# Evaluation of Developing Net Zero Energy Buildings in Northern Cyprus

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# ABSTRACT

In 21th century, the topics of energy and relevant issues involved the different sectors with several challenges. In past years, advent of greenhouse gas emission from consumption of fossil fuels in building sector, showed the importance of optimizing energy use in this sector more than every time. It is estimated that, energy consumption in building sector is growing up by growth in population and increasing for building demand. Hence, approaching sustainable and efficient residential and commercial buildings has been a priority for energy policy makers. Recently, building community is aimed to develop Net Zero Energy Buildings as much as it is possible. Net Zero Energy Buildings accepted as efficient buildings, which are smart choice to reduce energy consumption while maximizing comfort for occupants.

Northern Cyprus is almost completely dependent on hydrocarbon fuels to cover energy requirements. On the other hand, Mediterranean climate conditions caused, buildings demand a significant share of energy to meet their heating and cooling loads. The concept of Net Zero Energy Buildings might be effective to modify energy consumption pattern. Hence, this study attempts to evaluate developing of Net Zero Energy homes and is purposed to provide strategies and guidelines with special focusing on utilization of PV panels to achieve Net Zero Energy homes in Northern Cyprus.



**Keywords:** Net Zero Energy Buildings, renewable energy, energy efficiency

# ÖZ

21.yüzyılda,enerji konuları ve bununla ilgili meseleler,farklı sektörleri çeşitli güçlüklerle karşı karşıya bırakmıştır.Geçmiş yıllarda,bina sektöründeki fosil yakıtların tüketimi sırasında ortaya çıkan sera gazı emisyonu, bu sektördeki enerji kullanımını etkili kılmanın her zamankinden daha önemli olduğunu göstermiştir.Bina sektöründeki enerji tüketiminin,nüfusun çoğalması ve artan bina taleplerine paralel olarak arttığı tahmin edilmektedir.Bu yüzden, sürdürülebilir ve enerji verimligi olan konut ve ticari binalar, enerji sektörünun politika yapıcıları tarafından öncelik kazanmıştır. Son zamanlarda, Binalar Cemiyeti, net sıfır enerji binaları mümkün olabildiğince geliştirmeyi amaçlamıştır.Net Sıfır Enerji binalar, enerji tüketimini azaltan ve oturanların rahatını en üst düzeyde tutan verimli binalar olarak kabul edilmiştir.

Kuzey Kıbrıs, enerji ihtiyaçlarını karşılamak için hidrokarbon yakıtlara neredeyse tamamen bağlıdır.Bunun dışında,Akdeniz iklim koşulları ; binaların,ısıtma ve soğutma ihtiyaçlarını karşılamak için önemli oranda enerji paylaşımı talebine yol açmıştır. Net Sıfır Enerji Bina kavramı, enerji tüketimi modelini değiştirmek için etkili olabilir. Bundan dolayı bu çalışma; Net Sıfır Enerji evleri geliştirmenin değerlendirmek için bir girişim ve Kuzey Kıbrıs'ta Net Sıfır Enerji evler elde etmek için bir taslak ve de bunu başarmak için PV panellerin kullanımı üzerine odaklanan stratejiler ve yönergeler sağlamayı amaçlamıştır.

**Anahtar kelimeler**: Net Sıfır Enerji Binalar, yenilenebilir enerji, Enerji Etkinliği

For the most amazing woman I’ve met, for the strangest man I’ve met who battle with the dark days

***To my Parents***

To those who inspired it and will not read it

For everyone whose first love was a hard love

To my friends without whom this thesis would have been completed one year earlier

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| | |
|---|---|
| $/KW | Dollar per Kilowatt |
| $/KWh | Dollar per Kilowatt hour |
| $/Wp | Dollar per peak Watt |
| °C | Centigrade degree |
| AC | Alternating Current (electric charge) |
| AWEA | American Wind Energy Association |
| BIPV | Building Integrated Photo Voltaic |
| BOMA | Building owners and Manager Association |
| c- Si | Crystalline Silicon |
| Cal / $cm^2$ | Calories per Square Centimeter |
| CFL | Compact fluorescent lamps |
| CHP | Combined Heat and Power |
| $CO_2$ | Carbon Dioxide |
| DC | Direct Current (electric charge) |
| DOE | Department of Energy |
| DSHWS | Domestic Solar Hot Water System |
| EPBD | European Performance of the Building Directive |
| EU | European Union |
| EU | European Union |
| FIT | Feed in Tariff |
| GWh | Gigawatt-hour |
| HVAC | Heating Ventilation Air – Conditioning |
| IEC | International Electrotechnical Association |
| IEEE | Institute of Electrical and Electronics Engineers |

| | |
|---|---|
| ILs | Incandescent Lamps |
| Kg | Kilogram |
| KIB-TEK | Cyprus Turkish Electricity |
| KVA | Thousands of Volt-Amperes |
| KW | Kilowatt |
| KWh | Kilowatt-hour |
| KWh/$m^2$ | Kilowatt-hour per square meter |
| LCC | Life Cycle Cost |
| LCCA | Life Cycle Cost Assessment |
| LED | Light Emitting Diodes |
| LPG | Liquid Petroleum Gas |
| $m^2$ | Square meter |
| $m^2/m^3$ | Square meter to Cubic Meter (Area to Volume) |
| Mc- Si | Microcrystalline Silicon |
| MJ/$m^2$ | Mega Joule per square meter |
| MPAE | Ministry of Power and Energy |
| MVA | Mega Volt-Amperes |
| MW | Megawatt |
| MWh | Megawatt Hour |
| N.C | Northern Cyprus |
| NABERS | National Australia Building Energy Rating System |
| NZE | Net Zero Energy |
| NZEBs | Net Zero Energy Buildings |
| O&M | Operation and Maintenance |
| PV | Photo Voltaic |
| RES | Renewable Energy Source |

| | |
|---|---|
| SEDA | Sustainable Energy Department Authority |
| SEGAP | Sustainable Energy and Greenhouse Action Plan |
| SEI | Solar Energy International |
| Si | Silicon |
| SWT | Small Wind Turbine |
| UN | United Nations |
| UNOPS | United Nations office for Project Services |
| US$ | United States Dollar |
| V | volt |
| $W/m^2$ | Watt per square Meter |
| $W/m^2K$ | Watt per Meters squared Kelvin |

# Chapter 1

# INTRODUCTION

Buildings are seen as a key-part of the needed transition toward sustainability in its energy dimension. This derives from the fact that the buildings sector represents between 30% and 40% of the demand of final energy in most developed countries (Kapsalaki et al., 2012). On the other hand, there are many arguments about greenhouse gas and $CO_2$ emissions in all around of the world. There is no doubt that buildings effect on climate change, global warming, ozone layer depletion, etc. by using fossil fuels during their construction and operation phase. It is estimated that buildings are producing more than one third of total global greenhouse gas emissions during their operational phase (S.Srinivasan et al., 2012). Hence, energy efficiency in buildings sector dramatically has attracted attention of engineers, architects, and energy policy makers during the coming years. Net Zero Energy Buildings (NZEBs) are becoming a prime objective in fighting and reducing carbon emission and energy use.

The term of NZEB refers to a building with annual consumption of zero energy (0.0 kwh/m$^2$/year) and producing zero carbon emissions at the same time. NZEBs can be independent buildings from energy supply networks. Thus, NZEB is able to cover its energy demand by generating electricity or other energy carriers from local renewable energy resources such as solar, wind, geothermal, and bio-fuels. Additionally, using specific technologies for efficient cooling and heating systems, and high efficiency lightning has been attempted in designing and constructing of NZEBs. In the other word, in a NZEB optimizing energy consumption has been noticed besides producing clean energy. Smart use of renewable energy technologies will provide a balance between energy consumption and production.

The topic of Net Zero Energy Building is becoming an important objective for energy policy at regional, national, and international levels. NZEBs are recognized as a great option to develop sustainable architecture. Hence, new construction companies are being formed, especial eco-energy projects are prepared, and even sales offices are established in different countries to achieve NZEBs.

In the current years, various countries are trying to approach NZEBs in own country and are planning to meet this concept during a certain time. As on 19 May 2010, the European parliament has adopted that by December 2020 all new buildings should reach the Net Zero Energy (NZE) concept (EPBD recast, 2010). For the United States of America the Department of Energy of this country (DOE) is planning to develop high efficiency buildings and designed parameters to approach Net Zero Energy concept in at least 50% of commercial buildings until 2025 and Net Zero Energy homes (NZE homes) until 2020 (US, DOE, 2008). In Asia, many efforts have been approached by different countries such as Japan, South Korea, United Arab Emirates, and Malaysia to develop NZEBs. Additionally, Iran and Turkey have a future prospect to achieve this concept in their own country.

There are now some examples of NZEBs already built, which show that they are achievable (Kapsalaki & Leal, 2011). However, for each real example of NZEBs strategies and perhaps frameworks have been provided to achieve desirable results. It is important to develop strategies and guidelines that allow building designers, contractors, policy makers, occupants and even workforce to identify the design and construction variables while ensuring the achievement of Net Zero Energy Concept. That is the subject of this study, which explains the strategies and exemplifies existing potentials to purpose of achieving Net Zero Energy Buildings in Northern Cyprus.

## 1.1 Statement of the problem and the Significance of the Study

In order to specify existing problems in Northern Cyprus in term of energy usage and relevant issues that effect on future energy prospect, it is necessary to respond following questions: 1-What is actually happening in energy consumption constituency in Northern Cyprus?; 2- What should be happening in energy sector in Northern Cyprus?. Responding to mentioned questions might clarify the problems which Northern Cyprus is currently faced.

According to an energy consumption forecasting study by Erdil et al., (2008) it is revealed that the peak demand in Northern Cyprus would be increasing until 2020. Mentioned forecasting study indicated that peak demand in Northern Cyprus is dramatically affected by residential energy usage. On the other hand, reports on electricity consumption and electricity generation released by Electricity Authority of Northern Cyprus (KIB-TEK) highlighted that energy demand in residential buildings in Northern Cyprus is increasing by growing in constructing of new buildings and growth in building demand.

Increasing energy demand by the residential sector which has a significant contribution in total end use energy in Northern Cyprus is equal with importing more hydrocarbon fuels since energy production in Northern Cyprus is almost completely dependent on utilizing fossil fuels. Consequentially, irreparable damages such as environmental pollutions and even economic crises might be happen by increasing in fossil fuel consumption.

Northern Cyprus does not have luxury to waste the wealth of renewable energy resources. It can be realized that the inexhaustible sun and wind energy would be the main resource to generate electricity and other energy carriers in coming years. Unfortunately, in Northern Cyprus using renewable energy resources could not be appeared as a mature energy production option due to lack of consciousness about these alternative resources and worries about economical fluctuations that might be occurred by developing renewable resources.

Nowadays, a large number of countries is planned to achieve NZEBs or at least are in researching and studying stages. However, in Northern Cyprus insufficient attempts and efforts about promoting NZE concept is visible. At the present, Northern Cyprus has encountered several problems to align itself by other countries that are moving toward NZEBs. Existing awareness gaps about NZEBs prevents that Northern Cyprus approach the concept of NZEBs. Hence, this study can be a significant attempt to help alignment Northern Cyprus with other countries which are developing NZE concept in their own country.

Additionally, provided strategies would be useful for policy makers, decision makers and managers who are planning the future energy consumption of Northern Cyprus. Provided outlines might be effective to expand the information of government officials of Turkish Republic of Northern Cyprus about NZE concept as well. This study can be useful for those students who are interested in such an issue since the topic of Net

Zero Energy Buildings is in early researching stage at Northern Cyprus. Furthermore, owners and consumers can increase their awareness about Net Zero Energy Buildings through provided information.

## 1.2 Aim of Study and Research Question

This study is aimed to evaluate existing potentials of renewable energy resources in Northern Cyprus which can be used in approaching Net Zero Energy Buildings. Providing strategies, guidelines and frameworks based on utilization of PV panels to achieve Net Zero Energy Buildings is the main concern of the thesis. Additionally, the following thesis tried to provide an overview of further strategies related with building design approaches, building construction practices, building operation tasks, training and education of stakeholders, legislation and polices as well.

In fact, this thesis is aimed to answer following questions:

1- How Net Zero Energy Buildings can be achieved in Northern Cyprus?

2- What are the current potentials and opportunities in Northern in term of renewable energy resources to achieve Net Zero Energy Buildings?

## 1.3 Limitation and Scope of Study

This study is targeted to prepare outline for achieving Net Zero Energy Buildings. The term of buildings encompasses various range of buildings including commercial, industrial, public orders, health care, residential and even offices. Additionally, each type of buildings consists of several subsets. For example, residential buildings can be divided into apartments, single family homes, condominium and townhouses. It should be clarified that, the variables are different for each sub-type of buildings in designing, construction and operation levels. On the other hand, different types of buildings can be evaluated from different points of view. For instance, it is possible to either evaluate esthetic aspect of a building or evaluate energy lose/gain of that building. It should be realized that it would be really complicated to evaluate all types of buildings in different scientific areas at the same time. Therefore, Energy and Buildings is defined as research area for this thesis. Furthermore, this study is focused on promoting new single family detached homes in Northern Cyprus. Hence all strategies have been provided based on identified building type.

## 1.4 Methodology

The main method of this study is based on an exploratory research since the study will explore a series of studies to investigate a more extensive research. This thesis did not suggest any hypothesis rather its purpose is only to give an estimate of the topic. Additionally, it has been tried to expand the views and ideas about developing Net Zero Energy Buildings at Northern Cyprus and provides an appropriate background for better understanding of the topic. Hence, a quantitative and qualitative study have been performed. Quantitative study encompasses:

- Calculating Life Cycle Cost of on-grid electricity generation
- Calculation of electricity cost produced by energy infrastructures

Additionally qualitative study can include:

- Considering availability of renewable energy resources in Northern Cyprus
- Assessing performance of energy production sector in Northern Cyprus
- Evaluating legislation about utilizing renewable energy in Northern Cyprus
- Considering performance of construction industry in Northern Cyprus

# Chapter 2

# NET ZERO ENERGY BUILDINGS

Net Zero Energy definitions are still in the early phase of development as new knowledge is drawn upon to revise and classify buildings. NZE can be defined based on boundaries determined by energy flow and renewable supply options. While energy flow based Net Zero Energy definitions are determined by means of segregating the boundaries of energy consumption and generation (e.g., at the site or source levels), and their quantification (i.e., energy quantity or energy costs), the renewable supply options based Net Zero Energy definitions are established by way of demand-side location of onsite renewable capacities. These improvements can be derived from the buildings' energy consumption and/or generation (S. Srinivasan et al., 2012), they can be categorized as Net Zero Site Energy, Net Zero Source Energy, Net Zero Energy Costs and Net Zero Energy Emissions. On the other hand, demand-side renewable supply options based Net Zero Energy definitions such as "onsite supply options," and "off-site supply options" offer definitions based on the location of the site of the renewable contributions.

More importantly, for a building design strategy that aims to contribute the goal of sustainability the design, construction and operation requirements should be recognized. This chapter in addition of providing a consistent definition framework of Net Zero Energy Buildings indicates the different types of achievable Net Zero Energy Building. Barriers and requirements to develop NZEBs are addressed as well.

## 2.1 Definition of Net Zero Energy Building

One question raised in almost all of Net Zero Energy Building practitioners is “what is a comprehensive definition for Net Zero Energy Building that is accepted by scientific society and reliable energy departments?” Although the question becomes more complicated at the beginning but researchers could offer plenary and precise definition for Net Zero Energy Buildings during past years.

Different definitions are possible for a Net Zero Energy Building depending on project goals, country’s political targets, design team values, and occupants and owners. For example, energy departments are concerned about source energy. Owners usually care about energy costs. Maybe site energy usage is interesting for building designers to compensate energy requirements. Also reducing carbon emission is an essential challenge for those who are concerned about environment pollution. This study provides definitions of Net Zero Energy Buildings depending on different approaches.

Mazarsel et al., (2011) defines NZEB as energy efficient building that are able to produce energy to meet a significant share of its energy demand through connecting to a renewable energy supply infrastructure. The term of Net refers to building that is connected to an infrastructure while Zero Energy Building has a general meaning and includes non-connected and autonomous buildings. In fact, in Net Zero Energy Buildings there is balance profile between energy consumption and energy generation from renewable energy resources.

Figure 2.1 represents a graphically definition of Net Zero Energy Buildings by energy flow diagram (Sankey Diagram). End-use loads such as electricity, heating, cooling loads are shown on the right side while the available energy resources are shown on the left side. The figure illustrates that various energy resources can be used to cover energy demand in Net Zero Energy Building. Energy can be sold to the grid and can be purchased from the grid. Purchased and sold energy can be compared after they are converted to the uniform unit and compared weather Net Zero Energy Building energy aim is achieved or not.

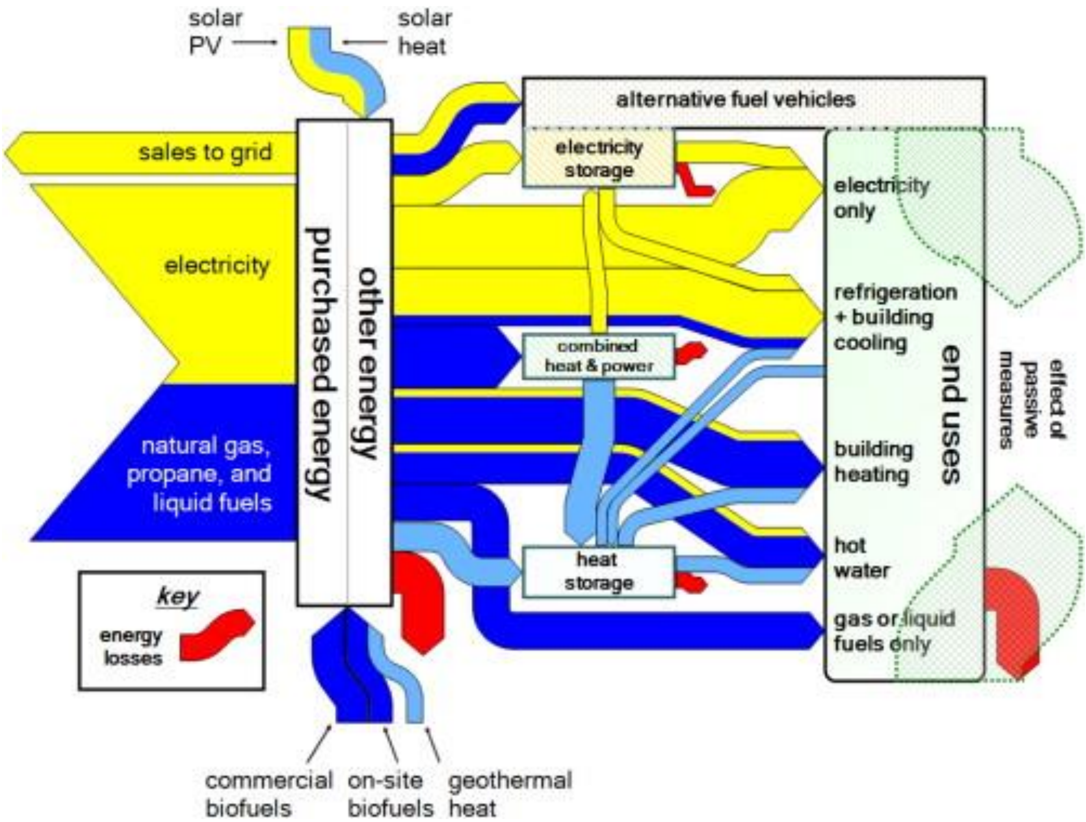


Figure 2.1: Energy Flow Diagram of Net Zero Energy Buildings (Deng et al., 2014).

Finally it should be noticed that, the goal of a Net Zero Energy Building and its definition influences on strategies, choices, purpose of policy, program direction and even specifying performance expectations. These different alternatives definitions prepare a wide scope that can support different requirements in different cases. In addition, various indicators make it possible that performance of Net Zero Energy Buildings measured and evaluated by several ways. May be it is not possible to present a single definition for a NZEB that works in that all cases but generally, a good Net Zero Energy Building should use renewable resources to produce as much energy as it uses and encourage energy efficiency. All the main concept of Net Zero Energy Building is that the building can meet all its energy consumption through renewable, locally available, low-cost, and nonpolluting resources.

## 2.2 The Concept of Balance in Net Zero Energy Buildings

In NZEBs, a condition is needed to satisfy energy demand by sufficient renewable energy supply nominally in a year. Now it should be realized that, achieving such a balance is the main priority of NZEBs. The Net Zero Energy balance can be determined either from the balance between delivered and exported energy or between load and generation. The former choice is named import/export balance and the latter load/generation balance**.** The Net Zero Energy Balance can be calculated through equation 2.1 (Sartori et al., 2012).

$$\text{Net Zero Energy Balance} = |\text{Weighted Supply}| - |\text{Weighted demand}| = 0 \qquad (2.1)$$

A weighting system converts the physical units into other metrics, for example accounting for the energy used (or emissions released) to extract, generate, and deliver the energy. Weighting factors may also reflect political preferences rather than purely scientific or engineering considerations. In equation 1 weighted supply represents the sum of all exported energy (or generation), obtained summing all energy carriers each multiplied by its respective weighting factor. Additionally, weighted demand represents the sum of all delivered energy (or load), obtained summing all energy carriers each multiplied by its respective weighting factor.

The Net ZEB balance can be represented graphically as in figure 2.2, plotting the weighted demand on the *x*-axis and the weighted supply on the *y*-axis.

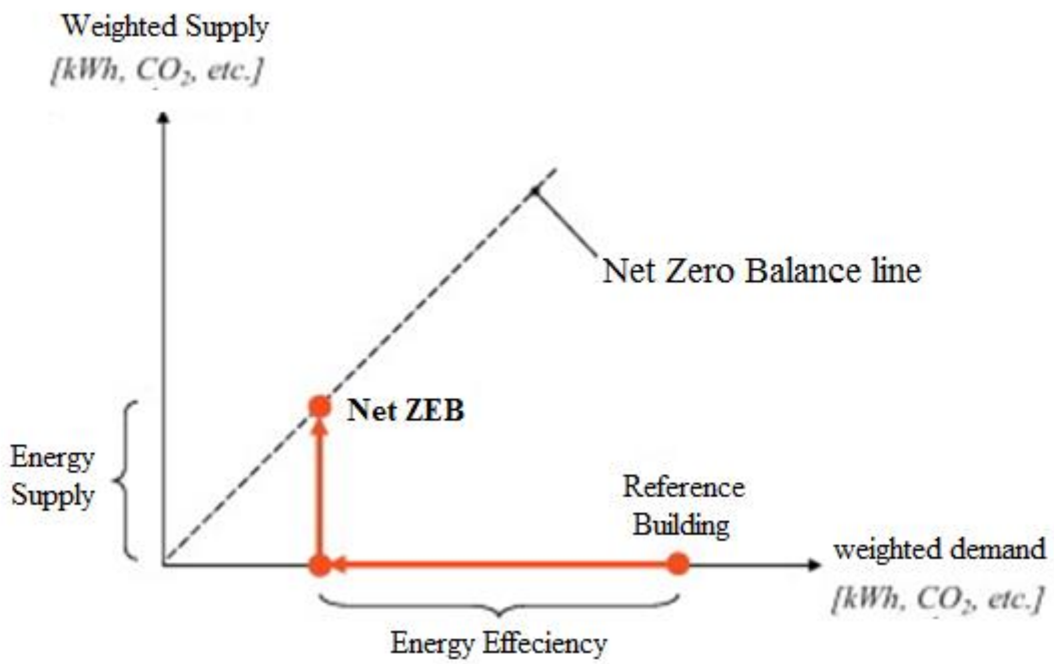


Figure 2.2: Graph representing the NZEB balance concept (Sartori et al., 2012).

