Pushing an existing villa in Dubai to nearly Zero Energy Building passing through AL SA'AFAT rating system

دفع فيلا قائمة في دبي إلى مبنى يقارب إستهلاك الطاقة فيه الصفر مروراً بنظام السعفات لتقييم المباني الخضراء

by

Meera Hamid Obaid Al Ali

A dissertation submitted in fulfilment

of the requirements for the degree of

MSc SUSTAINABLE DESIGN OF THE BUILT ENVIRONMENT

at

The British University in Dubai

Prof. Bassam Abu-Hijleh

May 2017

Abstract

Our surrounding environment is effected significantly due to the buildings impact which is a result of excessive energy consumption. Residential and commercial buildings use about 40% of the world total primary energy (Pless & Torcellini, 2010). During the years between 1980 and 2003 the consumption of energy had been doubled and it is still increasing and by 2025 it is expected to increase even more by 50% (Pless & Torcellini, 2009). Therefore, many countries already started to take actions regarding that. Taking into consideration one city, during the spectacular evolution of Dubai, many improper activities that have a negative effect on the environment had been spread between almost all sectors. Activities such as transportation, construction and daily routine habits had been attached by practices that have a detrimental impact on the surrounding environment. The excessive irreverence by consumers due to lack of awareness, led the governments and the associations in charge to take actions to prevent the aggravation of this phenomenon. Therefore, various regulations had been set to limit various problems in order to restore the order and aware people about the risks and the consequences of their improper habits. Recently, Dubai Municipality is finalizing a green buildings rating system called ‘AL SA’AFAT’, this rating system is divided into four certificates which are; bronze, silver, gold and platinum.

Moreover, a city like Dubai that grows very fast may need better solution than green buildings. Since buildings have a huge impact on the surrounding environment, minimizing this impact as much as possible should act as an option for Dubai. However, many different countries already set their roadmaps to reach their targets for nearly Zero Energy Buildings or

Net Zero Energy Buildings in order to participate in improving the energy performance and building efficiency of new buildings.

Therefore, this research aims to push existing villas in Dubai into nearly Zero Energy Building passing through ‘AL SAFAT’ rating system. The main challenge was to build a computer model for an existing villa taking into consideration the design, construction materials, orientation and exact location using IES-VE software. After analyzing the performance and making sure of matching the current situation of the villa using the software, implementing the requirements of ‘AL SA’AFAT’ rating system level by level comes next. This procedure showed a huge reduction in energy consumption that actually reached 61.1% when comparing the existing situation of the villa with the bronze level which is the lowest level in ‘AL SA’AFAT’ rating system. While the process of transforming the bronze level to silver, gold and platinum showed also reduction in energy consumption as the follow; 63.3% and 66%. However, both gold and platinum levels were exactly the same due to the software’s capability to absorb the requirements of the levels, were only the common requirements were able to be applied in the software. Eventually, the process of pushing the villa into nearly Zero Energy Villa using both active and passive strategies showed another huge jump in reducing energy consumption were the total yearly energy consumption was very close to zero which is 0.32 KWh, where the villa is actually considered as nearly Zero Energy Building.

ملخص

بيئتنا المحيطة بنا تتأثر سلبياً يومياً بسبب الإستهلاك المفرط للطاقة من قبل المباني المتزايدة. أثبتت دراسة أن المباني السكنية والتجارية تستهلك 40% من إجمالي الطاقة المستهلكة عالمياً بينما في الفترة الزمنية بين 1980م و 2003م تضاعف إستهلاك الطاقة ولا يزال في تزايد ومن المتوقع أن يزداد لأكثر من الضعف في عام 2025م. لذلك بدأت العديد من الدول فعلياً بإتخاذ الإجراءات اللازمة بخصوص هذا الموضوع. أخذاً بعين الإعتبار إحدى المدن, خلال الطفرة التي مرت بها دبي, بدأت العديد من الممارسات السيئة ذات التأثير السلبي على البيئة بالظهور تقريباً على جميع القطاعات. أنشطة مختلفة مثل النقل, البناء و اسلوب الحياة اليومي أصبح مرتبطاً بممارسات أخرى لها تأثير سلبي على البيئة المحيطة. فالإستهتار المفرط من قبل المستهلك بسبب قلة الوعي أدى الحكومات والمنظمات المسؤولة عن إتخاذ الأجراءات اللازمة وسن القوانين للحد من هذه الظاهرة. لذلك قد تم بالفعل سن عدة قوانين لتقليل هذه المشاكل وإعادة تنظيم ونشر الوعي بين الناس بخصوص مخاطر وتداعيات ممارستاهم السيئة. حالياً, قامت بلدية دبي بإصدار نظام السعفات الخاص بتقييم المباني الخضراء, هذا النظام قد تم تقسيمه إلى أربع فئات تسمى بالسعفات وهي البرونزية , الفضية , الذهبية والبلاتينية.

