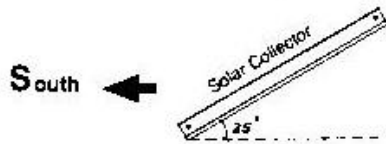
In summer time :

- The **Daily** consumption for one electrical heater is:  $2.0 \times 2 = 4.0 \text{kw/day}$
- The **Monthly** consumption for one electrical heater is:  $4 \times 30 = 120 \text{kw/month}$
- The **Monthly** consumption for 65 electrical heater is:  $65 \times 120 = 7,800 \text{kw/month}$
- For **6 Months** the consumption for 65 electrical heater is:  $7,800 \times 6 = 46,800 \text{kw}$
- The **Yearly** consumption for 65 electrical heater is:  
 $93,600 + 46,800 = 140,400 \text{kw/year}$
- The electrical cost is: **0.30 Dh/kw**
- **The Yearly heating cost is  $140,400 \text{kw} \times 0.30 \text{ Dh/kw} = 42,120 \text{ Dhs/Year}$**
- For 5 Years (**The Solar System Guarantee Period**) the electrical cost is:  
 $(42,120 \times 5) = 210,600 \text{Dhs}$
- The Total cost of Electrical water heater system within 5 years is:  
 $26,000 + 210,600 = 236,600 \text{ Dhs}$
- The Cosmosolar central water heater system cost is : **225,000Dhs**
- The return of the investment will be not more than 5 years

Mincom Trading L.L.C

Engineering Division

**Solar Water Heater Scheme :**



The size and performance of the solar system must be calculated using actual design and installation conditions taking into consideration all the affecting parameters including the collector slope angle and direction. Any changes that are incorporated into the system during construction shall be considered.

**Average Daily Hot Water Consumption:**

Average Daily Hot Water Consumption =	No. of Labours	<input type="text"/>	x 20 L	=	<input type="text"/>
	+ No. of Ablution Zone	<input type="text"/>	x 600 L	=	<input type="text"/>
	+ No. of Central Kitchens	<input type="text"/>	x 1000 L	=	<input type="text"/>
					<input type="text"/> L/day

**Design Parameters and Requirements:**

Design parameters and requirements shall be according to circular No. **183/2011** and International Best Practices, with emphasis on the following:

- 1- Hot water storage temp. = 60 °C.
- 2- Average dry ambient temp. (Summer): 42 °C.
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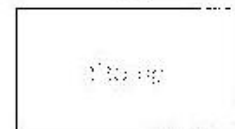
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**Notes:**

- 1- This sheet shall be attached to the roof plan of water supply drawings, and uploaded with sewerage drawings in the plumbing folder.
- 2- No separate electric water heater shall be used.

Applicant: .....





Source	Percentage	COP	Cooling Energy Consumption [kWh/yr]
From District Cooling Plant	80%	5.6	70,955,659
From Building Specific System	20%	3	33,112,641

Delivered Energy	
Total Delivered Energy before renewables [kWh/yr]	448,730,603
Renewables District-scale: Electricity	10%
Total Delivered Energy before renewables [kWh/yr]	403,857,543

Primary Energy Source	
Source	Percentage
From Power Plant: Electricity	80%
Natural Gas	10%
Fuel	10%

Primary Energy and Emissions	
Total Primary Energy [kWh/yr]	733,001,440
Total CO2 emissions[g/yr]	164,733,491,764
Total NOx emissions[g/yr]	254,834,110
Total SOx emissions[g/yr]	471,705,610



Performance	[E.2] Building Energy Delivery Performance		
Qnd,design [kWh/m2/yr]	Target Score	Edel,ref [kWh/m2/yr]	Edel,design [kWh/m2/yr]
69	0	89	80
109	0	98	88
110	0	88	79
140	0	73	66
99		87	79
Qnd,design [kWh/m2/yr]	Target energy improvement %	Edel,ref [kWh/m2/yr]	Edel,design [kWh/m2/yr]
	0%		
0		0	0
99		87	79

Infrastructure Delivered Energy			
Infrastructure Components	Alternative #1 Energy Performance [kWh/yr]	Alternative #2 Overall Energy Intensity [kWh/m2/yr]	Eref,infra [kWh/m2/yr]
Water Supply Energy from City Main	5,000,000		
Waste Water Treatment Energy	5,000,000		
District Cooling Plant Pump Energy	10,000,000		
Irrigation Energy	5,000,000		
Park Lighting Energy	5,000,000		
Traffic Lighting Energy	10,000,000		
Street Lighting Energy	10,000,000		
Other Energy Consuming Components	5,000,000		
Overall Energy Intensity [kWh/m2/yr]	13.75		10.00
Total Infrastructure Energy	55,000,000	0.00	