The reference building may represent the performance of a new building built according to Net Zero Energy requirements or the performance of an existing building prior to renovation work. Starting from such reference case, the pathway to a Net Zero Energy Building is given by the balance of two actions:

1- Reduce energy demand (*x*-axis) by means of energy efficiency measures;

2- Generate electricity as well as thermal energy carriers by means of energy supply options to get enough credits (*y*-axis) to achieve the balance.

## 2.3 Type of Balance in Net Zero Energy Buildings

As it was illustrated by Sartori et al., (2012), import/export and load/generation is the two important balance types in Net Zero Energy Buildings. While publications by Gilijamse (1995), Torcellini et al., (2006), Noguchi et al., (2008), and Rosta et al., (2008) illustrate that reaching balance between energy use and production of renewable energy is most favoured. However, energy balance concept refers to the energy transfer between building and energy supply systems in publications Laustsen (2008) and Mertz et al., (2007).

Furthermore, figure 2.3 indicates the different types of balance in Net Zero Energy Buildings.

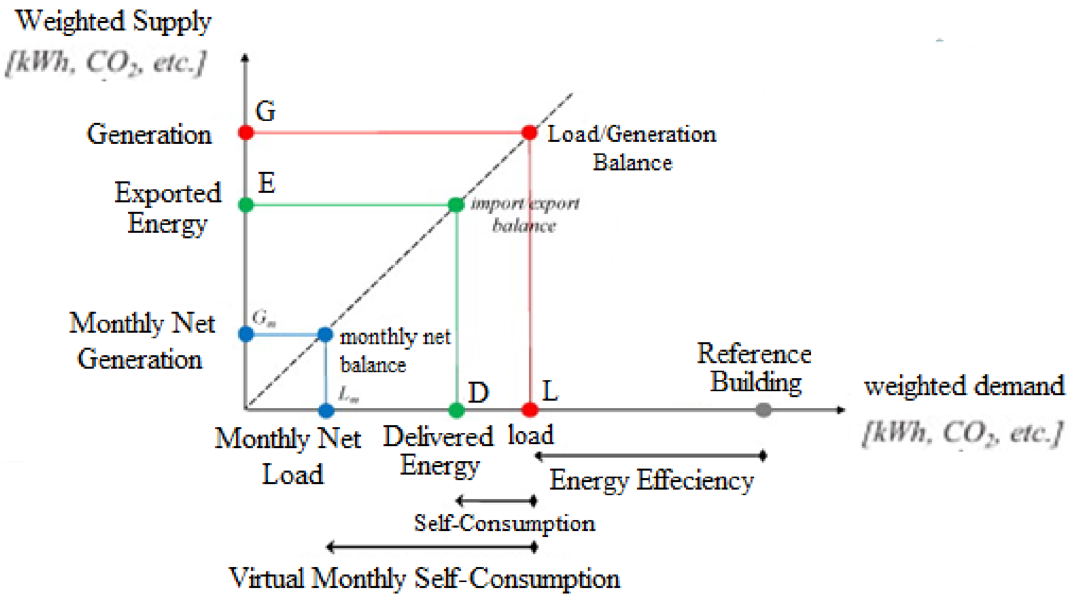



Figure 2.3: Graphical representation of the three types of balance in NZEBs (Sartori et al., 2012).

In figure 2.3 the energy demand in reference building was decreased to *L, D,* and $L_m$ level on the abscissa shown. These points shows different balance types than can be reached by Net Zero Energy Buildings. The load/generation balance gives the points for weighted demand and supply most far away from the origin; while with import/export balance and monthly net balance the points get closer to the origin.

## 2.4 Classification of Net Zero Energy Buildings

There are different approaches for Net Zero Energy Building that spotlight different aspects of Net Zero Energy Building complex concept. In fact, Net Zero Energy Buildings can be classified in different groups based on metric of balance.

### 2.4.1 Net Zero Site Energy Building

According to Torcellini et al., (2006), Net Zero Site Energy is a building that produces at least as much energy as it consumes in a year, when accounted for in site energy. Generation examples include roof-mounted PV or solar hot water and otther site-specific on-site generation options such as small-scale wind power may be available.

A limitation of a Net Zero Site Energy Building definition is that the values of various fuels at the source are not considered. For example, one energy unit of electricity used at the site is equivalent to one energy unit of natural gas at the site, but electricity is more than three times as valuable at the source. A Net Zero Site Energy Building has the fewest external fluctuations that influence the Net Zero Energy Building goal, and therefore provides the most repeatable and consistent definition.

‶This method is not robust when energy is delivered by different carriers; all energy is offset one-to-one by the energy exports, i.e. independently of the carriers″ (Bourrelle et al., 2013). In Net Zero Site Energy approach, the energy balance is done at the building site between delivered and exported energy. The concept of balance in Net Zero Site Energy approach is illustrated in figure 2.4.

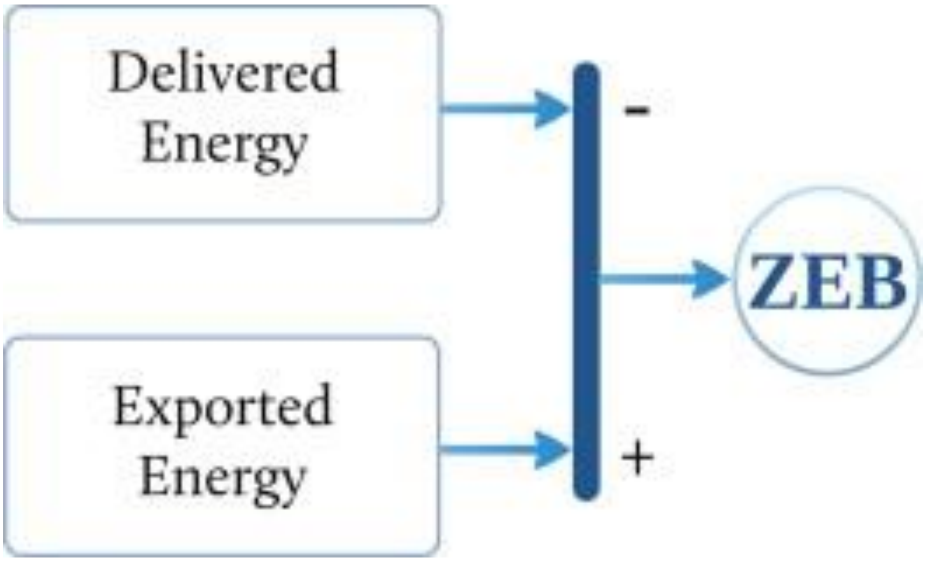


Figure 2.4: Net Zero Site Energy Balance Method (Bourrelle et al., 2013).

Mathematically the concept of balance in Net Zero Site Energy Building can be reached by equation 2.2:

$$\Delta Esite = \sum Eexp,_{i} - \sum Edel,_{i} \qquad (2.2)$$

**2.4.2 Net Zero Source Energy Building**

A building that produces at least as much energy as it uses in a year, when accounted for a source (including primary energy that is required to generate energy and energy losses). In this method, the energy balance is done at the primary energy level and termed Net Zero Source Energy (Kurnitski, 2011). To calculate a building's total source energy, both imported and exported energy are multiplied by the appropriate site-to-source energy factors. Figure 2.5 illustrates the approaching balance in source energy buildings.

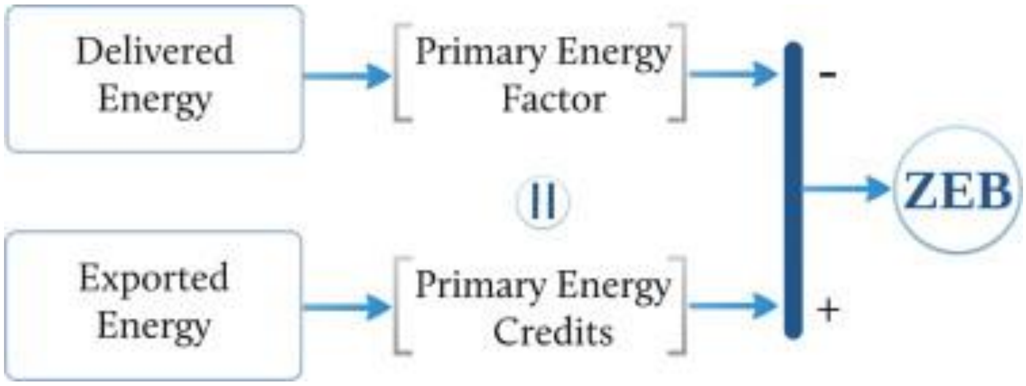


Figure 2.5: Net Zero Source Energy Balance Method (Bourrelle et al., 2013).

In Net Zero Source Energy Balance, each energy carrier is weighted according to its own primary energy factor. This permits a valuation of the different carriers in a way that reflects their energy quality, or exported electricity versus delivered gas/oil/heat. The concept of balance in Net Zero Source Energy method can be illustrated mathematically in equation 2.3:

$$\Delta E_{source} = \sum (E_{exp,\ i}\, f^{p}_{exp,i}) - \sum (E_{del,\ i}\, f^{p}_{del,i}) \qquad (2.3)$$

$$f^{p}_{exp,i} = f^{p}_{del,i}$$

### 2.4.3 Source Energy Balance with Building Embodied Energy

In the methods so far presented, all energy harvested from renewable sources offset energy imports towards achieving a Net Zero Energy Building status without regards to energy embodied in buildings and in technologies used to harvest renewables. The embodied energy is took into account in this method, i.e. the energy exports are to offset both the energy imports and the building embodied energy (Equation 2.4).

Equation 2.4 is used to represent the concept of balance in following method:

$$\Delta E_{source,embodied} = \sum (E_{exp,\ i}\, f^{p}_{exp,i}) - \sum (E_{del,\ i}\, f^{p}_{del,i}) - \sum (\ E^{p}_{emb,buuilding})$$

$$\boldsymbol{f^{p}_{exp,i}} = \boldsymbol{f^{p}_{del,i}} \qquad (2.4)$$

Figure 2.6 represents the concept of primary energy balance with building embodied energy method.

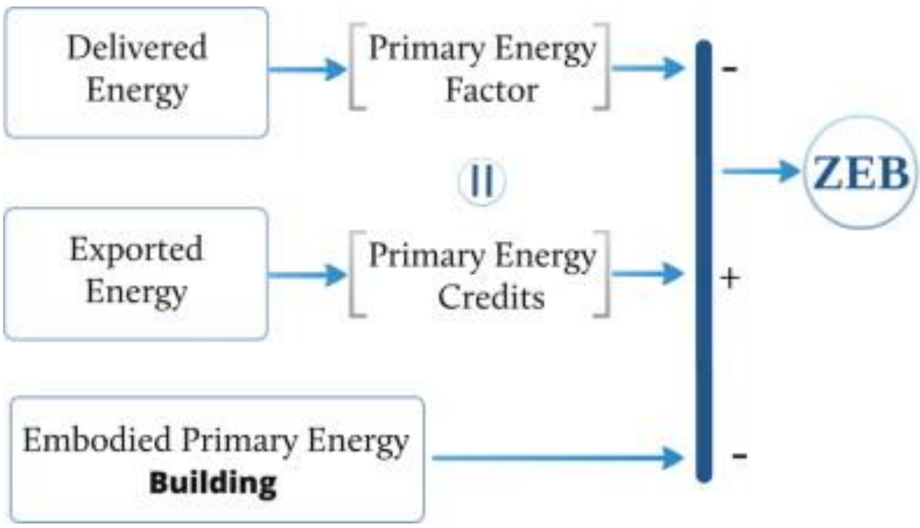



Figure 2.6: Net Zero Source Energy balance with building Embodied energy method (Bourrelle et al., 2013).

### 2.4.4 Source Energy Balance with Renewable Source Embodied Energy

Primary energy is required to convert renewable energy into electricity or other useful energy. This energy might constitute a significant part of total renewable energy output. This method presents the energy investment in Renewable Energy Source by considering a fraction of the energy exports as a payback for the energy embodied within Renewable Energy Source devices, e.g. PV system.

Equation 2.5 can be used to explain mathematically the concept of balance in this type of Net Zero Energy Buildings.

$$\Delta E_{source,embodied} = \sum (E_{exp,\ i}\, f^{p}_{exp,i}) - \sum (E_{del,\ i}\, f^{p}_{del,i}) - \sum (E^{p}_{exp,}\ i\, f^{p}_{NR,i})$$

$$f^{p}_{exp,i} = f^{p}_{del,i} \qquad (2.5)$$

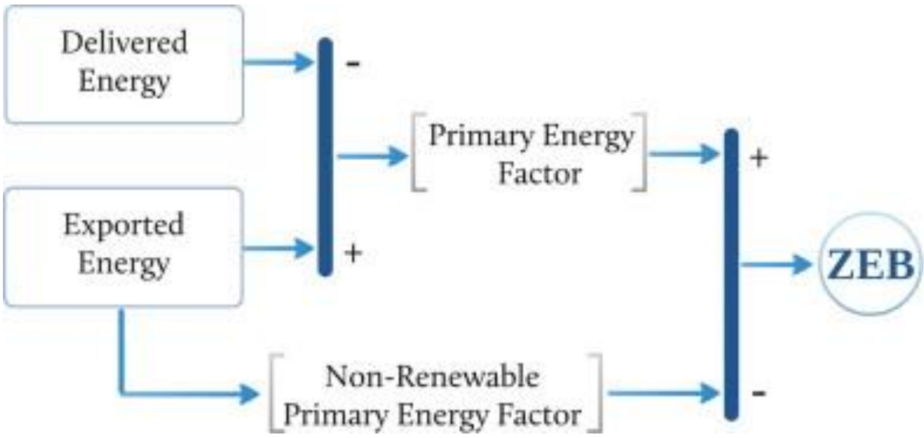


Figure 2.7: Net Zero Source Energy balance with Renewable Energy Source Embodied Energy Method (Bourrelle et al., 2013).

### 2.4.5 Net Zero Energy Cost Building

A building that incomes from selling the electricity to the grid is at least equal with the annual amount of payments to the grid.

"A Net Zero Energy Cost Building provides a relatively even comparison of fuel types used at the site as well as a surrogate for infrastructure. Therefore, the energy availability specific to the site and the competing fuel costs would determine the optimal solutions" (Torecellini et al., 2006). However, as utility rates can vary widely, a building with consistent energy performance could meet the cost ZEB goal one year and not the next.

### 2.4.6 Net Zero Energy Emission Building

A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

Success in achieving a Net Zero Energy Emission Building depends on the generation source of the electricity used. Emissions vary greatly depending on the source of electricity, ranging from nuclear, coal, hydro, and other utility generation sources. One could argue that any building that is constructed in an area with a large hydro or nuclear contribution to the regional electricity generation mix would have fewer emissions than a similar building in a region with a predominantly coal-fired generation mix (Torecellini et al., 2006).

## 2.5 Type of Covered Energy in Net Zero Energy Buildings

In seventies and eighties, a substantial share of energy was for heating in buildings. Therefore, definition of Net Zero Energy Building was focusing on heating demand in buildings. There is a definition by Esbensen and Korsgaard (1977): A Net Zero Energy Building should be able to cover its space-heating load and can supply required hot water through energy conservation technologies such as solar space heating, high efficiency insulation, hear-recovery system, etc.  Additionally (Saitoh et al., 1985) have taken first steps toward zero thermal buildings.

On the other hand, there are papers that only electricity demand is considered in Net Zero Energy Building definition. Gilijamse (1995) defined a Net Zero Energy Building as a building which does not consume fossil fuels at all and is able to generate electricity as much as it uses during a year.

Lausten (2008) in his paper emphasized on both electricity and heat demand to present a definition of NZEB. The author distinguished that NZEB exports electricity to the grid as much it imports from the grid over a year.

## 2.6 Type of Connection with the Energy Infrastructure in NZEBs

Net Zero Energy Buildings can be connected to an energy infrastructure such as public grid utilities (ON-grid) or can be autonomous buildings (OFF-grid). Mostly differences between both options are discussed in many literatures. In On-grid system, buildings are connected to the utility grid and energy can be transferred between buildings and grid. In this option energy demand by buildings can cover by the grid also building can feed the grid by extra generated electricity. Buildings in off-grid option are not able to use electricity energy when other renewable energy resources cannot cover building's energy demand. Off-grid Zero Energy Buildings are known as 'self-sufficient', 'autonomous 'or 'stand-alone' buildings. According to Laustsen (2008), Off-grid Zero Energy Buildings are buildings, which are not connected to the electricity grid, and buildings can supply themselves energy demand autonomously. Off-grid Zero Energy Buildings are able to store energy for later use.

## 2.7 Type of Renewable Energy Source in Net Zero Energy Buildings

Net Zero Energy Buildings can be classified by type of renewable energy resources what will employee such as wind energy, solar energy, biomass and geothermal energy. Several papers focused on use of solar energy in Net Zero Energy Buildings such as following publications: Esbensen and Korsgaard (1977) and Stahl et al., (1995). Even there is a definition of zero energy solar homes by Charron (2008): a Solar Net Zero Energy home is a building that is able to produce as much electricity through solar technologies such as PV system as annually consumes.

## 2.8 Type of Energy Supply Sources in Net Zero Energy Buildings

'On-site' and 'Off-site' are two supplying renewable energy options of Net Zero Energy Buildings. In on-site system technologies, which convert renewable source, are installed in/on building or on the site-attached building. Off-site system encompasses technologies, which are placed outside of the building site. Currently, the on-site options are much more popular than the off-site; however, taking into consideration the limited area of roof and/or façade may bring some difficulties to approach on-site options (Mazarsel et al., 2011).

According to Marszal et al., (2011) and Voss & Musall (2011), the most commonly used on-site renewable technologies, primarily generating energy and thus meeting the 'zero' energy goal, are photovoltaic (PV) and solar thermal panels.

In on-site supply option in Net Zero Energy Buildings the renewable energy sources which are available within the building footprint or are available at the building's site would be used. While in off-site Net Zero Energy Buildings renewable energy resources would be used off-site to generate energy for use on site. Additionally, in off-site Net Zero Energy Buildings off-site renewable energy can be purchased.

## 2.9 Barriers in Developing Net Zero Energy Buildings

Broad challenges are required to achieve Net Zero Energy Buildings. These challenges usually encounter barriers including lack of consistent evaluation and valuation process, insufficient financial supports and the lack of proven and reliable data on how to approach Net Zero Energy Buildings. Training of workers requires long-term period and usually costs are over round.

On the other hand, proper scoring system is needed to evaluate performance of buildings. Lack of such a scoring system makes it impossible to consumers easily compare and evaluate the energy performance of buildings. Therefore, the differences between performance of efficient buildings such as Net Zero Energy Buildings and performance of conventional buildings usually are not specified for consumers.

Additionally, lack of suitable life cycle cost calculation for buildings during designing process prevents to homeowners take all benefits by purchasing a building.

Buildings are mostly sold for initial cost and it is difficult to arrange a sufficient feedback system and mechanism for consumers.

Achieving Net Zero Energy Buildings is relatively difficult with dispersed information on construction methods, materials, relevant technologies, and siting options. Furthermore, there is no consistent and reliable sales infrastructure and solutions. Unproven affordability by insufficient numbers of real examples. Aversion of risk by stakeholders, builders, homeowners, and contractors. They fear to being the first presenter of new technology. Stakeholders are not well informed about Net Zero Energy Buildings. Insufficient financial supports by government officials, improper legislation and polices to utilize renewable energy resources and unavailability of technologies may be other barriers in promoting Net Zero Energy Buildings. For all those reasons and more, Net-zero energy is an ambitious goal for any building—one that cannot be achieved without scrupulous attention to every aspect of a building's design, construction, and operation. Therefore, every variable that prevents attention to design, construction and operation of buildings might be a barrier in approaching Net Zero Energy Buildings.

## 2.10 Attempts to Achieve Examples of Net Zero Energy Buildings

Net Zero Energy is quickly becoming a sought after goal for many buildings around the world – each relies on exceptional energy conservation and on-site renewable generation to meet all of its heating, cooling and electricity needs. There are directives provided by various number of countries in achieving Net Zero Energy Concept. For instance, Directive 2010/31/EU (EPBD recast, 2010) Article 9 requires that "Member States shall ensure that by 31 December 2020 all new buildings are Net Zero Energy Buildings; and after 31 December 2018, new buildings occupied and owned by public authorities are Net Zero Energy Buildings or nearly zero-energy buildings". Member States shall furthermore "draw up national plans for increasing the number of nearly zero-energy buildings" and "following the leading example of the public sector, develop policies and take measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into Net Zero Energy Buildings".

Additionally, in United States of America a national goal has been set to achieve net-zero energy in 50 % of U.S. commercial buildings by 2050 and in 50% of U.S. residential buildings by 2020 (DOE, 2010).

In order to comply real example of Net Zero Energy Buildings with climate conditions of Northern Cyprus, this thesis tried to present Net Zero Energy Buildings which have been built for same climate or similar climate conditions.

### 2.10.1 MASDAR City, a Net Zero Energy City Built in Tropical Climate

"Masdar City" is the name of a carbon-neutral, zero-waste city which is being built in a tropical climate conditions in Abu Dhabi/United Arab Emirates (UAE). Abu Dhabi has successfully given an offer to host the secretary of the International Renewable Energy Agency (IRENA) which was founded in 2008 in Germany. In June 2009 it was decided by the 114 member states of the International Renewable Energy Agency (IRENA) that Masdar City will host the headquarters of IRENA. IRENA will be the first global agency based in the Middle East (Reiche, 2010).

"Masdar City has been established for different reasons: First of all, the project is part of the long-term economic diversification strategy for Abu Dhabi. The economy of the emirate is still mainly dependent on exporting fossil fuels. But fossil fuels are finite, and the leadership of Abu Dhabi wants to prepare the emirate for the post-oil age and make other businesses competitive. The long-term goal is the "transition from a 20th Century, carbon-based economy into a 21st Century sustainable economy" (Masdar, 2009, p.1). This implies also "Abu Dhabi's transition from technology consumer to technology producer” (Masdar, 2009, p. 4). Finally, from a policy innovation and diffusion perspective, the emirate has the ambitious objective of contributing to global policy development: “Masdar City will provide a blueprint for future cities striving for sustainability and will serve as a model for how all future cities should be built” (Masdar, 2009, p. 6, 8).

This city has a construction budget of $18 billion and the first phase will open in 2015. This city enjoys more than 87,000 PV panels with additional roof top PV panels. Lead mechanical engineering including Teflon-coated wind towers and centralized solar PV panels are used in construction of this is city.

Figure 2.8: A Master Plan of Masdar City [URL 1]

Figure 2.9: Centralized Solar PV System in Masdar City [URL 1]. This figure shows the innovation and advanced technology use in Masdar City.