بالإضافة إلى ذلك, مدينة مثل دبي تنمو بشكل متسارع قد تحتاج إلى حل أفظل من مجرد مباني خضراء. بما أن المباني لها تأثير كبير على البيئة المحيطة بها, فإن تقليل تأثيرها السلبي على البيئة بقدر الإمكان يجب أن يكون أحد الحلول. هناك العديد من الدول التي قامت بالفعل بإنشاء خطط لإنشاء مباني قليلة الإستهلاك للطاقة أو عديمة الإستهلاك للطاقة من أجل تحسين أداء المباني الجديدة.

لذلك فإن الهدف الأساس من هذا البحث هو دفع فيلا قائمة في دبي لتقليل إستهلاك الطاقة فيها وتقريبه قدر المستطاع ليكون صفراً عن طريق المرور بنظام السعفات . التحدي الرئيسي كان بناء مجسم على الحاسب الآلي للفيلا القائمة مع الأخذ بعين الإعتبار مطابقة التصميم, المواد البنائية, الإتجاه والموقع الجغرافي للفيلا بإستخدام برنامج IES-VE لتحليل أداء المبنى وإستهلاكه للطاقة. فبعد دراسة أداء المبنى والتأكد من مطابقة المجسم للمبنى القائم قد تم تطبيق متطلبات السعفات سعفة سعفة. هذه العملية أظهرت إنخاض كبير في إستهلاك الطاقة الذي وصل لنسبة 61.1 % عند مقارنة الوضع الحالي مع السعفة البرونزية وهي أقل سعفة في نظام السعفات. بينما تطبيق السعفات الأخرى أيضاً أظهر تخفيض في إستهلاك الطاقة بنسبة 63.3 % للسعفة الفضية وبنسبة 66 % للسعفتين الذهبية والبلاتينية. فالسعفتين الذهبية والبلاتينية كانت النتيجة مماثلة

وذلك بسبب محدودية قابلية البرنامج على إستيعاب متطلبات كل سعفة, فبالنسبة للسعفة البلاتينية فقد إستطاع البرنامج إستيعاب المتطلبات المماثلة لمتطلبات السعفة الذهبية. في النهاية, عملية تحويل الفيلا إلى فيلا قليلة إستهلاك الطاقة عن طريق إستخدام الإستراتيجيات الإيجابية والذكية أدى إلى إنخفاض آخر كبير في استهلاك الطاقة, أوضح من خلالها أن مجموع إستهلاك الطاقة في السنة يصل إلى قيمة قريبة جداً من الصفر ألا وهي 0.32 كيلو وات في الساعة مما يعني أن الفيلا قد تم دفعها فعلاً إلى مبنى يقارب إستهلاك الطاقة فيه الصفر.

Dedication

I dedicate my study to my blessed family, my parents Hamid and Laila, my husband Hassan, my daughter Shamma and finally my sisters and brothers Amna, Hamad, Hamdan, Mohamed and Maryam.

Acknowledgement

First of all, I thank Allah for the unlimited blesses he gave me; health and family, which were the main reasons I was able to write this dissertation.

I also would like to thank my supervisor Prof. Bassam Abu Hijleh for his patience and unlimited support; he was always there to help me whenever I needed.

Special thanks for my family who believed in me especially my parents, my husband and my daughter Shamma who I gave birth to during the period of my dissertation. All of them were patient with me regardless the time I spent with them comparing to the time I spent working on my dissertation.

I would like also to thank all of my courses' tutors who gave me the knowledge I needed; Dr. Hasim Altan, Dr. Hanan Taleb.