DISTRICTS

[E.2-E.5] Energy Category Scores

ENERGY PERFORMANCE COEFFICIENT CALCULATION RESULTS

<b>[E.1] Reference Value and EPC calculation</b>					
Not Applicable					
<b>[E.2] Reference Value and EPC calculation</b>					
$E_{del,ND}$ [kWh/m <sup>2</sup> /yr]	45	$E_{ref,del,ND}$ [kWh/m <sup>2</sup> /yr]	53	EPC <sub>del</sub>	0.8458
<b>[E.3] Reference Value and EPC calculation</b>					
$E_{design,p}$ [kWh/m <sup>2</sup> /yr]	81	$E_{ref,p}$ [kWh/m <sup>2</sup> /yr]	102	EPC <sub>p</sub>	0.7954
<b>[E.4] Reference Value and EPC calculation</b>					
CO <sub>2</sub> <sub>design</sub> [g/m <sup>2</sup> /yr]	18,304	CO <sub>2</sub> <sub>ref</sub> [g/m <sup>2</sup> /yr]	23,025	EPC <sub>co2</sub>	0.7949
<b>[E.5] Reference Value and EPC calculation</b>					
NO <sub>x</sub> <sub>design</sub> [g/m <sup>2</sup> /yr]	28	NO <sub>x</sub> <sub>ref</sub> [g/m <sup>2</sup> /yr]	37	EPC <sub>nox-sox</sub>	0.7554
SO <sub>x</sub> <sub>design</sub> [g/m <sup>2</sup> /yr]	52	SO <sub>x</sub> <sub>ref</sub> [g/m <sup>2</sup> /yr]	71		

ENERGY SCORE CALCULATION RESULTS

<b>[E.1]SCORE</b>
Not Applicable

<b>[E.2]SCORE</b>	
Score	EPC <sub>del</sub> value
-1	EPC > 1.0
0	0.8 < EPC <= 1.0
1	0.7 < EPC <= 0.8
2	0.6 < EPC <= 0.7
3	EPC <= 0.6

<b>[E.3]SCORE</b>	
Score	
-1	
0	
1	
2	
3	

EPC <sub>del</sub> value Earned	0.8458
<b>Criterion Score Earned</b>	<b>0</b>

EPC <sub>p</sub> value Earned	
<b>Criterion Score Earned</b>	

## MEASUREMENT

The calculator evaluates the energy and emission performance of a development project. Project will complete determined from several input parameters including:

### USER INPUT

- Built objects that are or will be GSAS rated
  - Total floor area per building type
  - GSAS target score (0,1,2,3) for building energy need (E.1)
  - GSAS target score (0,1,2,3) for delivered energy (E.2)
- Built objects that can currently not be rated with GSAS
  - Total floor area per building type
  - Target energy performance improvement percentage that indicates performance relative to ref
- Infrastructure
  - Alternative #1
    - Water supply energy performance
    - Waste water treatment energy performance
    - District cooling plant pump energy performance
    - Irrigation energy performance
    - Park lighting energy performance
    - Traffic lighting energy performance
    - Street lighting energy performance
    - Other energy consuming components
  - Alternative #2
    - Overall infrastructure energy intensity for non-built area
- District energy system
  - Percentage provided by district cooling plant to meet annual cooling demand for project
- Renewable energy generation
  - Percentage of neighborhood-scale\* energy generation from power station using such as solar, v

\*Note: Building attached renewable systems which can improve building energy delivery performance are ex design stage part of the GSAS rating method of each single object.

### GIVEN DATA

- Reference Values: Reference Values for GSAS rated buildings, non-rated buildings, and infrastructure c
- Score: Scores of -1 to 3 are associated with where the performance indicator falls within a pre-defined

### COMPUTED VALUES

- EPC values for E.2-E.5
- Projected Criterion Score = Based on the performance indicator value achieved by the project, a final s

EPC_p value
EPC > 1.0
0.8 < EPC <= 1.0
0.7 < EPC <= 0.8
0.6 < EPC <= 0.7
EPC <= 0.6

0.7954

**1**

[E.4]SCORE	
Score	EPC_co2 value
-1	EPC > 1.0
0	0.8 < EPC <= 1.0
1	0.7 < EPC <= 0.8
2	0.6 < EPC <= 0.7
3	EPC <= 0.6