Figure 2.10: The Teflon-Coated Wind Tower in Masdar City [URL 1]. This efficient technology in Masdar City is used to provide cooler streets in city than surrounding desert.

Table 2.1 summarizes strategies which have been adopted in construction of Masdar City. Additionally, the table illustrates the achieved goals by highlighted strategies.

Table 2.1: Summary of Adopted Strategies in Approaching Net Zero Energy Concept in Masdar City (Reiche, 2010).

| **Strategies to Achieve Net Zero Energy Concept in Masdar City** |
|---|
| • Abu Dhabi has just started to transforming oil wealth into renewable energy leadership<br>• Abu Dhabi has set the long-term goal of a "transition from a 20th Century, carbon-based economy into a 21st Century sustainable economy."<br>• A core piece of the new approach is Masdar City, a project to build a carbon-neutral town<br>• Academic programs such as information technology, water and environment, engineering systems and management, materials science and engineering, mechanical engineering is taking place<br>• city hopes to attract more than 1500 companies in the field of sustainable energy technologies<br>• companies will benefit from the possibility of having 100 percent foreign ownership, zero taxes and zero import tariffs<br>• Torresol Energy, a joint venture between Masdar and the Spanish engineering group Sener, already has three solar power plants in Masdar City<br>• Masdar invested €120 million in WinWinD, a Finnish manufacturer of 1 and 3 MW wind turbines<br>• Masdar entered into the London Array offshore wind farm project through joint venture agreement with the German energy corporation EON<br>• Constructing of top-3 global thin-film PV Company in Masdar City and Abu Dhabi producing amorphous thin-film photovoltaic modules of an annual capacity of 210 MW.<br>• Masdar plans to create a network of carbon capture plants at emission sites, pipelines to carry the carbon dioxide to onshore oil-fields and an injection system to pump the carbon underground in order to enhance oil recovery. |

### 2.10.2 A Net Zero Energy Building Built for Mediterranean Climate

The considered building is a single family detached house, located in municipality of Mascalucia (Catania) in the Italian region of Sicily (Figure 2.11). This house follows the requirements of Passivehaus certification method in term of thermal performance: energy need for space heating lower than 15 $KWh/m^2y$, energy demand for cooling and dehumidification lower than 15 $KWh/m^2y$, primary energy for all domestic applications (heating, hot water and domestic electricity) lower than 120 $KWh/m^2y$. A solar thermal system with a mechanical ventilation system have been complemented in building. Triple glazing, thermal insulation, thermal mass in roof and walls and natural cross ventilation are a part of strategy in achieving Net Zero Energy concept (Causone et al., 2014). Table 2.2 represent the features of this building.

Figure 2.11: Net Zero Energy Concept Building Built for Mediterranean Climate (Causone et al., 2014).

Table 2.2: The Features of Net Zero Energy Building Built for Mediterranean Climate (Causone et al., 2014).

| | |
|---|---|
| Project name and location | *Progetto Botticelli* Mascalucia (Sicily) |
| Building type | Detached single family house |
| Conditioned floor area | 144 $m^2$ |
| Roof thermal transmittance | 0.13 W/ ($m^2$K) |
| External walls thermal transmittance | 0.13 W/ ($m^2$K) |
| Basement thermal transmittance | 0.23 W/ ($m^2$K) |
| Windows thermal transmittance | 0.90 – 1.10 W/ ($m^2$K) |
| Envelope air tightness | Lower than 0.60 ach |
| Construction type | Structural concrete and masonry, with mineral wool thermal insulation |

‟ The slope of the roof is 22° and assuming to install southwest facing mono-crystalline cells with a nominal efficiency of 18.4% and a peak power of 300 W per panel, and an overall DC to AC derate factor of 0.77, 20 PV panels are sufficient to balance (over one year) the whole electricity demand of the building. The PV field is characterized by a nominal peak power of 6.0 KWp and a covered area of 32.6 $m^2$. ″(Causone et al., 2014).

Results carried out after monitoring the building performance. Annual delivered electric energy for space heating amounts to 7.3 KWh/$m^2$y and annual delivered electric energy for space cooling is 9.5 KWh/$m^2$y. The overall energy electricity demand which includes all energy uses such as space heating and cooling, dehumidification, production of hot water, ventilation, lighting and plug loads is 7,253 KWh per year, i.e. 48.8 KWh/$m^2$y (Causone et al., 2014). While the overall electricity generation is more than electricity demand in this house. The total electricity generation amounts to 7,580 KWh per year.

Table 2.3 illustrates a list of adopted strategies to approach Net Zero Energy Concept in *Progetto Botticelli* home in Mediterranean climate.

Table 2.3: Summary of Adopted Strategies to Approach Net Zero Energy Concept in *Progetto Botticelli* Home (Causone et al., 2014).

| **Strategies to Achieve Net Zero Energy Concept in *Progetto Botticelli* Home** |
| --- |
| • Utilization of on-site PV modules including a solar thermal system to generate electricity. Installation of southwest facing mono-crystalline cells with a nominal efficiency of 18.4% and a peak power of 300 W per panel<br>• Use of high efficiency ventilation system<br>• Use of a thick external mineral wool continues layer<br>• Triple glazing windows and great care in construction details<br>• Use of high thermal insulation and guarantee of airtightness level<br>• Largely use of passive design strategies such as enhancing natural cross ventilation by means of disposition of windows<br>• Implementation of EAHE system including 3 circular ducts, 10 m long each, installed 3 m depth in the ground, with an internal diameter of 142 mm to optimize heating and cooling and reduce pressure losses in the building<br>• Use of a smart energy management and monitoring system |
| **Results** |
| • A good result has been carried out by coupling of use of high thermal insulation, on-site generation electricity and use of efficient technologies since the building produces electricity slightly more than energy demand and comfort level has been increased. |

### 2.10.3 Energy Dream Center Buildings, Built for Subtropical Climate

Energy Dream Center building was realized in 2012 in Seoul, South Korea. With a floor space of 3,500 m², the zero energy building houses exhibitions and offers a wide range of information related to the field of renewable energy. Headed by the Fraunhofer Institute for Solar Energy Systems ISE, an interdisciplinary team designed the building and accompanied the construction. The biggest challenge faced by the team of scientists, engineers and architects was to create a harmonious concept which combines energy savings and efficiency with architecture and functionality. What resulted is a flagship project which demonstrates applications of the latest technologies and the successful use of renewable energies. Figure 2.12 shows a side view of this building (Fraunhofer ISE Press Release, 2012).


Figure 2.12: A Side View of Seoul Energy Dream Center (Fraunhofer ISE Press Release, 2012).

The entire concept covering the energy and the technical aspects is customized for the comfort of the building occupants as well as for the climatic and technical boundary conditions in South Korea. Complementing the role of the building envelope, the ventilation system ensures both controlled heat in the winter and controlled humidity and cooling in the summer. ‶The efficient building services are mainly based on earth probes, which provide the radiant cooling system with cold in summer and which serve as a heat source for the heat pump throughout the year. In addition to this, a ventilation system with two-step heat recovery and evaporative cooling and a turbo compression chiller for dehumidification are installed. By applying these collective measures, the heating and cooling energy consumption of this building is 70 percent less than the standard consumption for South Korean buildings″ (Fraunhofer ISE Press Release, 2012).

The remaining annual energy demand of the Energy Dream Center is supplied by renewable energy sources. In addition to geothermal energy for supplying heating and cooling, grid-connected photovoltaic systems on the roof, the overhangs and in a small field supply the total amount of electricity required (about 280 000 KWh/year). The result is a building with Net Zero Energy consumption and zero carbon emissions in an annual balance – namely a Net Zero Energy Building. It fulfills the passive house standards and the Korean standards: Korean Green Building Certification KGBC and the Building Energy Efficiency Label (Fraunhofer ISE Press Release, 2012). Table 2.4 highlights the strategies and polices which have been applied in achieving Net Zero Energy concept in Energy Dream Center.

Table 2.4: Summary of Adopted Strategies to Approach Net Zero Energy Concept in Energy Dream Center ((Fraunhofer ISE Press Release, 2012).

| **Strategies to Achieve Net Zero Energy Concept in Energy Dream Center** |
|---|
| • Attention to best possible combination of design concept and technological solution<br>• In order to optimize building performance project simulation carried out by partners.<br>• Meet energy conservation strategies by largely use of passive design solutions, including optimal orientation, design envelope based on passive house design standards, optimizing use of daylight by use of square-shaped central atrium, radiant cooling and natural ventilation<br>• Use of reinforced massive celling to approach balance in cooling load.<br>• Use of efficient building services such as efficient lighting (LED) system<br>• Use of geothermal energy to supply energy demand in building<br>• Grid-connected photovoltaic systems on the roof, the overhangs and in a small field supply the total amount of electricity required (about 280,000 kWh/year) |
| **Results** |
| The result is a building with zero net energy consumption and zero carbon emissions in an annual balance – namely a Net Zero Energy Building. It fulfills the passive house standards and the Korean standards: Korean Green Building Certification KGBC and the Building Energy Efficiency Label. |

## 2.11 Required Design Elements for Net Zero Energy Buildings

Various design elements are required to pass toward Net Zero Energy Buildings. Efficient and mature energy technologies are required to provide comfortable indoor environment for occupants in Net Zero Energy Buildings. Improvement of insulation, increase of thermal mass, incorporation of high efficiency heating and cooling equipment and implementing innovative shading devices are only a part of efficient technologies than can be considered for Net Zero Energy Buildings. On the other hand, several variables should be considered in design of a Net Zero Energy Building in term of energy conservation. Since the Net Zero Energy Building design is a progression from passive sustainable design, energy conservation practices in Net Zero Energy building encompasses all architectural practices based on passive design strategies, semi passive design strategies and other efficient practices that can be performed in designing process. Additionally, use of renewable such as solar thermal systems, buildings' integrated Photovoltaic, small scale wind turbines and even heat pumps should be available in Net Zero Energy Building design process to cover energy demand. Hence, required design elements to achieve Net Zero Energy Buildings can be implied through three main headings:

### 2.11.1 Passive Design Strategies

Designing of NZEBs starts with understanding of the building use, its interior comfort, necessities, and study of natural and environmental available resources on the building site. Then passive design strategies must establish to take advantage of natural available resources. Passive design includes strategies for optimize daylightning use, improve indoor air quality, optimize direct and indirect solar gains, optimize thermal energy storage, and reduction heat losses. In addition, adding or reducing humidity, removing the built-up heat, and keeping the heat from building up are other passive design strategies to provide a more comfortable interior during cooling (Voss et al., 2007). Diagram 2.1 illustrates an explicative list of practices that can be applied in approaching Net Zero Energy Buildings.

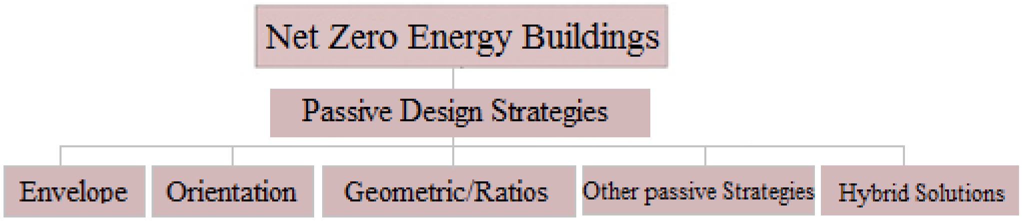



Diagram 2.1: Achieving Net Zero Energy Buildings through Passive Design Strategies (Rodriguez-Ubinas, et al., 2014).

#### 2.11.1.1 Building Envelope

Building envelope is the limit, which separates the interior conditions and exterior conditions of a building. Proper construction of envelope is dramatically effective for reduction of energy use in buildings. Since the envelope protects the building from exterior conditions, the *U*- value (thermal transmittance) is the most relevant characteristic. Envelope absorbance, thermal lag, and thermal energy storage capacity are other parameters that affect envelope performance.

#### 2.11.1.2 Building Orientation, Geometrical Parameters and Ratios

These are other three parameters connected to the envelope properties, which influence on thermal performance of buildings: orientation, geometrical parameters, and ratios. Gain or loss of thermal energy in buildings is determined by thermo-physical properties of that building. Building’s shape determines the size of surface exchange. Orientation determines which areas directly capture the sunlight or affected by the wind. Building’s orientation is helpful to determine the capacity use or protection of solar radiation and winds.

There are several ratios to give specific ideas of proportion and relationship of the building elements. The aspect ratio (*Wl)* shows the relation between equatorial-facing façade width *(W)* and lateral façade length *(l)* (Aksoya and Inalli, 2006). There are other ratios, which are related with envelope area and volume of the building. In order to describe building shape, the European Committee for Standardization proposed two different ratios: the compactness ratio ($A_e$ / $V_C$) and shape factor ($A_e$ / $A_C$). Where, $A_e$ refers to the thermal envelope area in $m^2$, $V_C$ is the volume of building in $m^3$, and $A_C$ is the building conditioned floor area $m^2$.

**2.11.1.3 Other Passive Design Strategies**

Table 2.5 represents different passive solutions, classified into three groups: heating, cooling and Thermal Energy Storage (TES).‟ The most common Thermal Energy Storage system used in buildings is the Sensible Thermal Energy Storage (STES). Moreover, the Sensible Thermal Energy Storage capacity of the ground may be used by those spaces located underground. Additionally, Latent Thermal Energy Storage (LTES), using Phase Changes Materials (PCM) as the storage medium, is becoming an attractive option since they increase the Thermal Energy Storage capacity, adding very little weight and require little or no additional space″ (Rodriguez-Ubinas, et al., 2014).

Table 2.5: Buildings’ Passive Design Solutions (Rodriguez-Ubinas, et al., 2014).

| Heating | Cooling | Thermal Energy Storage |
|---|---|---|
| Solar direct gain<br>Sunspace<br>Double skin glass facade<br>Mass wall<br>Trombe wall<br>Wind Protection | Solar shading<br>Green roof or walls<br>Natural ventilation<br>Night ventilation cooling<br>Ventilated facade<br>Solar chimney<br>Evaporative cooling<br>wind catcher | Sensible Thermal Energy Storage-thermal mass<br>Latent thermal energy storage |

#### 2.11.1.4 Hybrid Solutions

Hybrid Solutions which have been termed as semi-passive design strategies since they need low energy for their operation. ‶Hybrid solutions need low energy consumption devices, like fans or pumps, to function. Hybrid solutions are helpful to minimize the use of active HVAC systems, taking advantage of the available natural resources such as solar radiation, wind, thermal variability, daylight, clear skies and ground temperature″ (Rodriguez-Ubinas, et al., 2014). Table 2.6 indicates a list of buildings' hybrid solutions.

Table 2.6: Buildings' Hybrid Solutions (Rodriguez-Ubinas, et al., 2014).

| **Hybrid Solutions** |
| --- |
| Active solar shading |
| Fan-force ventilation cooling |
| Heat recovery systems |
| Ground air heat exchange |
| Mechanical night ventilation |
| Evaporative cooling |
| Dehumidification system |
| Unglazed transpired solar facade |
| Low temperature Radiant Surface |
| Night sky radiator cooling |

### 2.11.2 Technical Building Services

In Net Zero Energy Buildings technical building services should include efficient technologies to be able optimize energy efficiency and provide more foster indoor. In this thesis a part of efficient energy services that can be considered in designing of Net Zero Energy Buildings follow:

#### 2.11.2.1 HVAC System

It is estimated that, Heating, Ventilation, and Air – conditioning (HVAC system) can result 10% - 40% in saving energy, reduction of emissions, and cost savings in buildings (NIBS, 2012). A proper HVAC system provides a comfort zone for users and can increase thermal comfort and improve indoor air quality. A control phase is needed to determine how an appropriate HVAC system can be installed to provide comfort for users, be cost effective, and safe. Installation of an appropriate integrated HVAC system plays an important role in energy saving in buildings.

In such a system, heating demand can be supplied by central heating system. Heating parts consists of a boiler and heat pump to heat water, steam, or air. All the equipment will be located in a central place such a small room or in a facilities room.

A proper ventilation system such as HVAC makes it possible for occupants to manage the temperature and humidity of indoor air. In order to achieve a comfortable indoor air quality in cold climates, the humidity should be removed out from cold air. Therefore, dehumidification is needed to reject moisture from cold air. Dehumidification can be accomplished by mechanical systems. In dry climates, humidification provides a comfortable air. In order to provide humidification in dry climates, evaporators can be used. Furthermore, cooling radiator systems are suitable to use in dry climates.

#### 2.11.2.2 Solar Hot Water System

Generally, water heating contributes 20 to 30% of total energy demand of a building. Using solar hot water can supply more than 70% of required energy for water heating in buildings. Although, natural gas, LPG, and electricity are more common sources that are used for water heating system in buildings but using freely solar energy to provide hot water might be an appropriate option to cover water heating demand in buildings. Implemented solar hot water system can be effective to reduce total energy demand in a building.

A solar hot water system consists of two main parts: 1) collectors which absorb the sun heat and 2) water tank that is connected to the collector through pipes. Collectors capture the sunlight energy and transfer the heat to working fluid. The heated fluid moves toward the store and after passing through a heat exchanger, transfer the heat to the tank water. Pipes transfer warmed water to occupants.

In order to install a 100 LPD Domestic Solar Hot Water System (DSHWS) which would be enough for a three-bed room single family home, the requirements follow: an area of 3 $m^2$ than can support 200 kg static load, water supply system to provide cold water constantly, and electricity power. Integrating Domestic Solar Hot Water System (DSHWS) with building in early design stages is more efficient.

#### 2.11.2.3 Advanced Solar Control Windows

Window and glass types can be selected to balance concerns for daylighting, winter solar gain, and summer shading. Today, a range of different windows is available in the market. Selecting proper windows depending on climate zones is a key strategy to approach an energy efficient building. Several types of energy flows occur through windows:

1- Conductive and radiative flows through the window assembly
2- Infiltration gains and losses through air leakage
3- Solar radiant heat gain

Solar windows are an attractive alternative to approach an energy efficient building. Solar windows should be selected for the climate that they will be used in. Two important properties indicate the rate of heat flow through solar windows:

1- $U$ – Value
2- Solar Heat Gain Coefficient (SHGC)

Lower $U$ – Value refers to a better insulation. In Net Zero Energy Buildings, that passive solar heating is an essential key to reduce energy demand, low $U$ – Value windows can be effective to reduce winter heat loss. For cold climates, windows with low $U$ – Values are not necessary helpful; and windows which maximize the heat gain should be used. In hot climates, this is also important, where the glass itself can absorb solar heat.

Additionally, special care should be taken with windows, which are located in south face of building. The North face windows lose more energy than gain. Windows, which are located in the East and West need cooling during hot seasons due to high heat gain. Balancing the energy lose or energy gain in non-south facing windows is a key to manage energy efficiency in buildings.

**2.11.2.4 Insulation and Infiltration**

Insulation materials play an important role in improving energy efficiency in buildings. Building's thermal insulation prevents energy lose in buildings. Insulation the outside mass of walls, allows the mass to store heat of the rooms and stabilized the interior air temperature. Proper insulation provides cool condition in summer and warm in winter. Different types of insulation materials are used both construction of new buildings and the renovation of old buildings to attain high-energy efficiency standard. There are different forms of insulation materials such batts, rolls, loose-fill, rigid, and sprayed or injectable foams (Tettey et al., 2014). The R – Value measures the thermal resistance of a material. A proper insulation has a high R – Value. The range of R-Value of an appropriate insulation for a Net Zero Energy Building should be in level of 0.2 $W/m^2$ K up to 3 $W/m^2$ K (Kapsalaki et al., 2013).

Air infiltration or air leakage is another essential key that influences on energy performance of buildings. Energy can be lost easily through flowing out of heat from leakages existing in walls and roofs. The number of air exchanges per hour (ACH) measures air infiltration. The proper range of ACH for a high efficiency building is 0.35 to 0.50 of ACH (Ng et al., 2013).

**2.11.2.5 Efficient Lighting**

Globally, lighting is an important issue to minimize overall energy consumption. Almost all building owners are interested to decrease the consumption of electricity to save money. Decreasing electricity consumption in building sector benefits the environment through decreasing the fuel consumption.

Compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) use 80 to 85% less electricity compared to incandescent lamps (ILs) and last 6 and 26 times longer, respectively (Mills and Schleich, 2014) . Additionally, the use of optimal lighting devices not only reduces the heating load but also can substantially decrease the cooling load in buildings.

#### 2.11.2.6 Landscaping

Well-designed landscape and greenery spaces contribute to reduce emissions in buildings and mitigate energy demand. Trees are useful to reduce cooling load (figure 2.13) in warm seasons by moderating the environment temperature and shading (Geoffrey et al., 2009). The West positioned trees make lengthened shadow and can be effective for reduction of cooling load in the summer. Trees growing in the East side reduce the energy demand in morning hours when the air conditioning demand is the lowest through casting shadows. Trees that are positioned in the South side of a residential building would be effective to save energy demand if they are close to windows or the building. There is not any report to show that trees is North side are effective for energy saving in the buildings. Additionally, trees assist with indoor comfortable by altering airflow.

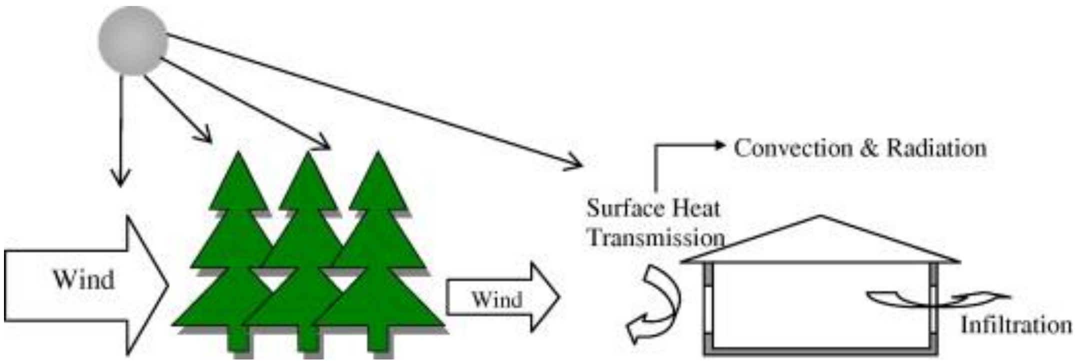



Figure 2.13: Schematic Diagram Showing the effect of Trees on Building Energy Consumption (Liu and Harris, 2008).

#### 2.11.2.7 High Efficiency Appliances

The household appliances are known as a major domestic energy consumer. For example, in Europe it is estimated that appliances use more than 30% of total in-home energy (Bertold and Atanasiu, 2007). Additionally, the studies showed the number of appliances growth up as average owner's incomes increases. Addressing appliance energy demand reduction is important because of its present energy consumption level, and also for its likely growth. Energy efficient appliances are useful to reduce energy demand due to long term' operating savings. Currently, there are lots of efficient appliances such as refrigerators, wash dryers, and HVAC systems.