Table of Contents

List of figures

List of tables

List of abbreviations

CdTe	Cadmium Telluride
CIGS	Copper Indium Gallium Selenide
CIS	Copper Indium Selenide
DHW	Domestic Hot Water supply
EPS	Expanded Polystyrene
IES-VE	Integrated Environmental Solution – Virtual Environment
ISO	International Standards Organization
NZEB	Net Zero Energy Building
PV	Photo Voltaic
RW	Rock Wool
SDW	Solar Domestic Water
SHGC	Solar Heat Gain Coefficient
STC	Standard Testing Conditions
XPS	Extruded Polystyrene
ZEB	Zero Energy Building

Chapter 1
Introduction

1. Introduction

1.1. Overview

Lately, after witnessing negative environmental impacts in different cities in the world such as environmental pollutions, excess energy and water consumption and heat island effect due to lack of awareness between consumers, some cities planned to set regulation in order to limit these negative impacts. Taking into consideration Dubai city which the research will study in details, a regulation that states the mandatory of building "green building" in Dubai has been set. Therefore, this research is concern about studying the efficiency and the reliability of this regulation on an existing villa. However, a further improvement for the villa will be implemented in order to reach nearly Zero Energy Building (ZEB). Therefore, different terminologies, features and strategies should be studied in details in order to reach the desirable target of the research.

1.2. Sustainability

It is very clear that sustainability become a popular word especially when it comes to environmental policies, not among scientist only but even among public. According to (Gatto, 1995), sustainability has three distinct definitions which are; applied biologist definition, ecologist definition and economist definition. The applied biologist definition is related to the sustained yields such as sustainable resources that are derived from the ecosystems beside the exploitation of consumers. While the ecologist definition is defined as the sustained abundance that is derived from the diversity of an individual species in ecosystems such as animals and plant while taking into consideration the environmental management such as regulating the hunting and fishing besides protecting habitants from lost. While the last definition which is the economist, is related to the sustainable economic development that takes into consideration the future generation.

1.3. Zero energy buildings

The concept of Zero Energy Buildings (ZEBs) is not a new one, many literature reviews and researches already discussed ZEBs since 1970's (Hemandez & Kenny, 2010) , but due to lack of knowledge and understanding these kinds of buildings, it have been found very hard to apply and implement these studies which unfortunately led to been discarded. ZEBs have many different definitions due to the broad field it covers. However, according to (Joanna & Heiselberg, 2011) ZEBs has four main definitions which are; net zero energy emissions, net zero site energy, net zero energy cost and net zero source energy. Net zero energy emissions is the building that is able to produce emissions-free source of energy by an amount that is equal or greater than the amount it uses from the emissions-producing energy sources. While net zero site energy is the building that is able to produce energy by an amount that is equal or greater than the amount it uses within a year. While net zero energy cost is the building that is able to produce energy with a cost to be paid to the building's owner by the utilities that is equal or greater than the cost of the energy used and paid to the utilities by the building's owner. While that last definition which is net zero source energy is the building that is able to produce energy by an amount that is equal or greater than the amount it uses while taking into account the procedure of producing or buying and delivering the power to the building.

1.4. Passive design strategies

According to (Rodriguez-Ubinas, et al., 2014) reducing energy consumption of a building is the first step to achieve nearly zero energy building (NZEB). However, this reduction in energy is related strongly to the passive design strategies used in the building. Passive design strategies improve the overall interior comfort such as visual and thermal comfort while reduces the energy consumption and ensure the energy efficiency of the building. passive strategies includes various aspects that will be discussed later such as the thermal properties of the building envelop, ratios, geometric parameters, thermal energy storage systems, night ventilation, night sky radiation cooling, evaporative cooling and solar gains. These passive strategies comply with the European Union goals of NZEB (Rodriguez-Ubinas, et al., 2014).

1.5. Active design strategies

Recently, active design strategies are trending between architects and engineers, it is believed that buildings with active design strategies has less energy consumption and greater energy production comparing to other buildings, therefore it is also called “intelligent buildings”. According to (Ochoa & Capeluto, 2008), intelligent buildings can reduce building’s dangerous emissions if proper strategies have been considered in the early stages of the design especially in hot climate regions. However, in some cases it is believed that this energy saving can reaches 50% to 55% when both actives and passive design strategies are used as a combination in buildings (Ochoa & Capeluto, 2008). Moreover, according to (Torcellini, et al., 2006) despite reducing the energy consumption in a building, NZEB needs to be supplied by renewable techniques. Renewable technologies are available today worldwide including Photo Voltaic solar panels (PV), solar water heaters, hydroelectric, wind and biofuels.

1.6. Overview about Dubai

Dubai is the second largest emirate in the United Arab Emirates (UAE), it have been settled for the first time in May 1933 by 900 peoples from a tribe that called “Bani-Yass” under the leadership of Sheikh Maktoum bin Buti from “Al-Maktoum” the royal family of Dubai. At that time Dubai was called “Al-Wasel”. Before oil discovery, Dubai economic was based on fishing, pearling and sea trade. However, in 1966 when oil was discovered, Dubai witnessed a huge evolution in infrastructure, services, transportation and telecommunications network and became Dubai that we lives in now (Wilson, 2006).