EPC_co2 value Earned	0.7949
-------------------------	--------

**Criterion Score  
Earned 1**

[E.5]SCORE
Score
-1
0
1
2
3

EPC\_nox-sox  
value Earned

**Criterion  
Score Earned**

EPC_nox-sox value
EPC > 1.0
0.8 < EPC <= 1.0
0.7 < EPC <= 0.8
0.6 < EPC <= 0.7
EPC <= 0.6

0.7554

**1**

## Appendix C: Raw interviews

### 1.1 Dr. Alex Amato:

#### Questions:

- How far it's the experience about net zero energy projects in Qatar?
- What is the role of Qatar Green Building Council in Such projects?
- Which case study at Qatar you advise me to take in district scale with available data and maps and studies?
- What about passive and active houses, I saw the video of Barwa passive house, why this idea doesn't implement in wider range since 2012, I mean on more houses and districts
- About solar system, I know it's working properly in UAE in Masdar city, is it applicable in Qatar and what are its limitations?
- To assess the net zero energy district I used Torcillini's 4 criteria, Net zero source energy, site energy, energy cost and energy emissions, do you have a better way to assess net zero energy projects??
- Regarding to Renewable Energy Systems which of these systems is applicable and which not for Qatar and what's the reasons??
- What are the plans for the future renewable energy for Qatar?
- Are there any upcoming NZE projects in Qatar?
- Did you make any activities to spread awareness about renewable energy among the population of Qatar?

#### Answers:

There is this debate between national and local scale, Qatar is small enough to implement such projects nationally, I mean keeping the gas and oil for trading and start use clean energy for internal using. You could make all your work about clean energy and zero emissions because all other types of zero energy are related at the end to zero carbon agenda, the plan for energy should be in national scale then the application could be locally part by part or step by step.

With the inspirit of sustainability we can do it in neighborhood level because then you have the beginning of sustainable community, with all its criteria fs recycling water, planting vegetables, using renewable energy...etc. and that has a physical impact on how you would plan the city. The other important question is within the Qatar national frame work- the physical master plan- they talk about rehabilitation of existing neighborhoods, in your discussion and your analysis could be about how can we do that and my suggestion is that your thesis should address that.

Lusail is not particularly interesting, the main point there that they have done district cooling, in my opinion you should stop using energy concept and look for carbon footprint because all energy activities are making carbon foot print at the end but they are differs in quantity.

It's so difficult to be zero energy and stay zero energy it's a fantasy, energy is not the issue. carbon is the Issue, our dream is not to be carbon neutral but to be carbon negative and if projects like Masdar city are assumed that they are positive energy and they are producing energy to the national grid, the really important thing here that they are carbon negative this is more accurate. All related to carbon because that is the impact. Look with dr. Esam from LCA perspective its better than looking for GSAS issues

Starts think about the kind of methodology that you came up with the, the key challenge for you now is existing neighborhoods, after that discussion of doing it nationally or locally let's do it in neighborhood scale some nationally and some locally. Think about rehabilitation of existing neighborhood in downtown Doha. Look at it from the architectural side windows, walls insulation systems...etc. the practical side would be interesting more for your research, put recommendations and start with the easy things then go more deeply, work under the frame of rehabilitation of existing neighborhoods which is

There is no lack of knowledge and there is no lack of money, the can do something probably better than Masdar City, obviously time going on and the experiences now better than the time was Masdar established... etc.

So the answer is yes it could be a model in Qatar, I think really the question is why has be no repeat of Masdar in Qatar and I think they have examined the idea itself before like energy city and Lusail ...etc. So they certainly have been pushing already in that direction , I think the Good question might be was Masdar city the right approach to take , I mean it was too large maybe or too high buildings, I think we can think in a different way and it's much more like Qatar looks like, start with small advances and start with small experiments in Doha , is it better to reduce carbon locally rather than working on national scale or not ... how can we take that question forward , what might be a mistake that start to examine national policy.. Qatar thinks in particular way, there is no doubt that if the government decided that they want to do something like Masdar the can do it tomorrow .... the question is WHY NOT??

Let's start with the owner of Barwa city and the CEO of it, why he didn't consider the zero carbon solution while planning for the city?? Why you didn't push Barwa city to be like Masdar for example especially that you have a passive Hause villa model,

Firstly, you have to get access to interview key people and stakeholders to answer your questions like owners of Barwa and the project architects in AECOM

Possibilities:

Might they need to deliver affordable houses by cheaper materials and fewer technologies.