#### 2.11.2.8 Interior Space Planning

Placing rooms in strategic locations helps to conserve energy in buildings. Placing rooms depending their function in different seasons and during daytime is an effective way to save energy and helps to provide a comfortable indoor. For instance, placing rooms with high level heat producing in the North face of the building helps to increase heating/cooling efficiency. In addition, locating of areas such as stores and bathrooms, which are not used too much by occupants in the North side would be effective for energy efficiency. These areas do not need to be heat by the southern exposure. Accordingly, interior spaces, which demand high level of heat should be located on the South side. Additionally, gathering the areas such as kitchen, bath, and laundry room that need hot water, near the hot water system can decrease the heat lose in water pipes.

### 2.11.3 Renewable Energy Generation

A Net Zero Energy Building can take advantages from locally available renewable energy resources such as solar and wind. Although, other renewable energy resources such as geothermal, biomass, hydropower and even wave energy might be available but the technologies in order to utilize these resources are not in a mature level in the most countries in the world. On the other hand, required technologies of utilizing solar and wind energy are almost completely available and these resources are currently largely used. Therefore, this study focused on utilizing solar and wind energy in Net Zero Energy Buildings.

#### 2.11.3.1 PV system

Converting sunlight to electricity received more attention since 1950 by the first invention of Photovoltaic cells. Abundance of solar radiation and availability of technologies caused, Photovoltaic cells gain supports by scientific world and decision makers. Photovoltaic cells played an important role with decreasing of electricity consumption during oil crisis in 1970. Today, implementation of PV system in local scale has received more attention than developing PV in mega scale to supply energy. PV technology has been a common option in rural areas of developed countries to cover energy demand in buildings.

Off – Grid and Grid – Connected systems are two major types of PV system at the moment. Off – grid system incorporates PV panels, batteries, and inverter(s) (figure 2.14). Two essential components, PV panels and Inverters make a grid – connected system (2.15). For grid – connected system a bi – directional meter system transfers excess electrical power between PV system and the main Grid. Since in grid – connected system surplus energy is exported to the main grid and electricity can be imported to cover energy demand, existing of an energy metering system is necessary. Bi – directional metering application would be able to meter and monitor the exported and imported energy tracks (2.16). This application provides an energy data to quantify energy saving. Bi – directional facility can conveniently calculate all energy usage in bills and credits.

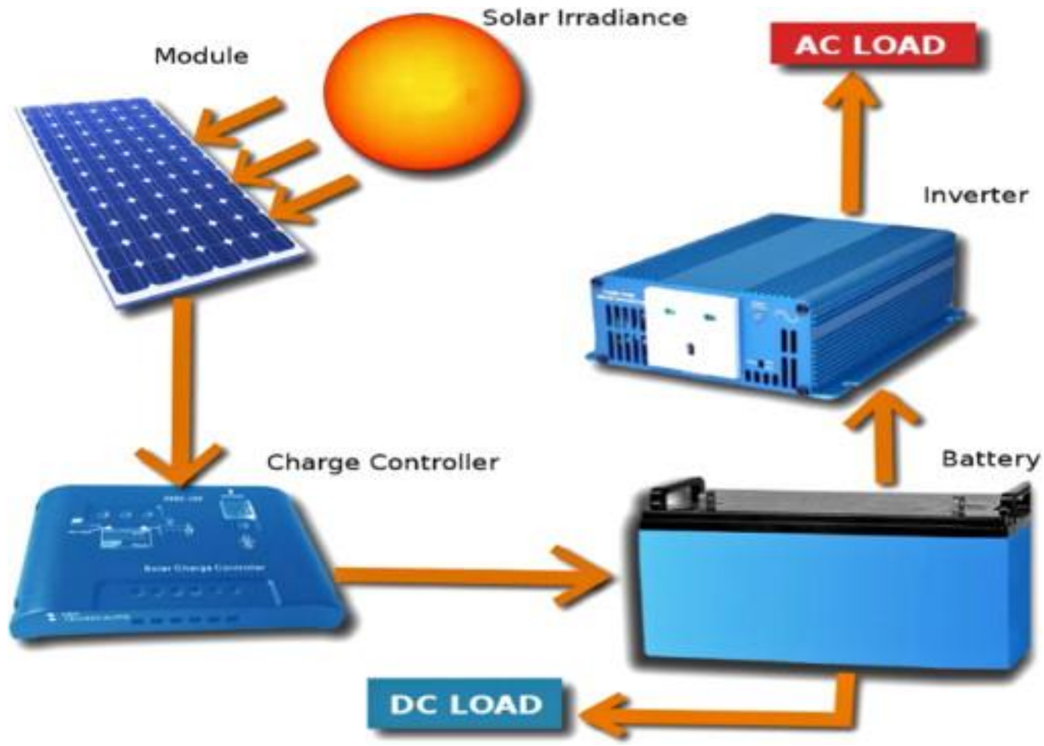



Figure 2.14: Layout of an Off-Grid PV System (Ghafoor and Munir, 2014).

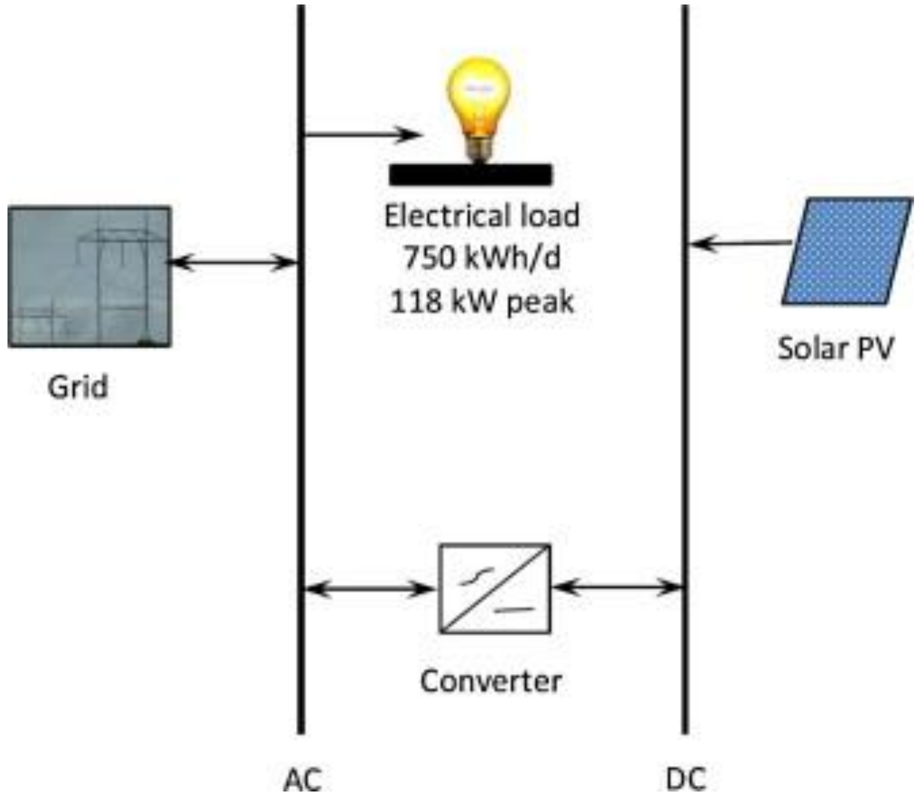



Figure 2.15: Layout of a Grid-Connected PV System (Muyiwa, 2014).

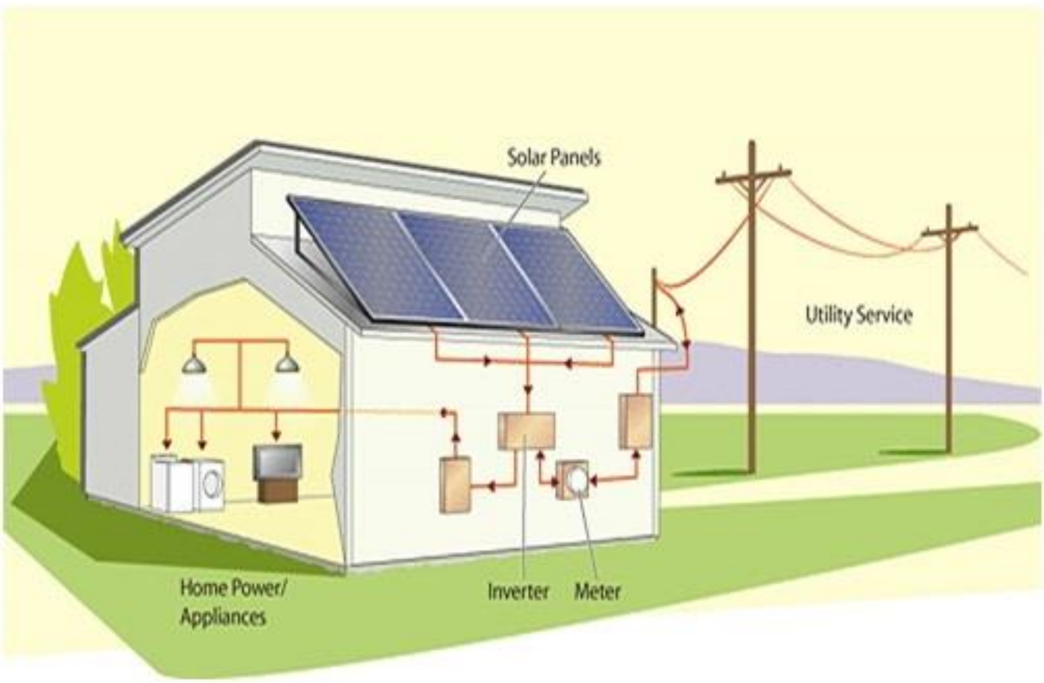



Figure 2.16: Bi-directional Metering System. Part 'meter' in figure shows a metering system for homes with grid-connected solar PV system [URL 2].

#### 2.11.3.2 Small Scale Wind Turbines

Small turbines are purposed to generate small amount of electricity to cover a household-based energy demand. Since the electricity demand pattern varies in buildings, the definition of a small wind turbine based on its characteristics might be different. For example, a 10 kW small turbine is enough to cover energy demand of an American family; a European family needs 4 kW small turbine while only a 1 kW turbine would be cover all energy demand of a Chinese family (AWEA, 2013).

Several definitions for small turbines are offered based on their technical characteristics. The International Electrotechnical Association (IEC) presents the most important definition. The IEC, defines a small wind turbine (SWT) based on International standardization: ‘small turbine is a device equipped a rotor that is able to sweep maximum area of 200 $m^2$, and able to generate 50 kW of power at in maximum voltage of 1,000 V AC or 1,500 V DC’. Additionally, each country defines small turbines technically based on own standards.

Currently, the world is witness for strong growth of utilization small wind turbines. As of the end of 2011, more than 730,000 turbines in small scale have been installed in the world (AWEA, 2013). There is a growth rate of 11% in erection of wind turbines during 2011. China, USA, and UK are three major markets in installation of small wind turbines.

The global capacity of installed small wind turbines in generating electricity reached 576 MW in the end of 2011. Installing 120 MW of new small wind turbines during 2011 caused increasing 27% of global capacity of generating electricity. This amount is a doubling market size in comparison of 2010 with only 64 MW increasing.

Bortolini et al., (2014) presented an economic analyzing of utilizing small wind turbines for countries France, Germany, Italy, Spain, and Netherlands. The main obtained results by mentioned study showed several factors affect small wind turbines profitability. Finally, the results indicated that in France and Germany small wind turbines are not economically feasible. The result was different for Italian case. Due to providing highest amount of feed in tariff in Italy, every small wind turbine is profitable. Despite, the Spain and Netherlands have better NPV comparable to the France and Germany but still installation of small wind turbines is not profitable in Spain and Netherland.

In a case study in Iran, profitability of small wind turbines has been analyzed based on Pay Back Period model. Obtained results by Mostafaeipour (2013) showed that wind turbines are acceptable to install due to cover household electricity demand.

# Chapter 3

# PERFORMANCE EVALUATION FOR NORTHERN CYPRUS

Evaluation performance of different functions in Northern Cyprus helps to identification measurement factors and specifying criteria against what is going to be evaluated and is useful to illustrate observations, achievements and ratings about several functions as well. Evaluation performance for Northern Cyprus will indicate existing reports on performance of different sectors. Additionally, indicates how problems are solved in different constituencies. Equally important, a performance evaluation is needed to explore the existing problems since providing solutions is the main majority of this thesis. It should be highlighted that, promotion of Net Zero Energy Buildings in Northern Cyprus is not possible without a proper overview of current performance.

This chapter evaluates climate condition, performance of construction industry, availability of renewable energy resources, the current situation of energy sector and profitability of renewable energy generation in Northern Cyprus. In the end of performance evaluation it is found out that, production energy in Northern Cyprus is highly cost and power plants might be encounter serious problems in the future. On the other hand, this chapter revealed that on-grid electricity generation by integrated PV panels and wind turbines is more profitable than purchasing electricity from the grid.

## 3.1 The Climate of Northern Cyprus

### 3.1.1 General

According to macro – climate classification, Northern Cyprus is located on`semi-arid zone. ‶Cyprus has an intense Mediterranean climate with the typical seasonal rhythm strongly marked in respect of temperature, rainfall and weather generally. Hot dry summers from mid-May to mid-September and rainy, rather changeable, winters from November to mid-March are separated by short autumn and spring seasons of rapid change in weather conditions″(Northern Cyprus Department of Meteorology, 2012).

‶In summer the island is mainly under the influence of a shallow trough of low pressure extending from the great continental depression centered over southwest Asia. In winter Cyprus is near the track of fairly frequent small depressions which cross the Mediterranean Sea from west to east between the continental anticyclone of Eurasia and the generally low pressure belt of North Africa ″ (Cyprus Department of Meteorology, 2013).

### 3.1.2 Air Temperature

Average annual temperature in Northern Cyprus is 19 degree Centigrade (˚C). In summer, the hottest temperature that is changeable from 37 to 40 degree Centigrade (˚C) can be felt during July. The coldest temperature differs from 9 to 12 degree Centigrade (˚C) during January (Northern Cyprus Department of Meteorology, 2012). Figure 3.1 shows the annual average temperature in different regions of Northern Cyprus.

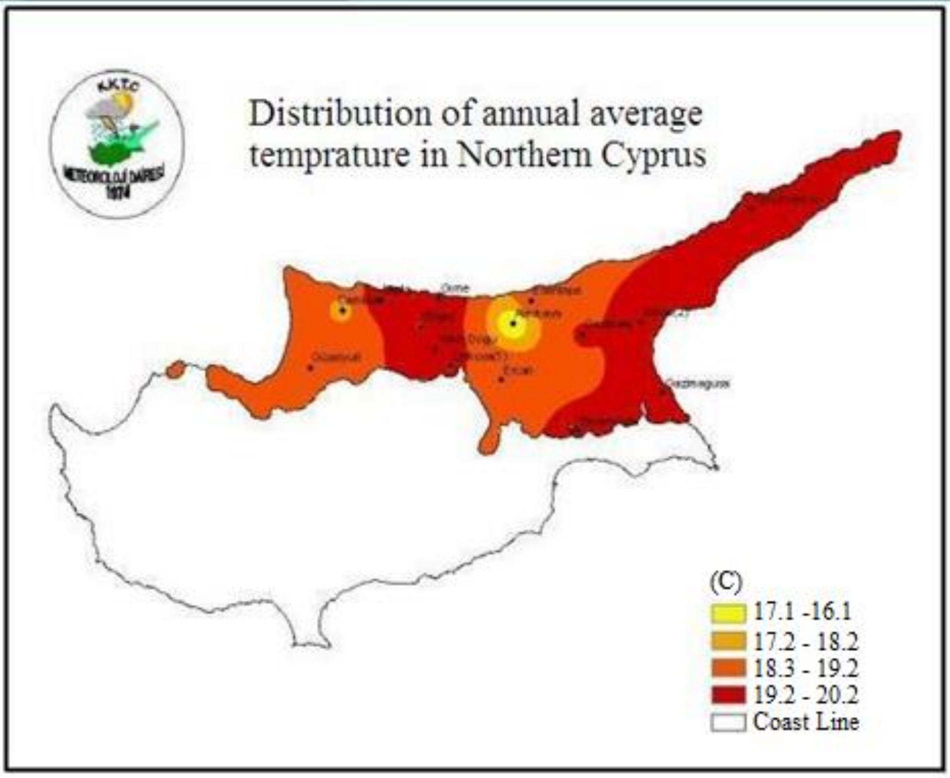



Figure 3.1: Distribution of Annual Average Temperature in Northern Cyprus (Northern Cyprus Department of Meteorology, 2012).

## 3.2 Energy Constituency

### 3.2.1 Electricity Generation and Consumption

At the moment**,** Northern Cyprus is excluded from oil and gas reverses, and mainly oil and petroleum products make up generating power resources in Northern Cyprus. The island of Cyprus has generated electricity since 90 years ago. The first new source of power generation was installed in 1903 by the British colonial government in the Nicosia the capital of Cyprus. In Northern Cyprus, Cyprus Turkish Electricity Authority (KIB-TEK) is almost completely responsible to generate, distribute and sell power to the sectors. Operation and Business Company belonging to KIB-TEK located on 13 km East of Kyrenia has two steam power plants that consume oil as the main fuel and are able to produce 60 MW electricity. The first power plant has been operating since 1 March 1995 and the second one has been producing electricity since

2 March 1996. Both units since commissioned in the first years, used oil fuel with sulfur content (by weight) of 3.5 – 4%. However, recently oil number 6 (no. 6) with actual sulfur content of 2% are used. According to KIB-TEK, in 2007 steam power plants used 191.164 ton of fuel oil. Taking into account of worst emission values, the proper height for each chimney calculated at a height of 85 m. The output of each chimney such as Carbon monoxide (CO), Nitrogen oxides (NOx), Sulfur dioxides ($SO_2$), dust emissions, Oxygen ($O_2$) and gas temperature is consistently monitoring by Siemens Company.

It should be noticed that, KIB-TEK Company is running three obsolete deficient gas turbines additionally. These turbines consume diesel fuel, which is too expensive in Northern Cyprus and are not efficient at low loads at all (Ilkan et al., 2005). The table 3.1 illustrates the power generation sources and their ability in electricity generation at Northern Cyprus.

Table 3.1: Current Power Plants in Northern Cyprus and their Ability in Electricity Generation (Cyprus Turkish Electricity Authority, report 2007).

| **Power Plants** | | **Power Stations** | **Units** |
|---|---|---|---|
| 2x60 MW Steam Turbine | | Teknecik | 120 MW |
| 1x20 MW Gas Turbine | | Teknecik | 20 MW |
| 1x10 MW Gas Turbine | | Teknecik | 10 MW |
| 1x20 MW Gas Turbine | | Teknecik | 20 MW |
| 4 x 17.5 MW Diesel Generator | 1 x 17.5 MW reserve service | Kalecik | 87.5 MW |
| 6 x 17.5 MW Diesel Generator | | Teknecik | 105 MW |
| 1.26 MWp Photovoltaic Plant | | Guzelyurt | 1.26 MW |
| Total Power Generation Capacity | | | 363.76 MW |

In order to provide an overview of electricity generation and electricity consumption in Northern Cyprus this thesis presents electricity generation and consumption statics from 2011 to 2013.

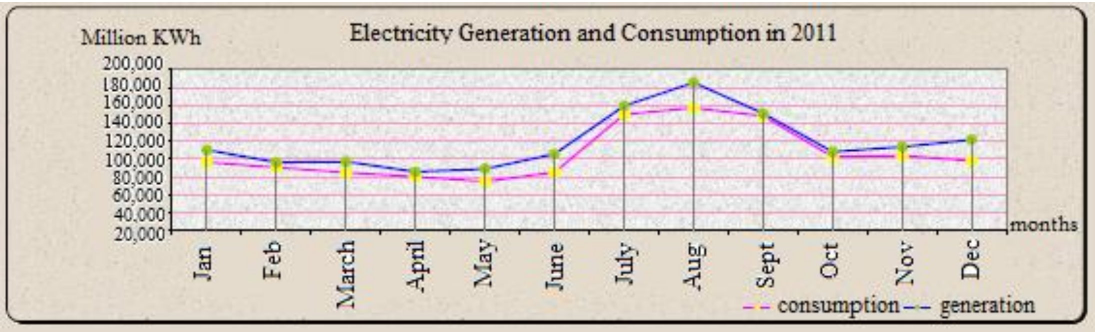



Diagram 3.1: Electricity generation and consumption in Northern Cyprus in 2011 (Cyprus Turkish Electricity Authority, report 2013). Vertical line represents amounts in million KWh.

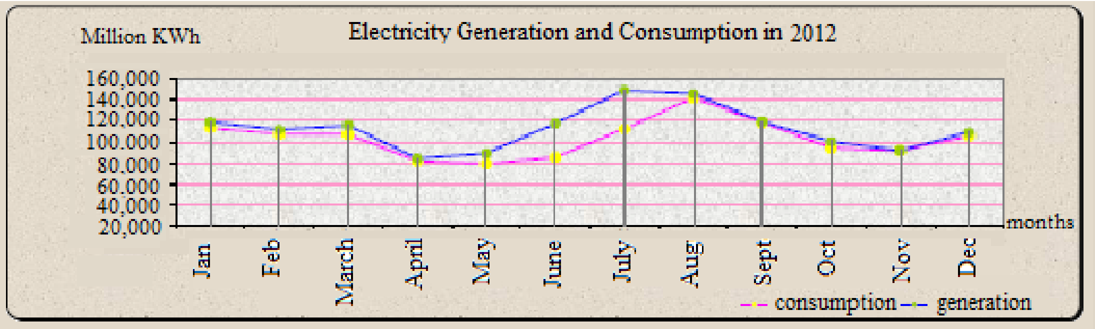



Diagram 3.2: Electricity generation and consumption in Northern Cyprus in 2012 (Cyprus Turkish Electricity Authority, report 2013). Vertical line represents amounts in million KWh.

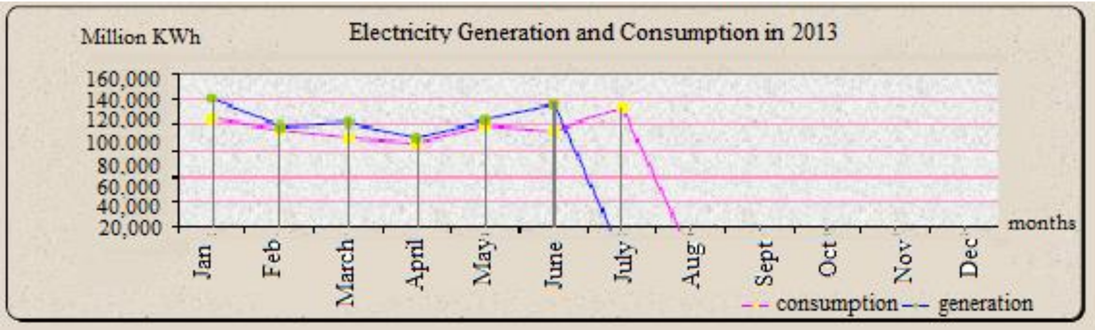


Diagram 3.3: Electricity generation and consumption in Northern Cyprus in 2013 (Cyprus Turkish Electricity Authority, report 2013). Vertical line represents amounts in million KWh.

### 3.2.2 Forecasting Electricity Consumption

Estimating future energy demand is a key to employee strategies to manage future energy consumption. Forecasting electricity demand helps to select related technologies and appropriate plans to meet future energy consumption.