1.7. Dubai's climate

Dubai is located in a hot desert climatic zone, due to the Tropic of Cancer line which is crossing through the UAE. The weather of Dubai in summer is extremely hot with temperatures that exceeds the mid 40's°C and with humidity over 90%. While the winter has an average of 25°C that reaches 12 °C near the coast and 5°C in the desert and mountains with a humidity that ranges between 50% and 60%. The average perception of rainfall in Dubai is low, usually is rains about five days a year only (Dubai.com, 2016).

1.8. AL SA'AFAT rating system

AL SA'AFAT rating system is a green building rating system that is released recently by Dubai Municipality and it is divided into four rating categories which are bronze, silver, gold and platinum. This rating system has been released in order to improve buildings performance in the city through energy and water reduction, using sustainable and regional materials and improves occupant's safety. This rating system will be implemented in various types of buildings while there are some exceptions for specific types, however it also have some limitation especially when it conflict with some other regulations such as civil defense regulations (Dubai Municipality, 2016). All of these aspects related to AL SA'AFAT rating system will be covered in the literature review chapter.

1.9. Motivation of the study

The motivation of the study is to test 'AL SA'AFAT' rating system on an existing villa then pushing this villa into nearly ZEB. Analyzing the efficiency and the performance of this villa while passing through the rating system categories will help configuring the reliability of the rating system. However, in case of succeeding in pushing this villa into nearly ZEB, this villa can represent a model for other villas in the country and other countries that has the same climatic zone.

1.10. Aims and objectives

The main aim of the research is to assess the potential of having nearly ZEB villa in Dubai. This is to be done while taking into consideration the cost, efficiency, energy reduction and energy production on site. Moreover, beside the main aim of the research, there are number of objectives that the research is aiming to achieve which are;

a) Studying the current consumption of energy for a normal existing villa

b) Testing the efficiency of the green building rating system in Dubai 'AL SAFAT'

c) Adopting techniques that helps reducing energy consumption as much as possible

d) Adopting techniques that help generating energy\electricity on site as much as possible on.

e) Comparing the energy consumption for the villa before and after implementing 'AL SAFAT' rating system

f) Comparing the energy consumption for the villa before and after pushing it to nearly ZEB

Chapter 2
Literature review

2. Literature review

1.1. Introduction

In this chapter of the research, an intensive literature review will be conducted in order to get deeper knowledge and understanding about such terminologies, concept, regulations and design strategies.

1.2. Zero energy buildings

A study by (Runde, 2015) mentioned that buildings sector are the first highest consumers for energy. Moreover, residential and commercial buildings consumes 40% of the United States' enegy and 74% of the electricity. Since energy is often considered as the largest controllable opertaing expenditure for a building, owners and investors can reduce these expenditures through a well design and operation concept. According to (Runde, 2015), NZEB is the building that use enegy over the year as much as it generates on site using renewable sources.. While (Torcellini, et al., 2006) defined ZEB as the building that can achieve the requirements of having nonpolluting, locally available, low cost, renewable resources. At a certain level, a ZEB should generates renewable energy that is equal or exceed its yearly energy consumption. Moreover, according to (Voss, et al., 2012) only a slight difference splits NZEB from nearly ZEB which is the slightly increase in energy demand comparing to energy consumption in nearly ZEB as shown in Figure (2.1).

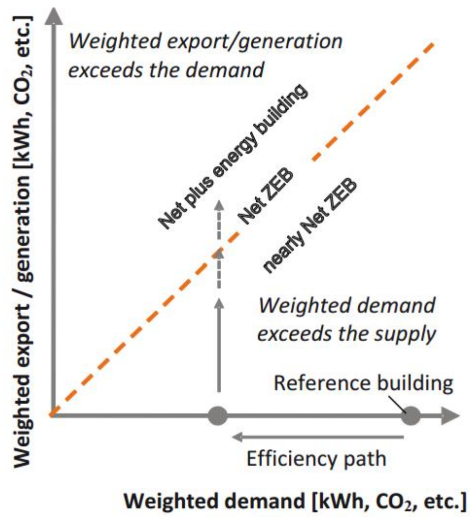

Figure 2.1 Graph showing the path toward a NZEB with the nearly and the plus variants. (Voss, et al., 2012)

However, Figure (2.2) below shows the important characteristic of NZEB, this reduction in energy can reaches up to 30% to 50% compared to a conventional building of similar usage supplied by renewable enegy source on site such as solar photovoltaic (PV).