The city could be completely self-contain, why that is not applied

What would be the first steps to take Barwa city into sustainability

You should worry more about insulation than orientation because even is the orientation is not right we can make it more efficient by using technologies

You need to make some calculations as well to know how many stories the energy will serve for example but you should think first about reducing the demand of energy.

## **1.2 Dr. Haidar Al-Safi (Barwa City's Senior Technical Specialist)**

**Q:** why large national projects like Barwa City did not start out as green, or at least carbon-free, districts?

**A:** The city was built in 2006 before the idea of Passive House in 2012 [Barwa Passive House is in the same location]. We have a great experience with net zero energy homes through the Passive House project, but Barwa City was implemented a long time before this experience. Anyway, we got one star according to the QSAS assessment tool, but this happened many years later, after the city construction stage, so the plans and designs of the city didn't consider the environment initially. Comparing with Lusail City, the latter has guidelines started in the design stage related to environmental systems. Furthermore, at that time, applying green rules was not mandatory and was adding an extra cost on the project. Maybe this cost is returnable in some stages and cases, but as a commercial project, we always try to reduce the cost as much as we can. Some points of net zero energy district are achieved by the design, even if we meant it or not, such as being near to the facilities and schools, public transit network, bike stations... etc. But other technical things, related to insulation and LV panels, for example, were not in the Barwa City company scope. As a commercial project, we calculate everything related to the project, like the electricity bills, which is usually paid by the tenants, not by the owner. So reducing consumption of electricity is not within our scope, for example. Rules related to the energy and carbon footprint should be enacted by the government. The latter should have strict rules related to insulation and energy consumption and production systems. If this happened one day, all investors and companies will put green systems in their scope while implanting new projects.

Barwa City's Senior Technical Specialist added that Passive House is a good starting point for the implementation of green systems by the Barwa Real Estate Company. In an experiment to test these systems and their validity in Qatar, the two villas, Passive House and the ordinary villa, will provide a good comparison. This will serve Barwa investors as well as other investors in Qatar. For Passive House, Barwa Real Estate used green materials and systems and green design to achieve the maximum reduction in energy consumption and maximum energy efficiency. Barwa City was built on reclaimed swampland and an old landfill site. Transforming this land from its polluted state into a green living environment has benefited both the investors and the 2500 residents. This is one of the greatest achievements of Barwa City, of which they are proud

## **1.3 Mr. Sultan Alenizy (Executive Manager of Qatar Railways)**

**Q:** When the metro project will finish??

**A:** It supposed to finish before 2022, the year of FIFA world cup and we all work hardly to achieve that goal. We faced some complications in the implementation procedure but everything is fine now and we are on the track.

**Q:** Is it serving all Qatar Areas

**A:** It serves most of Qatar areas especially those whose related to the new stadiums and their surrounded areas

**Q:** Do you think it will be useful for Qatari families??

**A:** Before using the metro, we need to spread some awareness about some concepts in the Qatari society, anyway the metro will be categorized into three categories, one of them is golden grade for those whose can't give up the luxury living and want something special, I think this will encourage many segments of the society to use the metro especially those who are not using KARWA busses for the same reasons

**Q:** What is the nearest station to Barwa city at Abu Hamour?

**A:** there is one station near ALSenaieiah area after Barwa city three to four kilos and I think it will be many substations in the future when needed

**Q:** Can I have a map for the future metro routes?

There is no final agreed map until now for the metro routes, but for the moment you can use the published map on the RAIL, it doesn't show a lot but this is what available right now.

#### 1.4 **Eng. Hossam Al Tagy** (Asset Manager at Qatari Diar Realestate Site Office Building)

I asked Eng. Hosam Al Tagy to give me all the plans, technical drawings, predesign analysis, and contracts for Barwa city and he help a lot to direct me to another key person in the project like Mr. Arvin to have all needed information.

#### 1.5 **Dr. Shadi Atiyyah** (PHD in Energy efficiency systems and Energy programing)

A three weeks' course was taken with Dr. Shady Attiyyah about design builder program, the program that calculate the Energy Efficiency Strategies influence on specific building, the program has many parameters related to the building that the designer can change them to reach the best energy efficient model for his project. Design builder program has a huge database contain information related to the countries location, climate, sun radiation, wind speed, water availability renewable energy systems.... Etc. this information used to design the best possible energy efficient model considering all the surrounded environmental factors.