Future energy demand can be determined through different variables and historical energy consumption data. Several parameters such as time, money, access to data, and staff effect on energy demand forecasting. Morales-Acevedo (2014) issued three methods to determine future energy demand. The methods follow:

1. Simple Time Series
2. End – Use method
3. Econometric method

A lot of information is needed in End – use and econometric methods and usually costs for these two methods are high. Time series method calculates the future required energy using historical data. Since this method are simple and results are usually reliable this method has been using more than other methods.

Erdil et al., (2008) provided an estimation of future energy demand in Northern Cyprus until 2020 based on time series method. Erdil et al., (2008) highlighted that, by the year 2015 the capacity of KIB-TEK's power plants will not be able to cover peak demand in Northern Cyprus. Additionally, the authors implied that, increasing capacity or reduction energy use should be planned until 2020. Diagram 3.4 represents the actual electricity consumption and estimated amount of electricity consumption until 2020 in Northern Cyprus.

According to Erdil et al., (2008), 4% reduction in electricity peak demand in Northern Cyprus can be reached if 5% of residential buildings be able to generate electricity through renewable energy resources.

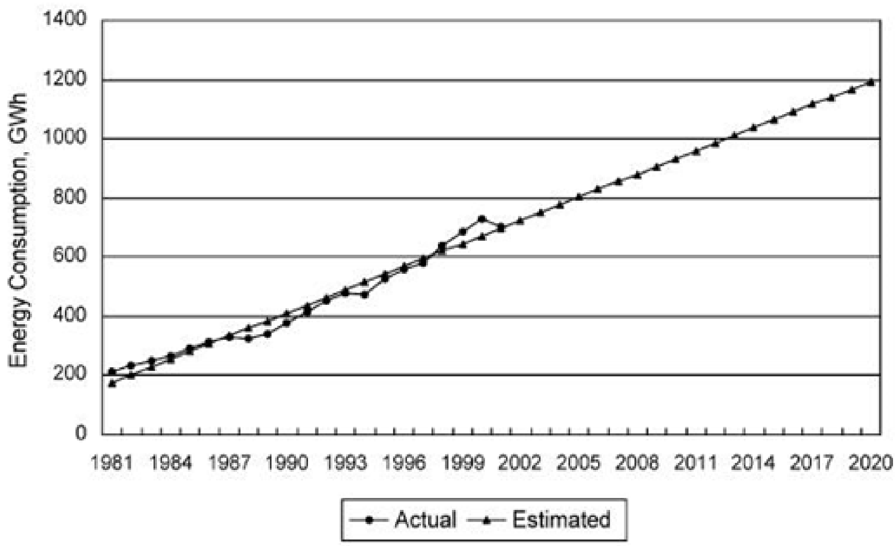



Diagram 3.4: Matching Actual electricity consumption and estimated electricity consumption in Northern Cyprus (Erdil et al., 2008). Vertical line represents energy consumption in Gigawatt hour (GWh).

### 3.2.3 An Overview of Generated Electricity Price

Republic of Cyprus was covering more than 90% of electricity demand of Northern Cyprus between the years 1974 and 1994 (Egelioglu et al., 2001). Among those years, Northern Cyprus had a constant growth rate in electricity price. In 1995, KIB-TEK took first steps to produce 90% of required energy in Northern Cyprus.

In order to cover the electricity production costs, electricity price increased by KIB-TEK from US$0.02/kWh to US$0.062/kWh (Cyprus Turkish Electricity Board, 1995). In 1997, the price of electricity per KWh decreased to US$0.06/kWh by the Government of Northern Cyprus. Diagram 3.5 illustrates the average electricity price rates from 1988 to 1997.

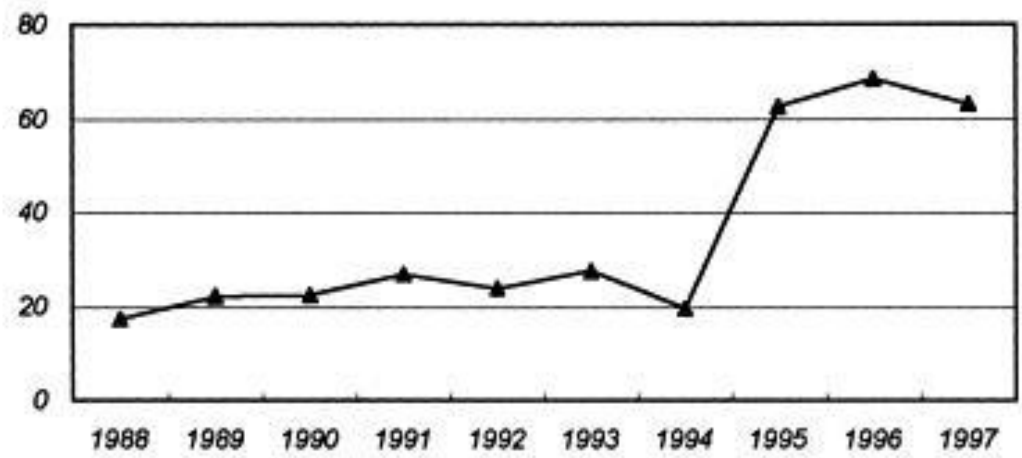



Diagram 3.5: Weighted Average Electricity Rate in Northern Cyprus from 1988 to 1997. Vertical line represents electricity price in US$ per Megawatt hour (Egelioglu et al., 2001).

Recently, the cost of generated electricity at Teknecik power plant in Northern Cyprus is calculated in Northern Cyprus Campus at Middle East Technical University (METTU-NCC) by Pathirana and Mutaroglu (2013). Table 3.2 represents electricity cost by main thermal power plant at Teknecik station.

Table 3.2: Generated Electricity Cost by the Main Thermal Power Plant at Teknecik Station in Northern Cyprus (Pathirana and Mutaroglu, 2013).

| | |
|---|---|
| Cost of produced electricity by grid (with transmission cost) | \$0.22/kWh |
| Cost of produced electricity by grid (without transmission cost) | \$0.18/kWh |
| Transmission cost | \$0.04/kWh |
| Annual fuel cost | \$0.16/kWh |
| externality cost due to reduction of carbon emission ($CO_2$ tax) | \$0.015/kWh |
| The cost of generated electricity by grid (with externality cost) | \$0.195/kWh |

### 3.2.4 Air Quality Protection in Power Plants

As the first choice to manage protection of environment from emissions, KIB-TEK is proposed to use low-sulfur fuels content of 2% sulfur. KIB-TEK is targeted to use 1% sulfur fuel in the future while the cost of gas purification system is too high.

Despite, Republic of Cyprus is a member country of European Union and purification systems can be implemented and operated easily, only the new made power plant is equipped with purification system and there is no filter in the other chimneys. Due to same meteorological conditions, wind direction and wind speed the air pollution in Republic of Cyprus might influence on air quality of Northern Cyprus. In 2003, UNOPS organized air quality project in Northern Cyprus and prepared pollution map. UNOPS indicated that, in high-density residential cities the air quality has been mostly deteriorated by $NO_2$. In the map, high concentration of $SO_2$ is determined in areas that power plants of Republic of Cyprus are located.

KIB-TEK claimed in a report in 2007, there is not any pollution in power plants and surrounding areas that can be a threat for human health. In 1999, KIB-TEK began to add fuel additive to fuel oils. Using additive fuel was effective to reduce emission contributors such as $SO_2$ in power plants. Recent studies show that utilizing fuel additives improves pulverization, helps combustion catalysis, ensures complete combustion, reduces the amount of fly ash and soot production, prevents of Sulfuric acid corrosion, reduces energy costs, and minimizes environmental pollutions.

In order to minimize the side effects of using fuel oils and reduction of emissions in power plants, necessary measurements and several analysis such as analyzing chemical cleaners and testing of central boiler tubes have been tried in KIB-TEK's laboratories and other laboratories in the foreign countries.

### 3.2.5 Availability of solar Energy

Northern Cyprus lies at 34° 33′ - 35° 34′ N and 32° 16′ - 34° 33́ E. Because of geographical location and where Northern Cyprus lies off the latitude, there is plenty of solar energy in Northern Cyprus. On the other hand, Ibrahim and Altunç (2012) highlighted that the solar energy even in winter abounds in Northern Cyprus. Northern Cyprus receives more than 12 sunny hours per day during the summer. Sunny hours reduced to 5 hours per day during winter. During a year average daily receiving amount of solar energy in Northern Cyprus is 427.3 Calorie per square meter ($Cal/cm^2$). The highest daily average receiving solar energy is 622.2 $Cal/cm^2$ during July and the lowest daily average receiving solar energy is around 214.5 $Cal/cm^2$ in December

(Northern Cyprus Department of Meteorology, 2012). Table 3.3 indicates the receiving amount of solar radiation in main cities of Northern Cyprus.

Table 3.3: Receiving Amount of Solar Radiation in Main Cities of Northern Cyprus (Northern Cyprus Department of Meteorology, 2012).

| Receiving Amount | Lefkoşa | Gazimağusa | Girne |
|---|---|---|---|
| Minimum Solar Radiation ($MJ/m^2$) | 9 | 6 | 7.8 |
| Maximum Solar Radiation ($MJ/m^2$) | 29 | 24 | 26 |
| Minimum Solar Intensity ($W/m^2$) | 110 | 70 | 90 |
| Maximum Solar Intensity ($W/m^2$) | 350 | 280 | 320 |

### 3.2.5.1 Profitability of Utilization of PV System

In an assessment study by Pathirana, and Muhtaroglu (2013) that is progressed in the Middle East Technical University in Turkey, the cost of generated electricity by PV system in Northern Cyprus has been determined. In addition, the feasibility of stand-alone PV system and grid-tied PV system has been analyzed for Northern Cyprus.

Results carried out in study by Pathirana and Muhtaroglu (2013) implied that the minimum cost of generated electricity without externality cost by different future off-grid PV technologies is approximately $0.24 per KWh which is 1.3 times higher than grid electricity cost. However, it is estimated that, the final cost of energy generation by stand-alone PV system will be higher than calculated values due to operation and maintenance cost during its life time. Finally, the results highlighted that, the off-grid PV system is not affordable for Northern Cyprus. Table 3.4 shows the electricity generation costs by different off-grid technologies in Northern Cyprus.

Table 3.4: Electricity Generation Costs for Different off-grid PV Technologies in Northern Cyprus (Pathirana and Muhtaroglu 2013).

| PV Technologies | c-Si | mc-Si | Thin film Si |
|---|---|---|---|
| Cost of Electricity Generation ($/kWh) | 0.25 | 0.24 | 0.24 |

Additionally, the profitability of grid-tied PV system in Northern Cyprus has been evaluated in same study. As a result, the final price of generated electricity by grid-tied PV systems in Northern Cyprus is $0.13 - $0.14 kWh. In comparison of current price of grid electricity, produced electricity from grid-connected PV system is less than public grid price. Therefore, Grid – tied PV system is a suitable alternative to against the conventional grid electricity generation in Northern Cyprus. Table 3.5 shows the electricity generation costs by different grid-tied technologies in Northern Cyprus.

Table 3.5: Electricity Generation Costs for Different on-grid PV Technologies in Northern Cyprus (Pathirana and Muhtaroglu 2013).

| PV Technologies | c-Si | mc-Si | Thin film Si |
|---|---|---|---|
| Cost of Electricity Generation ($/kWh) | 0.14 | 0.13 | 0.13 |

### 3.2.6 Availability of Wind Energy

According to Ozerdem and Biricik (2011), Northern Cyprus has potentials to generate electricity from wind energy. According to mentioned study, the estimated wind potential for Northern Cyprus varies from 30 to 60 MW. On the other hand, carried out results of a study which is performed at Near East University in Northern Cyprus by Altunç (2012) highlighted that utilization of wind energy to generate other energy carriers can be a promising alternative for Northern Cyprus.

According to topographic features of region of Northern Cyprus, generally wind blows from different directions. However, the general dominate wind direction is the West (W) direction in Northern Cyprus (Figure 3.2).

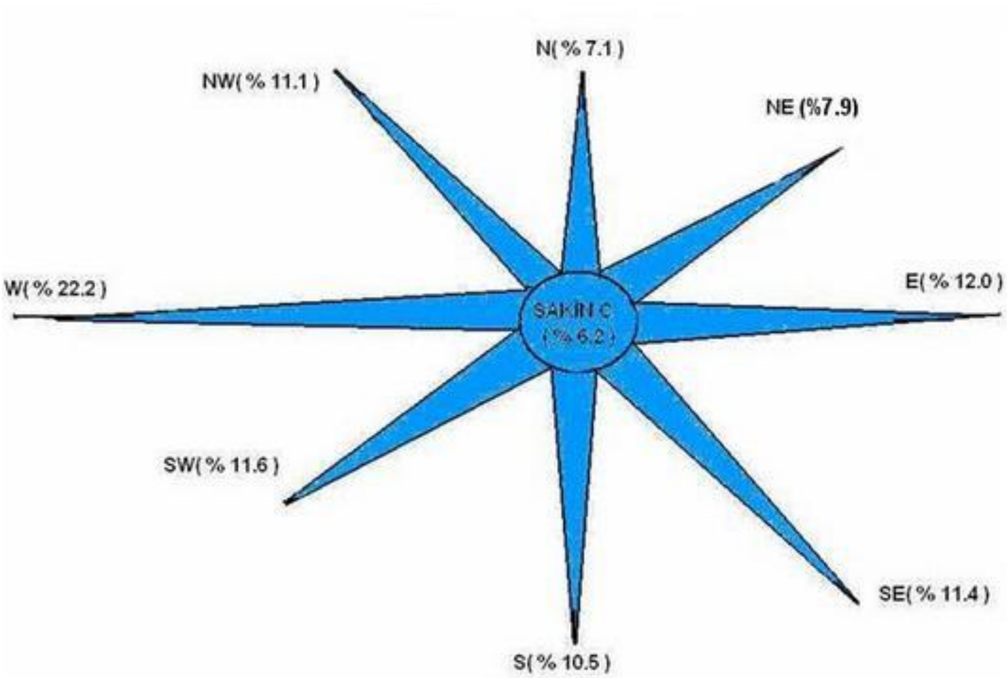



Figure 3.2: Wind Directions in Northern Cyprus (Northern Cyprus Department of Meteorology, 2012).

The average wind speed in Northern Cyprus varies from 2.9 to 3.2 m/s. This amount differs between 5 to 7m/s depending on different regions of Northern Cyprus (Ozerdem and Biricik 2011).

**3.2.6.1 Profitability of Utilization of Small Scale Wind Turbines**

According to press info released by press and Public Relations Directorate of University of Kyrenia, Energy Research Team of University of Kyrenia added new data to findings of research that has been carried out on alternative energy resources that can help to meet the needs of growing energy demand of Northern Cyprus.

According to data obtained from the research, getting energy from wind power is very cost effective investment and the cost of electricity generated by wind energy varies from €0.015 to €0.017 for KWh.

According to land analysis and results of data obtained by research team, the most suitable location to install vertical and horizontal wind turbines are the West and East ends of Pentadactylos Mountains and East end of Carpasia Peninsula and Cape Kormatikis as well. The results showed that deploying wind turbines in these locations will supply a considerable amount of energy to Northern Cyprus for a much cheaper cost (Scientific research team of University of Kyrenia, 2014).

### 3.2.7 Renewable Energy Application and Current Audit Regulation

The Council of Ministers of the Turkish Republic of Northern Cyprus has legislated renewable energy use. Recently, the Council of Ministers has confirmed the appendant part of legislation in 12.02.2014. It should be noticed that, these regulations are currently being implemented by Turkish Republic of Northern Cyprus for year of 2014 and might be changed in coming years. Pursuant to authority that is given to the Council of Ministers, a part of regulations follows:

- *Article '5', paragraph '1'*: Electricity generation from renewable energy resources that is purposed for whatever reason, needs approval of the Ministers responsible for energy affairs.

- *Article '5', paragraph'3', section 'A'*: All subscribers can produce electricity from renewable energy resources to cover own energy demand with permission of responsible Ministries.

- *Article ‘5’, paragraph ‘3’, section ‘B’*: Subscribers who supply the extra-generated electricity to the public grid would not receive any payments for extra-generated electricity from Electric authority of Northern Cyprus.

- *Article ‘7’, paragraph ‘3’*: Permits are issued free of charge delivered to applicants.

- *Article ‘7’, paragraph ‘4’*: permits should be kept by applicants and shall be submitted to inspectors during control process.

- *Article ‘8’, paragraph ‘3’*: Off-grid (stand-alone) systems on its own terms are allowed by Electricity Authority of Northern Cyprus to generate electricity from renewable energy resources.

- *Article ‘11’*: Electricity generation from renewable energy resources in term of amount of generated power are classified in low voltage, medium voltage, and high voltage.

- *Article ‘11’, paragraph ‘1’, section ‘B’*: the amount of power generation for low voltage systems follows: (a) Not more than 5 kW for single-phase residential; (b) Not more than 10 kW for three-phase residential.

- *Article ‘15’, paragraph ‘1’*: All equipment, supply components and imported tools to the country need the approval from responsible authorities.

- *Article '17', paragraph '2', part 'B'*: Extra-generated electricity by subscribers can be supplies to the main grid if all investments are meet by the owners.

### 3.2.8 Profitability of On-grid Electricity Generation in Single Family Homes

Economic evaluation as a critical issue is needed for owners, investors and private sector to be aware of profitability of NZEBs. The aim of economic evolution is to ensure that the benefits from the constructing of a Net Zero Energy Building are greater than the opportunity costs. Hence, this study is aimed to evaluate affordability of on-grid electricity generation in conventional buildings based on Net Zero Energy concept. Since the current legislations in Northern Cyprus do not support the utilization of small wind turbines to generate electricity, only on-grid electricity generation by PV systems has been evaluated based on Life Cycle Cost method.

#### 3.2.8.1 Life Cycle Cost Assessment (LCCA)

Life cycle cost is a cost management method to determine the cost of a project during a specific period of time. This method involves all cost of acquiring, owning, operation and maintenance and disposing of a project. Calculating life cycle cost is easier than other economic measures such as payback period, saving to investment ratio and return rate. Estimated LCC is useful to find out that, does the initial costs of project maximize the saving rate or not. It should be noted that, the initial cost for a project might be a lower amount at the primary stages but the project requires higher operation cost during its useful life cycle. It is estimated that, initial costs of a building just accounts 2% of total cost, cost of operation and maintenance accounts for 6% while personal costs equal 92% of the total cost (Han et al., 2014). LCC assessment of buildings aims to determine the overall costs of a building alternatives to ensures that the ownerships will take benefits by purchasing of a building.

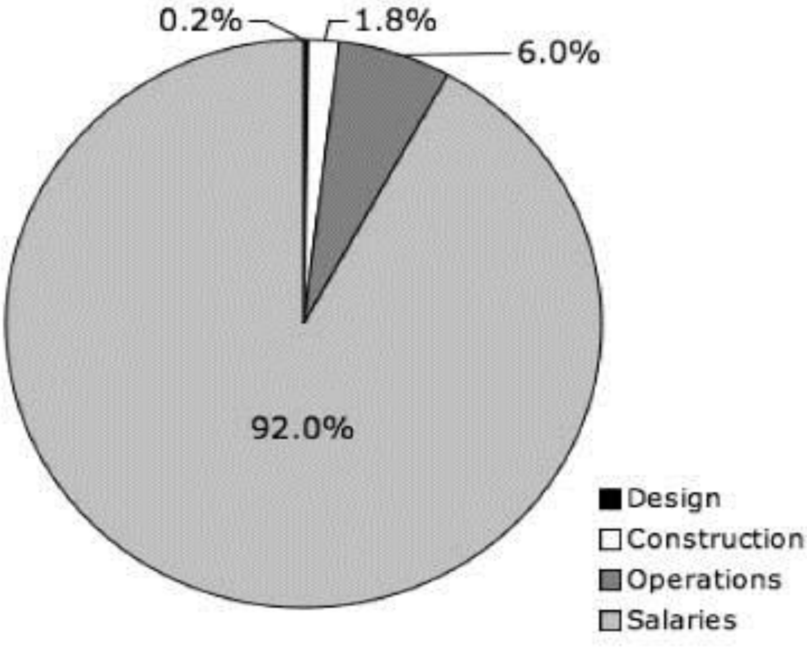



Figure 3.3: Over 30 Years Initial Cost, Operation Cost and Employee Salaries of a Typical Building (Han et al., 2014).

The first step for LCCA is determining a proper life cycle for project. Subsequently, the costs, what the life cycle of project includes should be determined. The life cycle costs can be classified into initial costs, constructing costs and operation costs. Initial costs are the costs that should be invested at the beginning of the project. Land acquisition costs, primary studies cost, data collection costs, demolition costs and licenses and permits cost all are in this category. Construction costs are the costs that are imposed during construction of the project. Construction costs includes costs of design, materials preparation, labor costs, and machinery costs. Operation costs such as maintenance costs, replacement costs, and cost of energy are the costs that occurred during operating phase of project.

The estimation of life cycle cost is a highly technical and professional discipline. It is difficult to estimate the exact cost of a construction. An appropriate estimation should be able to consider the whole project to have a proper judgment about technical aspects and related costs. Providing a good estimation needs training, enough experience, and enough time to be aware about the project details. Considering all project details and aspects is not possible since it needs several researches and studies. Hence, this thesis used cost information of existing buildings.

With determining the life cycle costs of each variable and calculating the benefits, it turns to economic evaluation. May be at first it seems that, costs and benefits can be gathered with positive and negative amounts and make total life cycle cost but doing such a process is economically impossible.

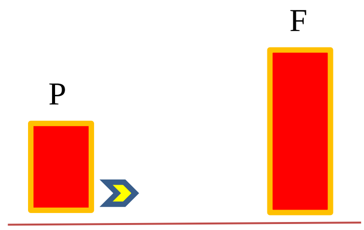
As regards, the value of money is changing over time, present values cannot be gathered mathematically with future values that will be imposed to the project. Therefore, the costs and benefits should be adjusted into specific time to be compared. Discount Factors make it possible to adjust values into specific time. LCCA methods follow (Badea et al., 2014):

1. Present Worth Method (PWM)
2. Annual Cost Method
3. Benefit-Cost Ratio Method
4. Internal Rate of Return (IRR)

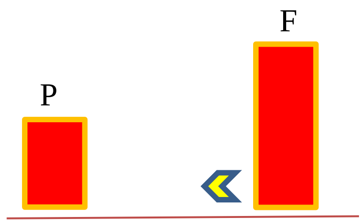
In the first method, all costs and benefits will be adjusted to the present value then lifecycle costs can be calculated. Lower present value shows better economic alternative. In second method, the average annual life cycle costs are calculated. Third method evaluates the ratio of costs to benefits. In IRR method, the interest rate of project is calculated and will be compared with other interest rates. An affordable project should offer same or higher IRR than other interest rates. This study is presented based on IRR method. All these methods have same results but the processes are different.

Following discount rates are needed to adjust economic variables to present or future values:

1- $F = P\,(1+i\,)^{n}$




2- $P = F\,(1+i\,)^{-n}$




Where in these equations,

'F' is the future value

'P' is the present value

'$i$' is an interest rate (or might be inflation rate)

'n' is the number of years

### 3.2.8.2 Reference Case Building

In order to evaluate profitability of on-grid electricity generation in Northern Cyprus, a single family home has been chosen as reference building (Figure 3.4). The categorization of reference building has been illustrated in table 3.6.