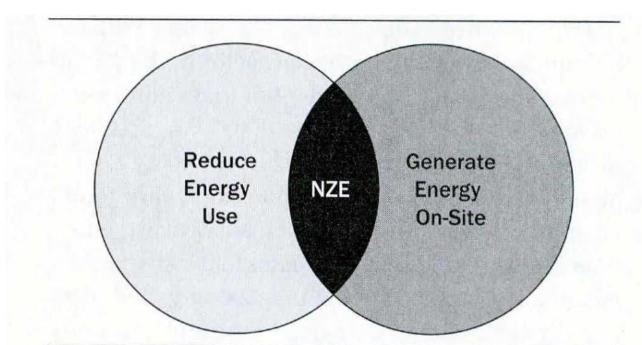

Figure 2.2 NZEBs combines both reducing energy use and generating energy on-site. (Runde, 2015)

Most NZEBs are connected to local electrical grids in order to send back the electricity when the generating capacity is exceeding the demand, at the same time it takes electricity from the grid when needed, therefore NZEBs are referred as grid-tied. This feature allows the building to obviate the need for energy storage system on-site such as batteries. Moreover, it allows the energy generating system to be sized average yearly demand instead of peak demand (Runde, 2015).

However, according to (Torcellini, et al., 2006), NZB definitions are classified into four definitions, but these four definition according to (Marszal & Heiselberg, 2011) have advantages and disadvantages.

1. Net Zero Site Energy: A building that produces energy that is equal to or greater than the energy it uses it uses in a year while taking into account the site.

    a) Advantages: easy to perform, demonstrable by on-site measurement, the performance can't be affected by externalities, conservative and easy to understand.

    b) Disadvantages: more PV requirement, doesn't takes into consideration all the utilities cost, doesn't consider some environmental issues such as pollution and resources availabilities and disability to equalize fuel types.

2. Net Zero Source Energy: A building that produces energy that is equal to or greater than the energy it uses it uses in a year while taking into account the source and the processes it takes into account the procedure of generating and delivering the energy.

    a) Advantages: ability to equalize energy value for different types of fuel, better influence on national energy system and count as one of the easiest Net Zero Energy (NZE) to achieve.

    b) Disadvantages: calculations of source are too extensive, negative impact can be larger than efficiency for fuel switching, doesn't consider some environmental issues such as pollution and resources availabilities and doesn't takes into consideration all the energy cost

3. Net Zero Energy Costs: A building that produce energy with a cost to be paid to the building's owner by the utilities that is that is equal to or greater than the cost of the energy used and paid to the utilities by the building's owner

    a) Advantages: easy to perform and measure, demonstrable from utilities bills and market forces conduct balancing different fuel types.

    b) Disadvantages: unsteady energy rates makes it difficult to track over time, the generating process can be more worthy than it is and agreements net-metering are required.

4. Net Zero Energy Emissions: A building that is able to produce emissions-free source of energy by an amount that is equal to or greater than the amount it uses from the emissions-producing energy sources.

    a) Advantages: represent the green power well, solves many environmental issues such as pollutions and greenhouse gasses emissions and count as one of the easiest Net Zero Energy (NZE) to achieve.

    b) Disadvantages: none are mentioned.

Moreover, (Pless & Torcellini, 2010) stated that to guarantee the maintainability of a building over a long-term, it should be designed in a way that reduces energy transfer as much as possible, this principle provide other advantages to the built environment such as; reducing the overall environmental impact due to encouraging the concept of energy-efficient buildings, using renewable energy with zero emissions, increasing the durability of the building and establishing a highly scalable buildings that are available widely. However, NZEB has a number of renewable energy supply options listed under three main categories as shown in Table 2.1;

Table 2.1 Renewable energy supply options for NZEB.

Option number	**Description**	**Example**
	Zero Energy Building Supply-Side Options	
1	Conducting low energy technologies in the building in order to reduce energy consumption	Natural ventilation\heating, day-lighting, evaporative cooling, HVAC equipment with high efficiency, etc.
	On-site Supply Options	
2	Using renewable energy resources available at the site	Solar heaters, PV cells, wind turbines, low-impact hydro located on-site.
3	Using renewable energy resources available within the footprint of the building	Solar heaters, PV cells and wind turbines located on the building.
	Off-Site Supply Options	
4	Using renewable energy resources available off-site in order to generate energy on-site	Biomass, biodiesel, ethanol and wood pallets that are available off-site and can be used on-site

5	Purchasing off-site renewable energy resources	PV cells, emissions credits, utility-based wind or other green purchasing options. Hydroelectric is considered sometimes.