The program is under development to be suitable for the district scale calculations and to consider in addition to the building itself; the surrounding areas, streets, services, infrastructure.... etc.

#### 1.6 **Bahdour** (Maintenance Worker at Barwa City)

**Q:** since when you work here (in Barwa city construction) and what is your job??

**A:** One year and half and I am one of the service and maintenance team.

**Q:** are you live here??



**A:** No I don't, me and other workers are living at alsenaieiah area and we come here using Karwa Busses.

**Q:** regarding to the transportation, is it easy??

**A:** There are two Karwa Bus stops here, it's not shaded and need long time waiting for the bus but the buses are clean and good. In addition; I have my bike here and I use it to reach places inside the city project, there is a free parking for the bikes. I think the transportation is good.

**Q:** how do you describe services in general in Barwa city??

**A:** well, It's safe place for children to run and play without fear of car accidents, unlike other many places in Doha, and there are markets around I can reach what I need all the day time by bike or walking, the market is little bit more expensive than outside prices but it's still in range.

### **1.7 Dr. Essam Elsarraj** (Executive manager of GORD Company)

**Q:** why GSAS system has been created while there are a lot of other used systems in the gulf area??

**A:** the idea of creating GSAS system is to create suitable system for the hot arid areas like gulf area and its most suitable with Qatar while other systems are so general and applicable everywhere and can't give an accurate indication about the situation in the projects.

**Q:** what was the idea of the Passive Hause??

**A:** the idea of passive Hause to implement a model of the dream Qatari house in its ideal case with all possible technologies that can serve the energy efficiency and decrease the environmental impact the passive house is a contribution from many companies to advertise their sustainable products and to support sustainable development in Qatar in general

**Q:** Is the same Idea Applicable on the district scale Barwa city for example?

**A:** until now we can't discover if the idea is applicable for the district scale in Qatar or not especially the cost, in passive Hause all the building materials come by free contribution from supporting companies that was very good for passive Hause budget but it causes failure in cost assessment also regarding to the renewable energy it was so easy to manage the required energy for one villa while I think it will face more complications at the district scale.

In GORD we have lunched GSAS Districts which help to put a framework for the district sustainability systems in the gulf area. GSAS District tests a most of considered criteria including culture and heritage to assess if the district is a sustainable community or not.

**Q:** how much Barwa city achieved in the GSAS assessment and why?

Barwa city achieved one point only in GSAS District because it lacks a lot of sustainability requirements but Newton school achieved 2 or three points I think because of using all available technologies to conserve energy and to produce energy.

### **1.8 Mrs. Wessam Nour** (Barwa City Resident)

**Q:** Are you live here (Barwa city)??

**A:** Yes, I live in flat 2 rooms in the part of Waseef company

**Q:** What are other parts and what is the deference between them?

**A:** there is other part for Tanween company its more luxury flats with higher prices and higher services.

**Q:** what do you think the level of the transportation and other services in general?

**A:** The best thing has been done in the city is the markets and other facilities, which are reachable by walking; they are amazing, especially in the winter months. For the transportation we are still using our personal car as usual and we have more faraway distances from Doha because of the location of the city, there is Karwa bus station but it is more used by Asian expats and workers and I don't feel safe to use it with my kids. Services like water and electricity is regular and we didn't face any problems related to them except the high bill prices which is not matching the electricity and water prices in other area in Doha,

We have other problem with the fire alarms system, it's so sensitive and it gives false alarms daily or more than one somedays which is too much annoying and make it ineffective in the real cases.

On the other hand, my kids are in the nursery and in newton school here and some of their teachers and colleagues are our neighbors which make me comfortable about living here. In addition to the nice green areas where I like to take my kids to play at afternoons in good days' weather.

### **1.9 Mr. Eng. Ahmed Yousef** (Electrical Engineer in SEMINS Global Company KSA)

(interview via phone call)

**Q:** Barwa city is fully reliant on electricity from the national grid as well as gas for cooking and gasoline for transportation the average annual consumption for electricity and water are estimated to be 6000MW and 420MIGD respectively could you explain this for me please?

**A:** These numbers are really high as well as most of the projects in the gulf Area, it means that the city needs 40,000 liter of petrol per day, in other words it consumes an amount of petrol enough to fill a room with size of 3m width X 5.7m length X 3.2 meters high every day.

1.10 **Mr. Arvin Flor Carisme** (Facility Manager at WASEEF operating company)

**Q:** First of all; do you have special substation for the project and can I have the bills of electricity and water for the whole year??