Figure 3.4: Southwest View of Reference Case Building.

Table 3.6: Categorization of Reference Case Building.

| | |
|---|---|
| Project location | Akgöl zone, Gazimağusa, Northern Cyprus |
| Building type | Three-bedroom detached single family home |
| Useful are | 170m$^2$ |
| Occupancy | Occupied by 4 persons |
| Annual average electricity bill | $2,400 |
| Construction type | Structural concrete and masonry without insulation |
| Windows type | Double glazed |
| Heating and cooling type | Mostly electrically heated and cooled with addition fire place for heating |
| Efficient systems | An out of work solar hot water system |
| Passive design approaches | Semi-orientated |
| Undesirable impacts | High rise neighbor building can effect on efficiency of PV panels by inappropriate shading. Improper landscaping might increase heating load during winter. |

The selected case building is followed in Northern Cyprus as a conventional home with a typical structure. Although in case building it has been tried to maximize heat gain by south facing approaches but already it cannot considered as the best alternative in term of orientation. On the other hand, the effectiveness of neighbor apartment and inappropriate landscaping on undesirable shading, increasing heat load in winter and decreasing efficiency of PV system cannot be neglected. For case building non-insulated walls and roofs contribute on increasing heat demand as well. According to personal conversation by the owner, annual average electricity bills accounts to $2,400 for owner.

According to personal conversation by Cyprus Solar Ltd. which is pioneer in installing different types of PV systems, the initial cost of an integrated on-grid PV system for such a reference building that is able to meet footprint of home and cover undesirable conditions such as inappropriate shading accounts to $10,000. It should be noticed that, the price for PV systems can vary in a wide range depending on quality and other properties but the obtained initial cost from Cyprus Solar Ltd. refers to relatively the best existing PV system in Northern Cyprus. According to additional calculation by Cyprus Solar Ltd. about determining proper size of PV system, it is carried out that a 5 KW on-grid PV system would be able to cover energy demand of reference building. Additionally, Cyprus Solar Ltd. highlighted that $100 (1% of initial cost) should be considered as annual operation and maintenance cost for PV system.

#### 3.2.8.3 Life Cycle Cost Assessment Outcomes

In order to perform Life Cycle Cost Assessment, all obtained data including initial costs, operation and maintenance costs and electricity saving have been inserted on Microsoft Excel (version 2013). Carried out results follow:

##### 3.2.8.3.1 Net Present Value (NPV)

Net Present Value (NPV) is the most important result that can be carried out by assessment of life cycle cost. NPV is one of the best method that is helpful to determine the profitability of an investment. NPV represents the discounted amount of costs minus discounted amount of profits that are discounted by a specific rate of return to present value. Overall, positive NPV indicates that the rate of return on investment is higher than expected rate of return. Projects with higher NPV would be desirable.

As results carried out, the amount of NPV highlighted the profitability of on-grid generating electricity by roof top solar PV system applied in reference building. According to results, when electricity is growing with an escalation rate of 10% (equal with inflation rate in Northern Cyprus) the NPV of renewable electricity supply systems accounts to approximately $59,000 during 25 years. It simply means that, an owner by installation such a system in a period of 25 years can take $59,000 more benefit than depositing money on the bank accordance to current interest rate which is offered by banks. Results ensure consumers about profitability of generating on-grid electricity in Northern Cyprus. Additionally, Diagram 3.6 represents the total saving amount for each year of life cycle.

Increasing in electricity escalation rate effects on NPV. It seems that growth in electricity price in Northern Cyprus follows an ascending rate since according to reports released by KIB-TEK, Northern Cyprus experienced an electricity escalation rate of 18-30% during 2013 to 2014 (KKTO, 2013). Hence, in another economic assessment by this thesis, carried out results revealed that with constant inflation rate NPV would be increased to $127,000 only by increasing 5% in escalation rate of electricity when electricity growth rate accounts for 15% instead of 10%. Diagram 3.7 indicates the total saving amount when electricity escalation rate accounts to 15%. This diagram represents the total saving amount each year of life cycle as well.

Total saving amount for each year can be obtained subtracting operation and maintenance cost for specified year from electricity saving amount of the sane year. The determined amount is representing the total saving amount for specified year. As diagrams 3.6 and 3.7 represents the total saving amount by assumptive PV system in reference building is increasing by passing years. It means that solar PV electricity generation would be able to save during entire of life cycle.

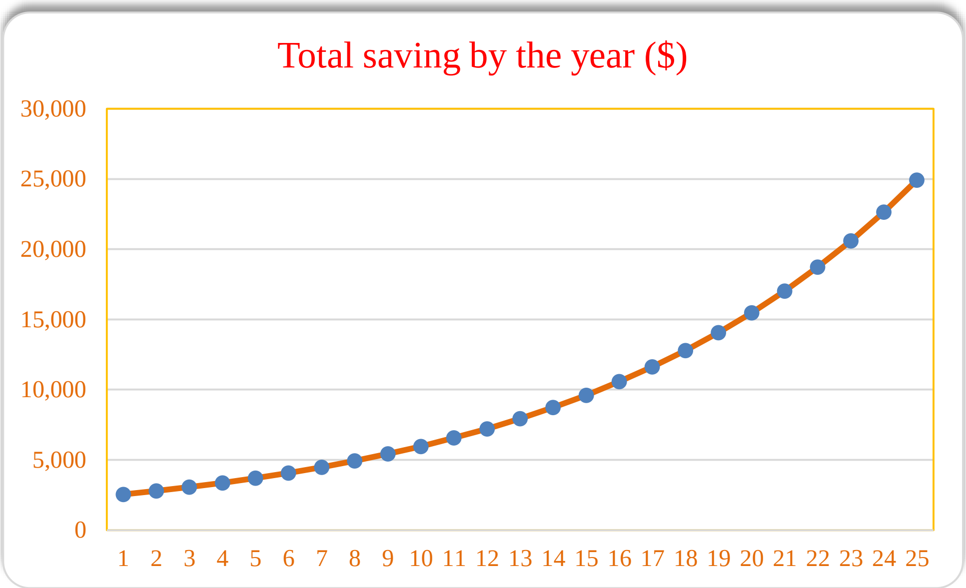



Diagram 3.6: Showing Total Saving Amount by the Year by Assumptive on-grid PV Electricity Generation System at Reference Building in Northern Cyprus when Electricity Growth rate is 10%. Abscissa line represents life cycle years and vertical lines represents net present values in US$.

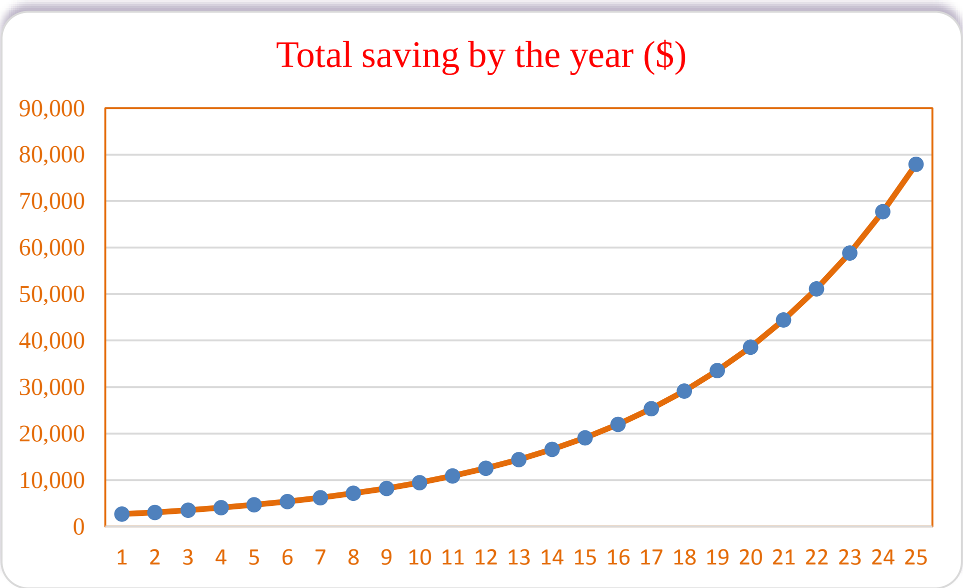



Diagram 3.7: Showing Total Saving Amount by the Year by Assumptive on-grid PV Electricity Generation System at Reference Building in Northern Cyprus when Electricity Growth rate is 15%. Abscissa line represents life cycle years and vertical lines represents net present values in US$

#### 3.2.8.3.2 Internal Rate of Return

In order to compare projects with different initial costs, Net Present Value method is not suitable since investment difference is not took into account. In such a situation, it is better to compare projects based on IRR method. In this method, the project with higher IRR would be accepted.

In order to evaluate the feasibility of IRR, a financial indicator known as Minimum Attractive Rate of Return (MARR) should be offered by evaluator of feasibility. MARR should be determined in a way that investment on risky project can be compared with risk-free investments. Interest rate that is offered by banks can be a logical amount for MARR.

In end of Life Cycle Cost Assessment, calculated IRR for a reference building in Northern Cyprus with an average electricity escalation rate of 10% carried out as 35%, while the current interest rate in Northern Cyprus that is offered by banks is 8.5%. In the other assessment the IRR calculated with an electricity escalation rate of 15%. In this case, IRR offers 42% for reference building. Higher IRR implies on-grid electricity generation in Northern Cyprus is more profitable than deposits in bank or investing on projects with different initial costs and with lower interest rates.

## 3.3 Construction Industry in Northern Cyprus

In many developing countries, the construction industry interfaces with several problems. Reported problems and weaknesses illustrate, construction industry in developing countries are substantially deficient (Yapicioglu and Lawlor-Wright, 2014). This industry in Northern Cyprus is in developing stages and encounters with several problems like construction industry in other developing countries.

A boom in construction industry occurred after promotion of Annan Plan by the UN in 2004. Increasing expectations to solve Cyprus problem and the hypothetical abundance of liquidity in the world caused this industry to play an important role in the economics of TRNC (AfsharGhotli and Rezaei, 2013). Although, negative aspects of occurred promotion in construction industry in Northern Cyprus cannot be neglected.

New construction companies emerged during 2004 to 2010 in Northern Cyprus. These new companies, started to take benefits of the boom and delivered inappropriate construction services due to lack of appropriate regulations. Additionally, internal problems including high production costs, lack of international workshops, lack of internationally certified construction firms, weak institutional and financial supports, low level of Value Management (VM) awareness among related authorities and private sectors and absence of country physical plan are a part of extra problems in construction industry of Northern Cyprus (AfsharGhotli and Rezaei, 2013). Hence, a common perception of construction industry in Northern Cyprus is an industry, which delivers improper products and is not successful being attractive for clients due to high costs.

During 2002 to 2007 because of positive effects of solutions for Cyprus problem, Northern Cyprus could achieve very high economic growth rates. Therefore, construction sector could influence on economic of Northern Cyprus via foreign demands. A number of researchers such as Şafakli (2011) highlighted the major effect of construction industry in Northern Cyprus.

Turkish Contractors Association noted that, the numbers of contractors are increased from 171 in 2003 to 378 in 2008. Şafakli (2011) indicated that out of total construction projects, residential construction had 68.4% share in 2007 and 71.1% in 2008. Likewise, total construction value allocated to building was increased from 71.5% in 2007 to 83.2% in 2008 (Şafakli, 2011). Considerably, the growth constant of the construction sector affected by foreign demand from 2006 and reached to -8.0 % in 2008 (AfsharGhotli and Rezaei, 2013).

‶The aforementioned characteristics of building construction industry of North Cyprus are clear enough to prove the critical condition of this sector. The improper building construction growth, economic fluctuations, instability in supply and demand of the construction sector, amount of generated waste (out of building construction, maintenance and demolition phases), and isolated economy are sufficient reasons to reevaluating this sector″ (AfsharGhotli and Rezaei, 2013). However in this process, it should be considered that the building construction of North Cyprus "does not have any proactive strategy shaped by relevant vision, mission and objectives" (Şafakli, 2011).

## 3.4 Architecture and Prospect of Developing NZE Buildings

Architecture of Northern Cyprus encountered a significant stagnation in 1974 by occurred war. Architecture, experienced uncertainty until 1990. During the early 1990s, architecture in Northern Cyprus was affected by several factors. Development in Turkey influenced architecture trend in Northern Cyprus. Turkish architects and developers introduced the 'late arrived post-modernism' that was emerged in Turkey during 1980s, to Northern Cyprus (Kiessel et al., 2011). In 2001, United Nations began to put forward Cyprus problem. After peace-plan that was initiated by the former UN-

General Secretary Kofi Annan in 2003, a magnificent vitality emerged in construction industry. Occurring boom strengthened the tendency of post-modernism in architecture process as well.

In Northern Cyprus, the emerged post-modernism covered residential, commercial, and recreational buildings. Residential architecture after 1990s, mostly affected by new classism design (Kiessel et al., 2011). Today, contemporary architecture of Northern Cyprus represents a strong tendency of a Post-Modern, Western classicism. Constructing modern and even post-modern buildings highlights that architecture of Northern Cyprus follows new concepts. One the other hand, local post-modernism in Northern Cyprus, first of all related to residential buildings. Hence, residential buildings are key option to develop architecture. Therefore, it is expected that, NZE homes would be accepted architecturally in Northern Cyprus.

NZE homes are equipped with technologies such as PV array, wind turbine, and shading devices that restrict designers and architects who care about esthetic aspect of buildings. However, whole building integrating options, using solar louvers instead of typical solar panels, implementation photovoltaic ventilated facades, use of solar roof tiles, integrated micro wind turbines, and installing automatic shading devices are strategies to preserve esthetic observe of buildings.

Providing sufficient land and proper landscape options are important issues that developing Net Zero Energy homes might encounter in the future. It seems that, during past years tendency to vertical construction in high population cities such as Lefkoşa, Girne, and Gazimağusa has been increased. Notwithstanding, single family homes and residential villas are currently being constructed around high population cites but the growing trend of constructing residential apartments might influence on developing single family homes in high population cities. Despite, constructing Net Zero Energy apartments are feasible but encounter serious problems such as lack of sufficient roof area to install PV arrays to cover energy demand of all occupants, difficult to use building envelope for renewable energy resources, and different footprints by different occupants makes it difficult to reach the concept of energy consumption balance.

Identity of architecture is another issue that might be affected by developing Net Zero Energy homes. Undoubtedly, developing Net Zero Energy homes influences on identity of architecture in Northern Cyprus but it is difficult to say absolutely has good or bad effects on architecture identity. However, it is possible to consider effects of developing Net Zero Energy homes. In order to clarify the issue, it is needed having a look to existing architecture identity and its developments among past years.

After constructing boom in 2003, 'rapid growth' and 'unplanned development' issues arose since country impromptu prepared to these issues. In addition of urban sprawl, several environment problems occurred. Deficiencies in planning, improper practices, lack of inspection strategies, permits for construction in green areas, and unprepared possibilities given by the existing legal order caused concretization damage to the ecological structure. For example, natural beauty around areas such as Çatalköy, Bellapais, Ozanköy, Karmi, and Lapta has been damaged. Consequently, in the current urban/residential areas, local/traditional textures are damaged, socio – cultural, historical, and natural values disappeared while traditional urban identity is lost.

On the other hand, rapidly growth in construction industry caused, architecture in northern Cyprus ignores the social, environmental, and climate conditions in designing process. Presently in Northern Cyprus, the important architecture principles such as diversity, integrity, and readability are neglected. Settlement areas are filled with almost uniform architectural examples. This uniformity can be observed in interior design of residential buildings as well. The newly constructed residential sites are mostly based on the design of a single building or are a copy of a design that is previously executed in somewhere else.

In Northern Cyprus, foreigners have a great role in urbanization process. A substantial part of constructed buildings is sold to foreigner buyers including British and Northern Europeans. Hence, residential buildings are built for commercial targets and construction industry is based on 'build more' logic. Designers are not looking for spatial quality and outdoor aesthetic issues. Neglected outdoor aesthetic concept by designers created automobile roads, which are devoid of spatial and social quality take place in traditional settlement areas. Additionally, traffic density and inability of the roads are the other problems caused by rapid growth construction.

Regarding existing architecture identity, NZE homes might be effective to improve identity of Northern Cyprus. Developing NZE homes offers a new identity. Perhaps it would be possible to introduce Northern Cyprus as an island for NZE homes. Achieving NZE homes can be seen as a herald of new architecture style.

Nowadays, the speed of change in architecture world is increasing. Every day there is a possibility of the emergence of various architecture styles. Time is always passing and successful people are those who understand the architectural needs and are aware about their community. Architecture always has accompanied the time and this is only the time that makes or changes cultures and traditions. Perhaps architecture is based on traditions but it does not belong to traditions. It should be realized that, the architecture of Northern Cyprus, which has been mainly formed since 1990s, is not derived from culture and traditions of Turkish Cypriots; and is only a construction process that is introduced by other countries or other nationalities. Heady constructions prevented that, the architecture in Northern Cyprus move through an evolutionary process. At the present, architecture of Northern Cyprus is in need of identification to return the forgotten concept of architecture to this country. Now, accepting the fact that, Northern Cyprus is in need of developing Net Zero Energy homes to sustain its future life, not only would be effective to cover energy demand but also may change the future architecture of this country.

## 3.5 An Overview of Existing Strengths and Weaknesses

Existing strengths and weaknesses in different constituencies have been highlighted by performance evaluation for Northern Cyprus. In order to provide a good framework, it is necessary to evaluate strengths and weaknesses in a parallel process then strategies can be suggested to overcome weaknesses by existing opportunities. However, this study focused on existing opportunities in renewable energy constituency in Northern Cyprus which can be utilized as energy alternatives in approaching Net Zero Energy Buildings. This section summarized strengths and weaknesses which have been revealed previously in following thesis (Table 3.7).

Table 3.7: Summary of Existing Strengths and Weaknesses in different constituencies at Northern Cyprus.

| Energy Generation | |
|---|---|
| Strengths | Weaknesses |
| • Producing 2 GWh of electricity annually by the largest PV power plant in East Mediterranean area at Serhatköy site in the Turkish Republic of Northern Cyprus (Maltini and Minder, 2015).<br><br>• Transmission of cable electricity from Turkey might be effective to cover electricity demand.<br><br>• Receiving grant by the Council of the European Union to support the Turkish-Cypriot Community.<br><br>• Willingness of Turkish Cypriots to support government policy in utilization of PV panels.<br><br>• Appropriate air quality management in power plants | • Dependency on fossil fuel imports<br><br>• Rising energy price<br><br>• Utilizing of obsolete power plants<br><br>• Non-competitive energy generation<br><br>• Improper common energy polices<br><br>• Lack of an integrated energy market<br><br>• Lack of technology productivity<br><br>• Improper energy supply security<br><br>• Inappropriate electricity network<br><br>• Inability to meet electricity peak demand by electricity authority<br><br>• Insufficient energy awareness<br><br>• Insufficient number of funds aiming at support investments on renewable energy resources<br><br>• Lack of encouraging programs to renewable energy utilization<br><br>• Insufficient financial incentives in the promotion of renewable energy sources |

Table 3.7: Summary of Existing Strengths and Weaknesses in different constituencies at Northern Cyprus (Continue).

| **Renewable Energy Resources** | | |
|---|---|---|
| | Strengths | Weaknesses |
| Solar | • Plenty of solar energy<br>• Maturity of technologies to utilize solar energy<br>• Affordability of electricity generation by on-grid PV system | • Insufficient polices and legislations to support on-grid electricity generation by means of PV panels<br>• Lack of productivities related with solar technologies<br>• High initial cost<br>• The price of generated electricity by off-grid system is higher than grid electricity price |
| Wind | • Abundance of wind energy to generate electricity and other energy carriers<br>• The price of generated electricity by small scale wind turbines is less than the price of grid electricity | • Existing policies do not support utilization of small scale wind turbines<br>• High initial cost<br>• Insufficient knowledge to install and maintenance required technologies<br>• Lack of consciousness by people in utilization of wind energy<br>• Lack of productivities related with wind energy technologies |
| Geothermal | • Might be available is some regions | • Lack of required technologies<br>• Unproven alternative for Northern Cyprus<br>• Insufficient evidences on utilization of geothermal energy in Northern Cyprus |

Table 3.7: Summary of Existing Strengths and Weaknesses in different constituencies at Northern Cyprus (Continue).

| **Renewable Energy Resources** | | |
|---|---|---|
| | Strengths | Weaknesses |
| Biomass | • Biodegradable waste is available | • Insufficient data about estimated biogas production<br>• Lack of investments to promote use of biomass energy<br>• Lack of required technologies<br>• Lack of consciousness about biomass energy<br>• Unproven alternative for Northern Cyprus |

| **Construction Industry** | |
|---|---|
| Strengths | Weaknesses |
| • Influence on economic growth rate via foreign demand<br>• Tendency to construct and design new concepts | • Substantially deficient industry<br>• Inappropriate construction services<br>• Lack of appropriate regulations<br>• High production costs<br>• Lack of international workshops<br>• Lack of internationally certified construction firms<br>• Weak institutional and financial supports<br>• Low level of value management<br>• Lack of proactive strategy shaped by relevant vision, mission and objectives<br>• Instability in supply and demand of constructions |

# Chapter 4

# STRATEGIES TO ACHIEVE NET ZERO ENERGY HOMES IN NORTHERN CYPRUS

Achieving Net Zero Energy Buildings requires a number of challenges. A part of challenges refers to optimizing energy efficiency in buildings. In the other word, achieving an efficient building is a primer strategy to path toward Net Zero Energy Buildings. Subsequently, strategies to generating energy carries from renewable energy resources should be considered.

In order to fulfill a partial of results of study, this thesis is purposed to present roadmap to achieve NZE homes in Northern Cyprus. Evaluating of existing strengths and weaknesses in Northern Cyprus to develop NZE homes and provide guidelines are the main concept of this chapter. The topic includes framework of the best practices for design, construction, efficient technologies, energy supply systems, educational mechanism, and financial policies that are needed to achieve NZE homes in Northern Cyprus.

## 4.1 Design Approaches

Achieving new Net Zero Energy single family homes requires design approaches. **Integrated design** approaches provide opportunities for designers, builders and even consumers to jointly achieve Net Zero Energy goals and features. In integrated design approach, a number of disciplines and strategies get involved from the beginning and allows explore to how goals of a Net Zero Energy home can be achieved. In contrasting of traditional design process, integrated design makes it possible to achieve an ultimate aim by designing and constructing a building. In traditional design process, designers offer limited options based on consumers or owners objectives, while integrated design approach is based on an up-front process and there are a large broad engagement. Diagram 4.1 represents a linear process for traditional construction paradigm while diagram 4.2 illustrates an integrated design process.