However, (Pless & Torcellini, 2010) stated that first of all energy efficiency should be encourages in building in order to achieve a good ZEB concept, and then using renewable energy resources that are available on-site. Buildings that buy all its energy from central location or wind farm has less stimulate to reduce the load of the building; therefore it has been referred as off-site ZEB. In most cases, it is always easier to reduce energy use that to produce energy.

1.3. International building regulations

Buildings regulations might vary between the countries and continent based on different elements such as the climatic zone and the human behavior at that specific area. Taking into consideration the UAE, citizens' residential areas should have specific setbacks for the villa and minimum compound wall heights in order to provide privacy for each family. While in Europe, where most of the houses are made of light structures and have a small width of setback or might have none, building regulations at this countries have specific requirements for sound insulation for dwellings (Rasmussen, 2010). According to (Rasmussen, 2010), these regulations are in line with International Standards Organization (ISO) standards. However, installing sufficient acoustic insulation between houses is important for privacy and protection against noise. While according to (Östman & Källsner, 2011), using wooden materials for buildings is limited by the building's height in Europe, beside providing proper acoustical insulation and fire protection as stated by Dutch Ministry of Housing. Moreover, according to (Goodhew & Griffiths, 2005), a building regulation in The United Kingdom (UK) states specific properties when using un-fires clay bricks, straw bales and a straw clay mixture. The regulations states that when using one of these materials, insulations with a minimum thermal transmittance of 0.35 W/m2 K should be used. In addition, according to (Pan & Garmston, 2012), The UK government revised building regulations that target zero carbon new houses starting from 2016. In addition, according to (Pless & Torcellini, 2009), The United States decided to take an action regard NZEBs for all new commercial buildings by 2030, while the California Public Utilities Commission are expecting to have NZEB by 2020 for all new residential buildings.

1.4. Green buildings regulation in Dubai

In March 2014, Dubai Municipality released a new regulation that has been named ‘Green Buildings Regulation’, the regulation states that all new buildings in Dubai should be green buildings. Since then, all green buildings requirements that had been set should be met in order to deliver permit for the new buildings to start the construction.

1.5. AL SA’FAT rating system

AL SA’AFAT rating system is considering the reduction in energy, water and resources while enhancing the health and safety of occupants by taking into consideration the processes of planning, designing, constructing and operating the building. Moreover, it takes into account the safety of the environment and the humanity even in the process of demolishing and recycling the building. However, implementing this rating system is mandatory for all new buildings in Dubai, including free zone areas. Table (2.2) below shows the types of building included.

Table 2.2 Types of buildings included in AL SA'AFAT rating system

Type of buildings		**Type of buildings**	
	Investment villas		Banks

	Private villas	buildings	Theaters and cinemas
	Arabic houses (courtyard houses)		Educational buildings
	Apartments		Governmental buildings
	Labor accommodation		Restaurant and cafes
	Students and staff campus		Health care buildings
	Hotels and hotel apartments		Historical buildings
	Laboratories		Museums
	Offices		Petrol stations
	Resorts		Post offices
	Restaurant and cafes		Shopping malls
	Factories		Mosques and houses of worship
	Warehouses		Galleries and ballrooms
	workshops		Gymnasiums and fitness clubs
			Entertainment complexes

2.7.1. Exceptions and conflicts

Although the rating system is mandatory for all types of new buildings, there are some exceptions such as temporary buildings that are going to be removes within less than two years, traditional buildings due to the difficulties of implementing the green building regulations and some high rise buildings and huge shopping malls depending on the difficulties it face. However, extensions and renovations should fulfill the green building requirements in addition to the converted buildings (such as changing the usage of a building from residential to educational) the requirements of the new usage should be fulfilled. Moreover, in case of conflicts with other regulations such as conflict with civil defense requirements, regulations of civil defense should be fulfilled, while in case of conflict with other international references, Al SA'AFAT requirements should be fulfilled. However, in some cases where requirements of the list have conflict with other organization, the stricter requirement should be fulfilled (Dubai Municipality, 2016).

2.7.2. Implementing 'Al SA'FAT'

In order to implement the requirements of AL SA'FAT, a procedure should be followed to implement a certain frond. First of all, one of the four fronds should be selected; bronze, silver, gold or platinum. Then the usage of the building should be determined and finally the applicable and non-applicable clauses should be identified. However, AL SA'AFAT rating system covers various topics such as;

a) Ecology and planning

b) Building vitality

c) Resources effectiveness: Energy

d) Resources effectiveness: Water

e) Resources effectiveness: Materials and waste

While each one of these topics has also sub-topics. However, as the category goes higher, as new requirements appears in addition to the requirements of the previous category. Appendix B shows the requirements of the four categories in details.