**A:** there is a substation for each zone in the project and it has its own meters for the water we have a huge station here feed smaller stations who feed building's tanks, and we have our own generators as well, Yes I can give you approximate number of the yearly water and electricity consumption.

**Q:** what is Barwa city Buildings facades materials??

**A:** Painted Breakast concrete and the floors are breakast as well but the internal partitions are gypsum boards.

**Q:** Is there any isolation under the painting??

**A:** No there is no isolation for all the previous mentioned materials.

**Q:** Do you use any kind of isolation material inside the buildings or on the rooftops ?

**A:** No we didn't.

**Q:** Did you use any green certified materials or appliances in the buildings?

**A:** In the residential building we used the most money saver materials with no additions but in some other areas like newton school and nursery and in the malls we used some energy efficient electric equipment's, Newton school was looking for green certification in the first place that why they spent more in these materials. Also we have passive Hause which is done by using latest technologies related to energy efficiency.

**Q:**Is these appartments are furnished??

**A:** Some of them are furnished and some not.

**Q:** Is the appliances and electrical equipments in these flats are chosen by some specific standards about energy effeciency and consumption??

**A:** No actually they have been chose according to their price and durability, most of our appliances are got by a contractor with Sharp and LG companies with no special specifications.

**Q:** What is your irrigation system?

**A:** We are using recycled water for irrigation 100%, all the sewege are going to the recycling unt at the eastern side of the project wher it recycled and pumped again to irrigate plants, in winter this water can cover the whole irrigation process but in the summer we import sewege from the nearby project like al wakra by the infrastructure network to recycle it here and use it. We use some solar panels to produce energy for the recycling process but it is cover only les thanm 20 percent of the needed energy and we import all the rest electricity from Kahramaa.

**Q:** What about the transportation system??

**A:** We have only Karwa busses in addition to private cars and bicycles, Karwa busses has many bus stops inside the project, I will get there number soon and tell you about them. And you can find some Karwa taxis around LuLu supermarket some times but they are not regular and can't be rely on them.

**Q:** Do you see people walking around here like women going to shopping or playing kids... etc?

**A:** Yes actually at afternoon time there are a lot of people women with strollers and men going to pray walking around, its so vibrant especially in good weather, in addition to the cyclists who are using the cycle lane provided in the city, they are continuous clean and safe lanes with appropriate bike parkings.

**Q:** Do Barwa city has a waste management program?

**A:** In Barwa City, the garbage is collected and taken to a landfill site almost in meseed area by the ministry through Qkleen company. Recycling bins are regularly used in Doha, and there is no segregation of waste or training of residents in recycling segregation. The owner of Barwa City hired a company called BS Milano to provide various waste segregation amenities around the project. Unfortunately, this contract has been terminated for financial reasons by Waseef management.

**Q:** What about the district systems??

**A:** We have many district systems like district water heaters and district cooling which we are share it with barwa commercial avenue.

**Q:** Is there any complains for these systems??

**A:** No Untill now, but barwa commercial avenue doesn't work yet so the pressure on these system is still under control, these systems are manual controlled which will ause problems in the future. And there are no sensors to orgnize the temperature and save the energy. Chelled water cooling system is a good apportunity for barwa city but it is not for barwa commercial where it is very far away and it will face atechinicalproblems in the future. We have problems also in the blow down pibes since this system is discharging around 500 cubic meter of water daily (I was seeing water in the street) and we are waiting for ashghal to dig inside and to provide us a report about the system problem since we are not alloud to do street works. I suggested to plant all this open areas to binifit from the discharged water.

**Q:** Do you think that it will be a metro station here in the future?

**A:** Until now there is no plans for metro station near barwa city.

**Q:** I there any energy audits done in Barwa city??

**A:** We as a Waseef company has some audit by ISO9001 regarding to all sustainable issues but Barwa city Not.

**Q:** what is kind of energy use of heating system??

**A:** Gas Boilers, and its distriputed by gravity in a good mechanichal system so we don't need to consume more energy in bumbing

**Q:** Did you face some fails in phase one and you wish if you can revise them??

**A:** Yes actually I wish if we used some isollation materials to reduce the cooling need, also we received complains regarding to the new systems people are not used to use it, for example people expecting that if we shut the water heaters in the summer they will receive cold water which is prefered in the summer time like in the separated heater units but this is not happening in the district systems. Also if we shut down the water heater system it will shut on the whole zone because there is no isolation.