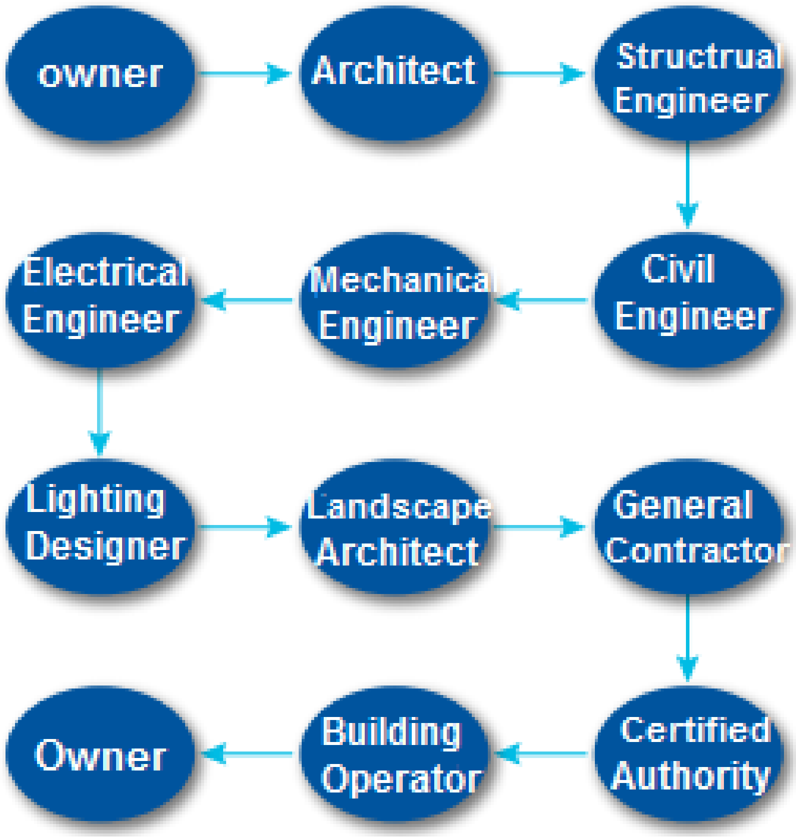



Diagram 4.1: Traditional Design Construction Process (DeGuire, 2011).


Diagram 4.2: Integrated Design Approach (DeGuire, 2011).

In northern Cyprus, residential buildings including apartments and single family homes mostly are designed and constructed based on traditional methods. Traditional design practices not only contribute in increasing energy demand but also make undesirable esthetic problems. There are buildings in Northern Cyprus which inappropriate design approaches in utilization of technical services such as solar water heating devices and PV panels caused improper views in those buildings (Figure 4.1). Therefore, integrated approaches not only is useful to optimizing energy efficiency and doing economically but also offers opportunity for designers to integrate PV system, small wind turbines and other efficient devices with whole building in Net Zero Energy homes.

Figure 4.1: Undesirable View in Residential Apartments by Inappropriate Design Approaches, Gazimağusa, North Cyprus.

There is no doubt that passive design strategies play an important role in reduction energy demand in buildings. Building design and choice of location might be effective to reduce heating load in winter and optimizing cooling load during summer. A study by Jaber and Ajib (2011) demonstrated that applying **passive design** strategies in residential buildings which are located in Mediterranean region can be dramatically effective to reducing buildings' energy load. For instance, Nazif and Altan (2013) highlighted that use of passive cooling techniques can minimizes cooling loads in Cyprus.

Net Zero Energy homes should be designed depending on climate conditions. Hence, all designing process should be based on microclimate conditions. Additionally, designing should be focused on largely use of passive design methods to gain maximum benefits of alternative energy resources and reduce energy consumption as much as it is possible. The site, where NZE home will be placed, should be suitable for efficient landscaping, natural day lighting, smart irrigation, and gray-water systems

The information to design Net Zero Energy Buildings is available, but it needs to be gathered since information is dispersed and are from different sources. The gathered **information should be evaluated** and organized to make it more clear, accessible, and useful. Regulations and local rules should be studied in this stage. Existing incentives and other supporting systems should be specified as well. Feasible and possible options to reduce energy consumption should be identified.

It is offered, **using a proper design tool** that is accepted by construction community to promote transparent communication. An appropriate tool evaluates all design aspects such as orientation, energy supply options, determines proper size of mechanical equipment, considers construction methods, and selects proper materials to meet the customer expectations. Computer modeling, building information modeling, and easy visualization are software tools that help having a more accurate building design process. Additionally, this study suggests a pre-design stage for in Northern Cyprus. Pre-design and design make a feedback loop and improves design process. Pre-design method may be useful to overcome the problems caused by lack of inspection during construction process in Northern Cyprus. Equally important to these strategies, integrated design method is a key option to approach NZE homes.

## 4.2 Construction Features

Today, impact of construction features on energy performance of buildings has been proved. There are protocols such as ITACA that emphasize on sustainable construction in building sector. Use of high efficiency materials and bio-climatic construction might be effective options in optimizing energy efficiency in buildings. All the phase of buildings' life cycle (Construction, fir-out, operation and demolition) have a significant impact on human life and environment. It becomes more important when construction is considered for Net Zero Energy Buildings. A proper construction is required for Net Zero Energy Buildings to optimize performance of building through use of sustainable materials, reduction of energy consumption, control consequent pollution and waste, and considering efficient infrastructure (Baglivo et al., 2014).

It seems in Northern Cyprus, functional and constructing features of the building are mainly based on the repetition of a simple, modular, residential unit, whose structure based on widespread use of concrete. In Northern Cyprus, a substantial share of energy goes to heating and cooling in buildings due to insufficient use of insulation. It should be underlined, achieving Net Zero Energy homes in Northern Cyprus is in need of appropriate construction strategies.

In order to approach Net Zero Energy homes in Northern Cyprus, this thesis indicates a part of construction strategies which consider appropriate constructing solutions to achieve Net Zero Energy Buildings in Mediterranean climate conditions. These strategies are related with building components and cost effective design solutions. It should be highlighted that, these strategies are only a part of possible strategies while other strategies might be on research stages.

### 4.2.1 Building Envelope

As historic architecture and international studies demonstrated, because of hot – summer in Mediterranean areas, appropriate level of indoor quality and optimizing energy efficiency can be reached only through massive techniques that adapt their behavior with a deep relation with external climate rather that the adoption of solutions that behave as thermal barriers (Di Perna et al., 2011).

In a study by Stazi et al, (2014) 3 buildings with low energy envelops which are adopted in Mediterranean area have been evaluated. Envelops include masonry with external insulation layer, wood–cement hollow block with insulation in the cavity, wood with external insulation layer. Envelopes applied to 3 multi-family low energy residential buildings which are located in Ancona, in the Marche Region. According reports by mentioned study, masonry (hollow clay brick and brick floor slab for envelope and concrete and reinforced concrete for structure*)* and wood-comment envelope (wood–cement blocks) have major impacts on optimizing energy efficiency. The results demonstrated that, **massive solutions** for envelope are preferable than lightweight one.

It should be noticed that in Mediterranean climate where summer covers the major period the occupants 'comfort is more important than environmental issues. Therefore, is such a Mediterranean climate the **thick insulations** should be combined with high **internal masses** (masonry) capable to dynamically interact with the internal environment (Stazi et al, 2014).

Additionally, the experimental study results carried out for evaluation of Zero Energy Buildings for Cyprus by Nazif and Altan (2013). The study analyzed thermal performance of three different Cypriot houses with different thermal mass properties. The houses have been selected according to different structural characteristics including Adobe (Figure 4.2), Stone (Figure 4.3) and concrete (Figure 4.4). After monitoring the thermal data, the study demonstrated that in Stone Cypriot house correlation of temperature rise is significant at night and in afternoon while in Adobe house correlation rise is at night, midday and in afternoon. For concrete house coloration rise is at night, in morning and in afternoon. Evaluation indicated that, Stone structure performed better that Adobe and Concrete structure in term of thermal performance. It should be underlined that, the Concrete structure had the worst thermal performance in contrasting of two other structures. Eventually, the carried out results revealed that high thermal mass structures perform better than other structures in Cyprus. Therefore, **use if thermal mass was** suggested to minimize indoor temperature fluctuations.

As it is clear use of thermal mass and massive envelope structures can be effective strategies in approaching efficient buildings such as Net Zero Energy homes in Northern Cyprus because of same climate conditions with evaluated case studies.


Figure 4.2: Selected Adobe House in Study by Nazif and Altan (2013).


Figure 4.3: Selected Stone House in Study by Nazif and Altan (2013).


Figure 4.4:  Selected Concrete House in Study by Nazif and Altan (2013).

### 4.2.2 External Walls

Results carried out in a study by Baglivo et al., (2014) to identify efficient external walls for Net Zero Energy Buildings in Mediterranean climate conditions. Calculation and results revealed by mentioned study that it is always possible to reach efficient external walls in Mediterranean climate conditions approximately 40 cm (forty centimeter) through using eco-friendly materials currently available in market. The study demonstrated that, best sequences of layers are with high surface mass, in particular concrete, for the first layer (internal side), followed by common insulating materials for the middle layer and eco-friendly insulating materials for the external layer. Table 4.1 illustrates the 3 types of highly recommended external walls base on available material in the market which can be considered as the best wall structure for Net Zero Energy Buildings in Mediterranean climate conditions.

Table 4.1: Example of High Performance External walls Suitable for Net Zero Energy Buildings in Mediterranean Climate (Baglivo et al., 2014).

| **Wall** | **Type 1** | **Type 2** | **Type 3** |
|---|---|---|---|
| Layer 1 | 10 cm, Concrete Ms>300 kg/m$^2$ | 10 cm, Concrete Ms>300 kg/m$^2$ | 10 cm, Concrete Ms>300 kg/m$^2$ |
| Layer 2 | 7 cm, Cellulose fiber | 3 cm, Cement mortar | 3 cm, Cement mortar |
| Layer 3 | 3 cm, Cement mortar | 12 cm, Polyurethane exp. | 12 cm, Polyurethane foam |
| Layer 4 | 16 cm, Cross-laminated timber panel | 10 cm, Tuff | 16 cm, Cross-laminated timber panel |
| Layer 5 | 3 cm, Cement mortar | 6 cm, Cross-laminated timber panel | 1.5 cm, Plaster |
| U (W/m$^2$) | 0.28 | 0.15 | 0.15 |

In order to clarify the structure of recommended walls, figures 4.5 – 4.7 represent the section layout of high efficiency walls that can be applied for Net Zero Energy Buildings in Mediterranean climate. These figures indicate the arrangement of wall's components from internal side to external side.

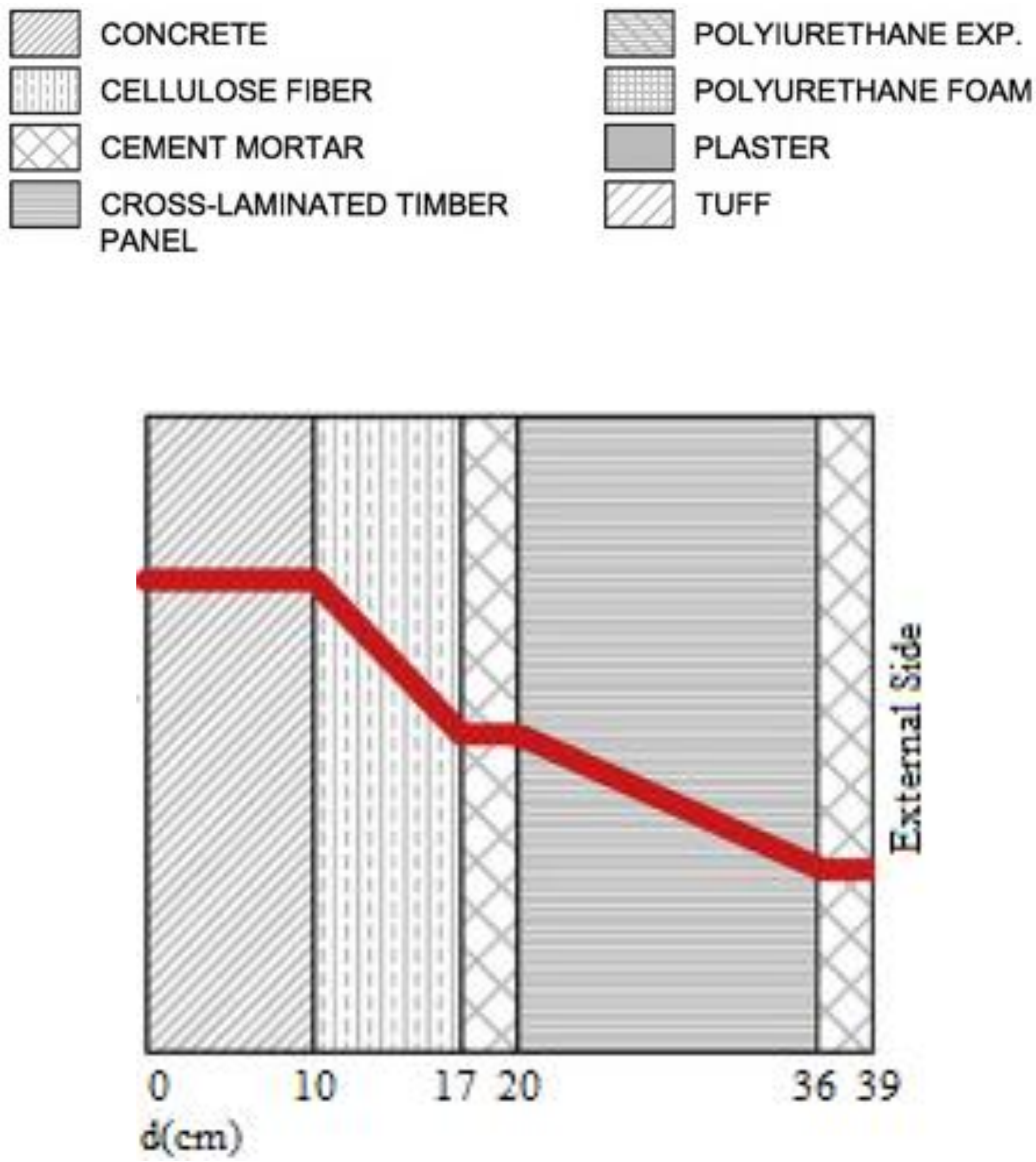



Figure 4.5: Layout of High Efficiency External Wall Type 1, Suitable for Net Zero Energy Buildings in Mediterranean Climate (Baglivo et al., 2014).

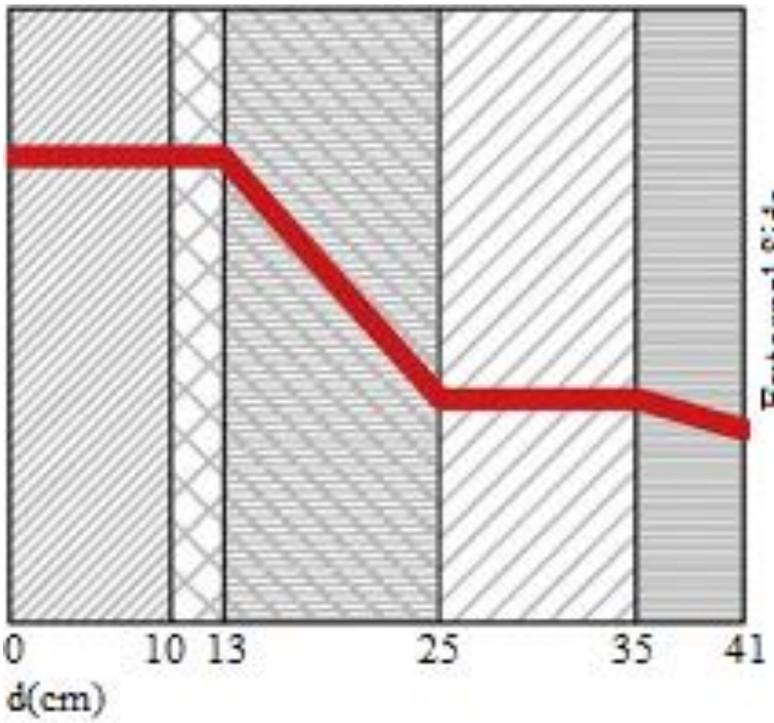



Figure 4.6: Layout of High Efficiency External Wall Type 2, Suitable for Net Zero Energy Buildings in Mediterranean Climate (Baglivo et al., 2014).

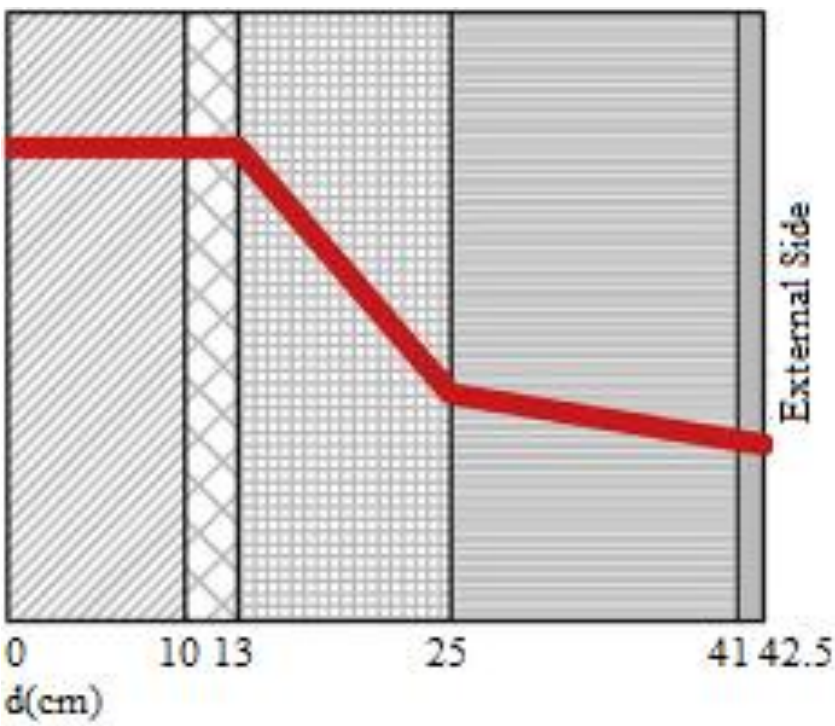



Figure 4.7: Layout of High Efficiency External Wall Type 3, Suitable for Net Zero Energy Buildings in Mediterranean Climate (Baglivo et al., 2014).

### 4.2.3 Roofs

Roof as a building component influences on energy performance of buildings. Heat transfer through roofs has a significant impact on indoor thermal comfort. A damaged roof increases heat lose during winters. Today, several efficient roof types such as cool roofs, green roofs, steep-sloped roofs and etc. are offered. Adopting an appropriate roof type based on climate conditions might be useful to optimize energy efficiency and improving indoor comfort. Therefore, selecting proper type of roof is a key option in approaching efficient buildings such as Net Zero Energy homes.

The experimental study by Özdeniz and Hançer (2005) has attempted to identify suitable roof construction approaches for warm climates. The research evaluated 14 different widely used roof types by applying in a case building in Gazimağusa, Northern Cyprus. The roof constructions which have been evaluated follow: 1) Roof tile; 2) timber lath 2.5 cm; 3) Extruded polystyrene heat insulation 4 cm; 4) Polymeric bituminous membrane water; 5) Timber board 2.5 cm; 6) Timber rafter; 7) R.C slab; 8) Gypsum plaster 0.5 cm; 9) Soft glass wool heat insulation 4 cm 10) Terrazzo 4 cm; 11) Leveling concrete 4-6 cm; 12) Hollow clayblok floor 17 cm; 13) Pebble 3 cm; 14) Hard glass wool 4cm.

The results demonstrated that, **roof approaches with thermal insulation** have the best performance in such a Northern Cyprus region. Additionally, the study highlighted that the‶**location of the thermal insulation materials towards the inner surface of the section** increases the performance″ (Özdeniz and Hançer 2005). It should be mentioned that, although inclined timber roof on concrete celling is effective to prevent overheating in summer but the **attic space needs to be very well ventilated**. Finally, the study concluded inclined **timber roof with a ventilated attic space**,

**terrace roofs**, and the roofs by placing the thermal insulation materials towards the inner surface, are the best performed roofs (Özdeniz and Hançer 2005). Now it can be realized that, these roof construction approaches are recognized as efficient roofs that can be considered in construction of Net Zero Energy homes in Northern Cyprus.

There are further strategies that can be considered in roof constructions to improve functional performance of roofs. For instance, green roofs, high reflection roofs and use of highly reflective paint for roofs are a part of strategies to enhance energy efficiency in roof constructions in warm climate. Eventually, efficient roofing strategies can be summarized into following practices:

1- Increasing Roof R-Value: utilization of proper insulation might be effective in increasing R-Value of roofs.
2- Reducing Thermal Discontinues: reduce gaps and voids to increase energy efficiency
3- Installation of a Climate-Appropriate Roof Structure: implementation of proper roof structure by considering proper solar reflectance and thermal remittance based on climate conditions

### 4.2.4 Transparent Building Elements

Additional strategies are needed to construct an energy efficient building. Other building's components should be considered and selected as efficient ones. For example, transparent building elements are dramatically effective on energy efficiency in buildings. According to reports of Hee et al., (2014) windows responsible for 20-40% wasted energy in buildings. Proper size and appropriate orientation of windows significantly influence on reduction of heating and cooling demand. Hence, appropriate window design and use of high efficiency windows might be a key option in construction of efficient buildings such as Net Zero Energy homes.

An appropriate window glazing can improve fenestration system through its thermal and optical properties. Thickness, coating, tinted and spacer between panes are important parameters in selecting of energy efficient windows (Hee et al., 2014). The study by Hee et al., (2014) demonstrated that different window types show different performance depending on their orientation in buildings. Therefore the study offered several windows based on suitable orientation that they can be installed. However, the study suggested a specific type of window which contributes energy saving in all directions. The window's component consists of:

- Insulating glass unit composed of: outer pane: 6 mm clear glass, air space: 12 mm, inner pane: 6 mm clear glass.

The mentioned window can be recognized as the simplest efficient window that can be used to enhance energy efficiency in buildings. Although, various types of high efficiency windows are available but in some cases efficient windows should be selected and installed based on availability in local markets. For instance, triple-paned or double-paned windows currently available in construction market of Northern Cyprus are suggested to install in Net Zero Energy homes. However, **triple-paned** windows are preferable.

It is hard to suggest use of a special kind of window in Net Zero Energy homes in Northern Cyprus since several evaluation such as techno-economic assessments are needed to select the best alternative. Nevertheless, adopting efficient windows can be followed by general strategies to select proper high efficiency windows in warm climate. According to Hee et al., 2014 strategies to use of appropriate windows in warm climates follow:

- *U*-value of a glazing effects on heat transfer between exterior and interior of a building. For warm climates the window ***U*-value around 1.5** is recommended.

- Solar Heat Gain Coefficient (SHGC) indicates the amount of solar heat that penetrates into buildings through windows. It is suggested for warm countries such as Northern Cyprus where is a summer dominated country use of **lower SHGC** can be effective to prevent of overheating in buildings.

- Visible Transmittance (Tvis) represents the amount of natural lighting within the building. **Proper size and appropriate position** of windows are effective strategies to optimize energy saving in buildings.

### 4.2.5 Other Construction Approaches

A part of additional strategies can be adopted to optimizing energy saving and durability of buildings during construction and even operation phase. Although, these strategies are considered during construction stage but investigation of these strategies during operation phase would be helpful in energy saving. For example, blocking pathways for moisture to enter walls and ceiling from the exterior and controlling rain-water flow through walls and roof are strategies to optimize durability in buildings. Additionally, existing of air leaks increases the heat or air transfer between interior and exterior of buildings. In this case, sealing air leaks should be performed in places such as cracks in recessed fixtures, holes in electrical boxes, leaky windows and doors, cracks in floor slab, window framing and drywall and etc.