1.6. Passive design strategies

Reducing energy use in a building is the first conventional solution for NZEBs. This energy reduction could be achieved using passive design strategies that tend to use natural factors such as wind, sunlight and temperature differences (DeKay & Brown, 2014). However, passive design strategies are selected and implemented on a building based on the climatic zone. Therefore, this paper is going to discuss such passive design strategies that could be implemented in a hot climate since Dubai is the concerned city. Meanwhile, these passive strategies are requirements of AL SA'AFAT rating system. However, might differ from category to another.

2.8.1. Orientation

Orientation of a building refers to the position of the building on a site with respect to the position of rooflines, windows and other features. Building orientation can takes advantage of solar passive strategies such as day-lighting and natural heating, solar active strategies such as using solar collectors, natural ventilation and controlling solar heat gain and heat loss in order to reduce demand for energy (NJ Green Building Manual, 2011). Figure (2.3) below shows different elements of passive solar design in a temperate and hot climates, although these elements performs separate function, all should work together in order to succeed, these elements are; aperture, absorber, thermal mass, distribution, and control.

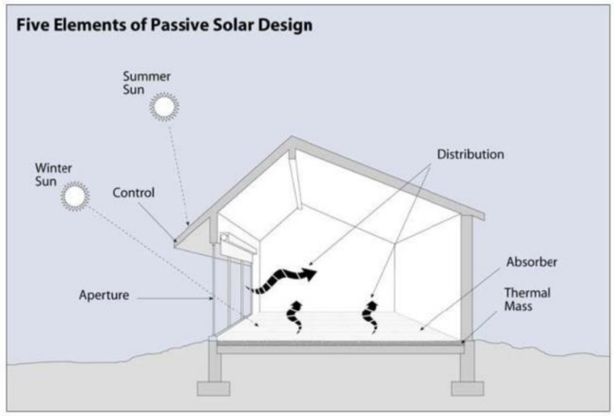

Figure 2.3 The five elements of passive solar design (NJ Green Building Manual, 2011)

However, in order to achieve the target of passive solar functions, a number of building components should be provided in the building. Table (2.3) below shows these building components with some examples;

Table 2.3 Building components and passive solar function (NJ Green Building Manual, 2011)

Passive Solar Function	Example Construction/Material/Action
Collect	South-facing glazing
Store	Masonry, water, other mass
Distribute	Radiation, convection, other natural heat transfer
Control	Light shelves, insulation, light-shaded paints

Moreover, optimizing building orientation requires incorporation of passive solar systems in the initial design stage of a building. However, according to (NJ Green Building Manual, 2011) it usually consist of a number of features such as;

1. Uniformed rectangular floor plans extended on the east-west axis.
2. South facing glazed wall
3. Thermal storage exposed partially to the solar radiation

4. Shading devices such as light shelves and overhangs in order to shade the south glazed wall from summer sun; usually south elevation requires horizontal shading devices while east and west require both vertical and horizontal shading devices.

5. Windows to be places on both east and west elevations while north elevation preferably have no windows.

2.8.2. Vegetation and landscape

Vegetation and landscape can create different pattern of air flow, it also provides shading which helps keeping surroundings cooler in hot and warm weather. Moreover, taking buildings into consideration, it could be used for energy conservation in various ways such as;

1. Roof gardens (green roofs)
2. Shading for open spaces and buildings
3. Shading of both horizontal and vertical surfaces (vertical gardens\green walls)
4. Changing wind's directio0n
5. Barrier against hot and cold winds (depends on the climate)

Vegetation and landscape are considered as a flexible controller of wind and solar penetration in buildings. Providing such elements can reduce direct sun radiation from striking and rising up the heat of building surfaces. Moreover, it lowers outdoor air temperature which will subsequently reduce heat transfer from outer spaces to inner spaces (NZEB, 2016).

2.8.3. Shading devices

Shading devices are considered as important strategy in passive design especially when it comes to facades with large glazed elements, while highly glazed facades are trending lately and widely used in new buildings in order to provide external view and natural light. However, a risk of creating high heating loads in these buildings should be considered. Therefore, different types of shading devices should be used in the design of the building to improve the energy performance of it based on the climatic region and the desirable target, such as external roller shades, internal shading, overhangs and venetian blinds. Many case studies by different researches have been used these different shading devices, all of these studies proved the importance of using shading devices in buildings. Thus, the application of shading devices in buildings is essential in order to decrease the buildings' cooling loads in hot regions. However, the most important reason of using such shading devices is to block the penetration of solar radiation and direct sunlight which causes discomfort and glare besides permitting the desirable amount of solar radiation during cooling\heating periods (Kirimtat, et al., 2016).