Use of internal or external shading devices or overhangs in cases that design of building is not able to provide proper shading can be an effective strategy to prevent overheating during hot summers in Northern Cyprus. On the other hand, undesirable shading by neighbor buildings influence on thermal performance of buildings. Improper shading by neighbor buildings or even by trees and other landscaping elements influence on efficiency of PV roof top panels. Therefore, appropriate shading approaches should be considered during designing and construction phases.

Finally, utilization of high efficiency technical services such as HVAC system, high efficiency appliances, high efficiency lighting system, smart energy management system, solar water heating system and etc. are strongly suggested to achieve Net Zero Energy homes in Northern Cyprus. Additionally, water purifying system or rain-water system are efficient technology that can be used to reach elite goal in Net Zero Energy homes.

## 4.3 Renewable Energy Supply Options

As it was mentioned in this thesis, solar and wind energy are recognized as suitable renewable resources that can be used to produce electricity or other energy carriers in Northern Cyprus. At the moment, existing legislations do not support the utilization of on-site small wind turbines in homes. Other renewable energy resources such as geothermal, biomass and wave energy are not widely use in northern Cyprus and in some cases required technologies are not available. While utilization of solar PV panels is a common technology in Northern Cyprus. On the other hand, this thesis demonstrated that on-grid electricity generation from integrated PV panels in single family homes are economically affordable. Therefore, renewable energy strategies should be focused around use of **PV** panels to **on-grid** electricity generation.

It should be highlighted that, utilization of PV panels should follow a part of **standards** in term of efficiency and amount of generated electricity. According to existing protocol and low on renewable energy use in Northern Cyprus- article 12(1) - life cycle of PV panel systems should be considered at least 25 years with a minimum performance of 90% during the first 10 years and 80% for the next 15 years. Additionally, the minimum efficiency for PV system should be set to 15%. Minimum inverter output should be at least 97%. Maximum square meter for 1 KW PV system should be eight (8) $m^2$. In on-grid PV system inverter should be able to turn on/off automatically. AC frequency should be in range of 5 Hz to 50 Hz. Furthermore, specific standard codes are required by TRNC government for PV system. For instance all material and equipment which are used in PV system should be based on IEC (International Electro technical Commission), BS (British Standard) or EN (European Norms) standards. Now it should be realized that, installation of PV system to generate electricity in Net Zero Energy homes at northern Cyprus should follow these regulations.

**Mono-crystalline** PV cells are the most common PV type in Northern Cyprus. Mono-crystalline PV cells are cheaper and more durable than other PV types such as poly-crystalline and thin-film PV systems. Operation and maintenance technologies are available for mono-crystalline PV cells in Northern Cyprus as well. Hence, utilization of this type of PV system would be recommended.

Integration method is highly recommended to placement of PV and solar collectors in buildings. In this method PV system can be incorporated into building envelope, where the system forms a part of the building envelope. In a study by Radmehr et al., (2014) a method that is recognized as ‘Willingness to Pay’ has been developed to explore people′s preferences for a Built in Photovoltaic (BIPV) renewable energy system to be integrated into housing construction in case of Northern Cyprus. The results demonstrated that, in Northern Cyprus the capital cost of PV is not instrumental in choice, and a lower feed-in tariff could be acceptable. Calculations indicated that individuals in Northern Cyprus are willing to pay estimated cost of €6,000 including 25% subsidy, for installation of 4 KWp PV system. The study underlined **Turkish Cypriots are willing to support government policy**, and this could be done with lower financial incentives.

Already, in Northern Cyprus there is lack of proper policies to promote on-grid electricity generation from PV panels. It means that, polices should provide appropriate licensing and authorization procedures to eliminate current problems in developing Net Zero Energy homes. Development of a strategy communication is important to increase public awareness about utilization of PV panels in term of generating electricity. Additionally, eliminating barriers related with financing, monitoring system and restrictions related to visibility of PV systems in historic areas are required to provide a proper framework for developing PV systems.

## 4.4 Building Scoring System

A consistent evaluation system is needed to compare energy performance of different buildings. Customers should be able to evaluate performance of their home easily. Occupants usually are interested to find out the differences between an existing and a new home. Easily evaluation system makes possible realizing how the energy performance of a building changes by changing occupant’s behavior and operation. Buildings can be easily selected based on their performance through offered evaluation labels by scoring systems.

Additionally, scoring system would evaluate real estate transaction, interest rates, insurance, energy costs, and taxes. A proper valuation process evaluates buildings based on life cycle cost instead of initial costs due to consumers gain maximum benefit of purchasing a home.

In northern Cyprus, establishing institutes or any other official organization is needed to provide a proper scoring system. Providing local certification for buildings might be cheaper than international buildings' performance certifications. Therefore, it is suggested that evaluate buildings in design, construction and operation levels.

## 4.5 Incentives and Financial Policies

Developing Net Zero Energy Buildings directly depends on encouraging renewable energy use. In order to encourage using renewable energy resources, various strategies are promoted in several countries. Generally, these strategies can be grouped in three main headings:

1. Price markers and generation amount incentives,
2. Cost reduction and public investments policies,
3. Incentives to ensure developing renewable energy use.

**'Price markers'** and the 'generation amount incentives' can be guaranteed for consumers through of 'feed-in-tariff' and/or 'Renewable Energy Portfolio Standards (RPS)'. It is expected that, a substantial contribution of **feed-in-tariff** applications supports the electricity generation from renewable energy resources. This quota system can be standardized based on a specific amount of electricity during a certain time. Additionally, certain percentage of electricity generation can be considered as a based-generation standard.

Subscribers who produce electricity from renewable energy resources, can be certified by the government. Electricity producers should be able to take benefits from receiving certifications to be encouraged generate more green power.

**Subsidies**, **rebates**, and **cost reduction forms** are key options of financial encouragement policies. **Tax rebate** is another method that can be effective to encourage investors, contractors, and consumers to build and operate NZE homes. Additionally, financial strategies can follow: providing **investment tax credits**, **accelerated depreciation**, production **tax credits**, **ownership tax credits**, **income tax incentives, tax exemption**, **environmental tax exemption**, **import tax reductions**, **grants**, **equipment credits**, **loans**, and similar strategies.

Banks and other financial institutes should be involved in this process. The government can provide mortgage with 1-2% lower than the market for NZE homes. New technologies need to be imported. Importing equipment can be facilitated by reduction import tax and reduction in **custom tariffs**. Grants should support small – scale projects and individual constructions as large-scale projects.

## 4.6 Education and Training

In Northern Cyprus, builders construct buildings based on traditional methods and usually are not aware about concept of Net Zero Energy homes. **Construction industry** should be informed about new technologies and equipment to be able select appropriate technology and equipment to construct a Net Zero Energy home. **Labors** and **subcontractors** should be trained to install new technologies. Designers should be informed about details of Net Zero Energy homes. **Owners** and consumers should be trained to how operate and maintenance Net Zero Energy homes easily. **Real state**

**sector** should have sufficient information about selling Net Zero Energy homes. Financial institutes such as banks, mortgage lenders, and insurance companies should be convinced that how they can take profits by providing loans and investments. It should be realized, an educated workforce team usually has a good perception of concept of NZE homes. Trained **workforce team** is well-informed to how incorporate new technologies into new buildings. Training stakeholder helps to ensure that operating and maintenance of NZE homes would be accomplished conveniently.

**'User Manual guide'** is suggested for consumers of NZE homes. 'User Manual guide' provides a list of required guides to operate and maintenance homes. Proper selection of restoration materials, required information to reduce energy consumption, and other useful information about energy saving would be identified in user manual guide.

Builders should learn to build homes based on Life Cycle Cost instead of initial costs; to provide maximum benefits for consumers. Equally, owners and consumers should be trained to purchase homes based on rating and scoring system. Generally, new projects are not attractive for people due to uncertainty at the beginning. People are not interested to being first in unproven projects. Hence, owners and consumers should be informed about profits of NZE homes and ensure that extra investment how will return to them in the future.

A consistent education and training mechanism is needed to provide reliable information. It is suggested that schools, institutes, and universities should be engaged. Internships can be offered throughout universities for students who are interested about NZE concept and relevant issues. Students can take courses in universities and learn more about this new concept. Research centers can be established to gather and spread appropriate information. Information between universities in Northern Cyprus and other information pilots can be effective obtain updated information. Being partner with institutes that are pioneer in this issue might be useful to accomplish jointly projects in Northern Cyprus. Conferences, lectures, and articles are also effective to make public mind agreeable with concept of Net Zero Energy. Additionally, the role of media cannot be neglected in spreading information. Media can influence on promotion NZE homes by preparing appropriate programs such as discussions, advertising, and educational programs. Involving local industries such as fenestration industry, lighting industry, and energy generation sector with might improve developing NZE homes.

Finally, approaching NZE homes would not be possible without sufficient science about this concept. As much as decision makers, policy makers, builders, owners, and consumers be well-informed, public disagreeing with concept of NZE would be decreased and NZE homes can be developed more easily.

## 4.7 An Overview of Recommended Strategies

This section is aimed to summarize strategies which have been indicated previously in this thesis. Table 4.2 illustrates the important strategies that should be adopted in different constituencies to accelerate developing Net Zero Energy homes in Northern Cyprus. It should be noticed that, these strategies are recommended for Northern Cyprus based on current potentials and weaknesses while other strategies might be available for other countries. In the thesis, it has been tried to focus on available technologies and material, existing knowledge on innovations, local policy and regional building codes.

Table 4.2: Key Strategies for Future Net Zero Energy Homes in Northern Cyprus.

| **Design Approaches** |
| --- |
| • Integrated design process instead of traditional design methods.<br><br>• Largely use of passive design solutions including: passive heating, solar shading, landscaping, proper orientation, appropriate geometrical ratios, cross ventilation by use of small voids, maximizing functionality of semi open spaces can reduce unnecessary area usage and subsequently can reduce energy consumption.<br><br>• Use of proper design tool, use of computer modeling, building information modeling, easy visualization software, developing pre-design stage to make a feedback loop. |
| **Construction features** |
| • Envelope: Massive solutions instead of lightweight ones, use of thermal mass, combination of thick insulation with high internal masses (masonry).<br><br>• External walls: use of high surface mass, in particular concrete, for the first layer (internal side), followed by common insulating materials for the middle layer and eco-friendly insulating materials for the external layer. Use of high performance walls that was mentioned in this thesis. Use of thermal insulation on the external face of walls.<br><br>• Roofs: roof structures with thermal insulations, timber roof with ventilated attic space and location of the thermal insulation materials should be towards the inner surface of the section. Use of an exposed floor slab, with some thermal contact with the ground to exploit thermal mass. |
| **Building Transparent Elements** |
| • Use of Triple-glazed windows,<br>• Use of windows with U-value of 1.5,<br>• Use of windows with lower SHGC,<br>• Proper size and direction of windows in buildings should be considered. |

Table 4.2: Key Strategies for Future Net Zero Energy Homes in Northern Cyprus. (Continue).

| **Renewable Energy Supply Options** |
|---|
| • Developing on-grid integrated PV systems,<br>• Eliminate existing barriers to encourage use of PV electricity generation system. |
| **Building Scoring System** |
| • Adopting local certification for buildings,<br>• Investigation of buildings during design and construction levels,<br>• Developing a proper valuation process evaluates buildings based on life cycle cost instead of initial costs. |
| **Incentives and financial policies** |
| • Applying feed-in-tariff applications,<br>• Subsidies, rebates, and cost reduction forms<br>• Tax rebates and accelerated depreciation,<br>• Production tax credits, ownership tax credits, income tax incentives, tax exemption, environmental tax exemption, import tax reduction and reduction in custom tariffs<br>• Grants, equipment credits, providing loans |
| **Education and Training** |
| • Construction industry should be informed about new technologies and equipment,<br>• Labors and subcontractors should be trained to install new technologies,<br>• Owners and consumers should be trained to how operate and maintenance Net Zero Energy homes easily,<br>• Real state sector should have sufficient information about selling Net Zero Energy homes,<br>• User Manual guide’ is suggested for consumers of NZE homes, schools, institutes, and universities should be engaged. |

# Chapter 5

# CONCLUSION

Northern Cyprus is one the richest countries in Mediterranean region in term of receiving sun radiations. Northern Cyprus does not have luxury to waste the wealth of renewable energy resources. It can be realized that, the inexhaustible sun and wind energy would be main resource to generate electricity and other energy carriers in coming years. The largest cause of environment pollution in the world i.e. oil use, in Northern Cyprus is also rapidly consumed and makes irreparable damages to the environment. Unfortunately, in Northern Cyprus renewable energy resources could not be appeared as largely used alternatives to cover energy demand. There is already lack of consciousness about theses alternative resources. On the other hand, Building sector in Northern Cyprus has a significant contribution in increasing of energy peak demand. Hence, reduction energy demand in construction sector is a majority for Northern Cyprus. This thesis evaluates approaching Net Zero Energy homes in Northern Cyprus as a proper option to mitigate energy consumption in building sector.

Net Zero Energy homes help to use passive design methods as much as it is possible. These homes are constructed based on climate conditions, are efficient, and well-insulated buildings, are equipped to high efficiency solar hot water system, water purification system, garbage separation, and rain water-harvesting system. Therefore, developing Net Zero Energy homes captures an image showing entrepreneurial, innovation, visionary in Northern Cyprus.

According to KIB-TEK, total electricity consumption in Turkish Republic of Northern Cyprus was approximately 653 GWh in 2013. If TRNC is targeted to achieve the membership of European Union, it is required that, Northern Cyprus should be able to generate annually 114.6 GWh electricity from renewable energy resources. Generation of daily 313 MWh electricity from renewable energy resources is needed to meet 114.6 GWh per year. The average cost of 1 MW wind turbine that generates 3MWh electricity per day is approximately $910,000. Therefore, TRNC should expense more than $94,500,000 to reach the objectives of European Union. However, NZE homes can be as an alternative to generate electricity from renewable energy resources with a lower cost in comparison of wind farms or solar power plants. Net Zero energy homes can be effective for Northern Cyprus to reach the future goals as well.

Approaching NZE homes might influence on related industries in Northern Cyprus. Companies to produce high efficiency devices such as PV panels and small wind turbines would be established. New companies will employee new workforces. Sustainable architecture and proper construction will be promoted. Investments will prosper the stagnant real estate market of Northern Cyprus. Promotion NZE homes provide opportunities for citizens to live in a modern and comfortable home and offers sustainable investments for foreigners. Furthermore, NZE homes would be a great advertisement in media that introduces Northern Cyprus as a clean and civilized country.

Transfer electricity from turkey to Turkish Republic of Northern Cyprus (TRNC) through Mediterranean Sea is an important issue that Northern Cyprus has been involved nowadays. In this project, Turkey is aimed to supply electricity to Northern Cyprus by cable power transmission through Mediterranean Sea. According to primary published data, this project may help to improve relationship between Turkish Republic of Northern Cyprus (TRNC) and Republic of Cyprus since this project is targeted to meet electricity demand of Republic of Cyprus. Accepting the fact that, this project has been left for many years due to embargo, financial problems, and existing disputes between Turkey and Greece, but even bring up this project may influence on developing of NZE homes in Northern Cyprus. Transfer electricity from Turkey as an alternative to cover energy demand in Northern Cyprus can change the priority of generation electricity from renewable energy resources and subsequently marginalize developing of Net Zero Energy homes.

It would be difficult to express that NZE homes are entirely sustainable for Northern Cyprus. Promotion NZE homes might be sustainable under certain conditions and when it is compared with other projects. However, it can be realized that Net Zero Energy concept has a great attention to economic, environmental, and social aspects. These homes are affordable, mitigate $CO_2$ emission, and involve people directly. It is expected that, NZE homes would be sustainable in comparison of other unproven projects are taking place in Northern Cyprus.

Eventually, developing NZE homes is suggested for Northern Cyprus to follow international protocols for reduction greenhouse gas emissions, provide more comfortable environment for occupants, manage own energy resources, and approach sustainable architecture. Additionally, Northern Cyprus can overcome to several problems due to taking an important step leading to independence of fossil fuels. Developing NZE homes is promising alternative for Northern Cyprus since the cost of technologies is decreasing and required equipment are going to be more available. However, in such a case the explosion in energy market and boom in construction industry might be a matter in Northern Cyprus. It seems that, policy-makers in Northern Cyprus would not be able to manage the consequences of development in energy market and construction industry. The hope is that, Northern Cyprus be able to achieve NZE homes and manage the results by enacting appropriate strategies.

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# APPENDICES

## Appendix A: Excel Spreadsheet Inputs Explanation

### Inputs

| | | |
|---|---|---|
| Life Cycle | 25 | EPBD requires 25 years life cycle for PV system. According to existing legislation of installment of PV panels at Northern Cyprus, life cycle of 25 years should be considered in installation of PV systems. |
| Initial Cost | $10,000 | According to personal conversation by Cyprus Solar Ltd. the initial cost for a 5 KW roof top on-grid PV system accounts to $10,000. |
| O&M Cost | $100/a | Cyprus Solar Ltd. claimed that annual operation and maintenance cost for 5 KW roof top on-grid PV system accounts to 1% of initial cost i.e. $100 annually. |
| Electricity Saving | $2,400/a | According to personal conversation by the owner, the total electricity bills accounts to $2,400 per year. |
| Discount rate ($i$) | 8.5% | According to Central Bank of the TRNC, banks in Northern Cyprus offer maximum 8.5% interest rate for long term deposits. Electronically available at http://www.kktcmerkezbankasi.org/ |
| Inflation Rate ($i$) | 10% | According to Central Bank of the TRNC, average inflation rate in Northern Cyprus is 10%. http://www.kktcmerkezbankasi.org/ |
| Electricity Escalation rate | 10% | The Electricity Escalation rate in this study is considered to be same as inflation rate in Northern Cyprus. However, current growth rate is higher than this amount. |

All present values in is adjusted to the future values with an **inflation rate (*i*)** of 10% through following formulas:

Future Value in the year n = Present Value $(1+i)^n$

The column of ‘total by the year’ calculated the sum of **Annual Electricity Savings** minus Annual **M&O costs**. This amount shows the net saving amount in every year.

The Column ‘**Present Value in the Year 0**’ represents the discounted amount of column ‘total by the year’ based on a **discount rate (*i*)** of 8.5%. The amounts of column ‘total by the year’ is adjusted to the present value through equation:

Present Value in the year 0= Future Value in the year n / $(1+i)^n$

## Appendix B: Economic Evaluation Excel Spreadsheet (Calculated for Electricity Escalation Rate of 10%)

| | | | Annual Cash Flow | | |
|---|---|---|---|---|---|
| Year in study | Initial Cost ($) | M&O Costs ($) | Electricity Savings ($) | Total by the Year ($) | Present Value in Year 0 ($) |
| 0 | 10,000 | | | -10,000 | -10,000 |
| 1 | | 110 | 2,640 | 2,530 | 2,307 |
| 2 | | 121 | 2,904 | 2,783 | 2,364 |
| 3 | | 133 | 3,195 | 3,062 | 2,397 |
| 4 | | 146 | 3514 | 3,368 | 2,430 |
| 5 | | 161 | 3865 | 3,704 | 2,463 |
| 6 | | 177 | 4,252 | 4,075 | 2,498 |
| 7 | | 195 | 4,677 | 4,482 | 2,532 |
| 8 | | 214 | 5,145 | 4,931 | 2,567 |
| 9 | | 236 | 5,660 | 5,424 | 2,603 |
| 10 | | 260 | 6,225 | 5,965 | 2,638 |
| 11 | | 285 | 6,848 | 6,563 | 2,675 |
| 12 | | 314 | 7,533 | 7,219 | 2,712 |
| 13 | | 345 | 8,286 | 7,941 | 2,750 |
| 14 | | 380 | 9,114 | 8,734 | 2,787 |
| 15 | | 417 | 10,025 | 9,608 | 2,826 |
| 16 | | 460 | 11,028 | 10,568 | 2,865 |
| 17 | | 505 | 12,131 | 11,626 | 2,905 |
| 18 | | 556 | 13,344 | 12,788 | 2,945 |
| 19 | | 612 | 14,678 | 14,066 | 2,986 |
| 20 | | 673 | 16,146 | 15,473 | 3,027 |
| 21 | | 740 | 17,761 | 17,021 | 3,069 |
| 22 | | 814 | 19,537 | 18,723 | 3,111 |
| 23 | | 896 | 21,490 | 20,594 | 3,154 |
| 24 | | 985 | 23,640 | 22,655 | 3,198 |
| 25 | | 1,083 | 26,003 | 24,920 | 3,242 |
| Total | | 10,818 | 259,641 | 238,823 | 59,051 |

**Results**

| | |
|---|---|
| **IRR** | **35%** |
| **NPV** | **59,051** |

## Appendix C: Economic Evaluation Excel Spreadsheet (Calculated for Electricity Escalation Rate of 15%)

| Annual Cash Flow | | | | | |
|---|---|---|---|---|---|
| Year in study | Initial Cost ($) | M&O Costs ($) | Electricity Savings ($) | Total by the Year ($) | Present Value in Year 0 ($) |
| 0 | 10,000 | | | -10,000 | -10,000 |
| 1 | | 110 | 2,760 | 2,650 | 2,442 |
| 2 | | 121 | 3,174 | 3,053 | 2,593 |
| 3 | | 133 | 3,650 | 3,517 | 2,753 |
| 4 | | 146 | 4,198 | 4,052 | 2,923 |
| 5 | | 161 | 4,827 | 4,666 | 3,103 |
| 6 | | 177 | 5,551 | 5,374 | 3,294 |
| 7 | | 195 | 6,384 | 6,189 | 3,496 |
| 8 | | 214 | 7,342 | 7,128 | 3,711 |
| 9 | | 236 | 8,443 | 8,207 | 3,938 |
| 10 | | 260 | 9,709 | 9,449 | 4,179 |
| 11 | | 285 | 11,166 | 10,881 | 4,435 |
| 12 | | 314 | 12,841 | 12,527 | 4,706 |
| 13 | | 345 | 14,766 | 14,421 | 4,993 |
| 14 | | 380 | 16,982 | 16,602 | 5,298 |
| 15 | | 417 | 19,529 | 19,112 | 5,621 |
| 16 | | 460 | 22,458 | 21,998 | 5,963 |
| 17 | | 505 | 25,827 | 25,322 | 6,327 |
| 18 | | 556 | 29,701 | 29,145 | 6,711 |
| 19 | | 612 | 34,156 | 33,544 | 7,552 |
| 20 | | 673 | 39,280 | 38,607 | 7,552 |
| 21 | | 740 | 45,172 | 44,432 | 8,011 |
| 22 | | 814 | 51,948 | 51,134 | 8,597 |
| 23 | | 896 | 59,740 | 58,844 | 9,012 |
| 24 | | 985 | 68,700 | 67,715 | 9,558 |
| 25 | | 1,083 | 79,006 | 77,923 | 10,863 |
| Total | | 10,818 | 587,310 | 576,492 | 127,631 |

**Results**

| | |
|---|---|
| **IRR** | **42%** |
| **NPV** | **127,631** |