A case study for (Freewan, 2014)in Jordan examines shading devices on a university. Jordan is categorized as a subtropical area that is hot and dry during summer and cold in winter with clear sky conditions almost along the year while in winter a moderate rainfall and medium to overcast sky conditions. The average direct sun radiation in Jordan is about eight hours per day. However, the offices in the 3rd floor of the university are exposed to direct sun radiation starting from afternoon to sunset which causes raising the temperature to unbearable levels. Offices are encountering high temperate in sunny days while experiencing very low level of daylight during cloudy days. Therefore the study transact with three types of shading devices as presented in Figure (2.4).

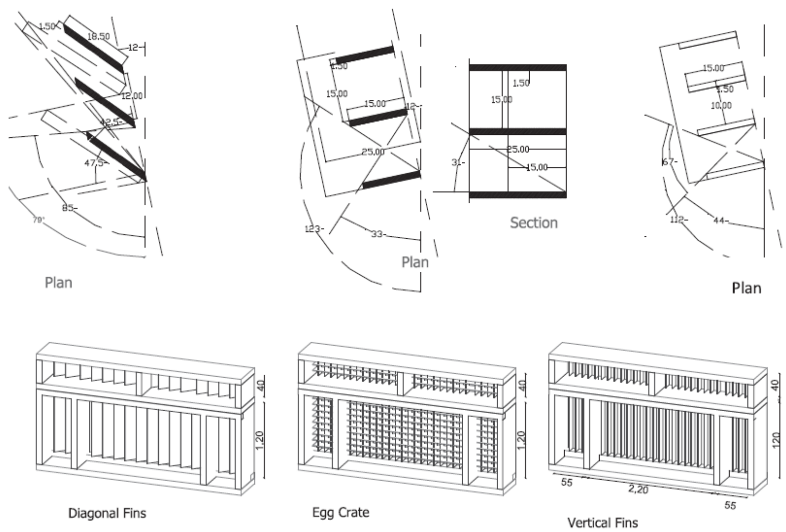

Figure 2.4 Types of shading devices installed for the tested building. (Freewan, 2014)

Starting from the left;

1. Diagonal fins: the fins are angled in order to control direct sunlight, but they almost block all the view.

2. Egg crate: it consists of both vertical and horizontal fins with small spacing in between in order to allow view to outside.

3. Vertical fins: the fins are vertical with spacing in between that allow view to outside.

However, the main objective of shading devices is to control direct sun radiation while maintaining thermal comfort besides introducing enough daylight for inner spaces while avoiding overheating. Moreover, shading devices' type and dimensions should be designed as an integrated part of the openings and fenestration system for the building in order to achieve the balance between the various requirements such as; day lighting, heat gain, maintaining the view and improving occupants performance.

In the case study, offices facing southwest have been selected to implement the study on. The study was conducted in two stages;

1. The first stage: fixed shading devices with temporary materials had been used.
2. The second stage: fixed shading devices with permanent materials had been used.

Both stages experiments all the three types of shading devices with specific features like spacing and angle for both vertical and horizontal parts. These features have been summarized in Table (2.4).

Table 2.4 Features of shading devices in stages 1 and 2. (Freewan, 2014)

	Vertical parts		Spacing		Angle		Horizontal part		Spacing	
	1st stage (cm)	2nd stage (cm)	1st stage (cm)	2nd stage (cm)	1st stage	2nd stage	1st stage (cm)	2nd stage (cm)	1st stage (cm)	2nd stage (cm)
Diagonal	30	18	17	12	45°	47.5°				
Egg crate	10	15	10	15	0	0	10	25	10	15
Verticals	15	15		10	0	0				

Comparing the results of offices with shading devices with the ones without shading devices, the results show that offices with vertical shading devices witnesses air temperature reduction by up to 6% in the afternoon in summer. While diagonal fins reduced air temperature by up to 19% in the afternoon in summer. While finally the egg-crate reduced air temperature by up to 10% in the afternoon in summer.

Moreover, thermal image analysis has been done to show the distribution of temperature in the examined offices. The analysis showed clearly that diagonal fins are the most effective way to prevent solar radiation from interning inner spaces as shown in Figure (2.5).

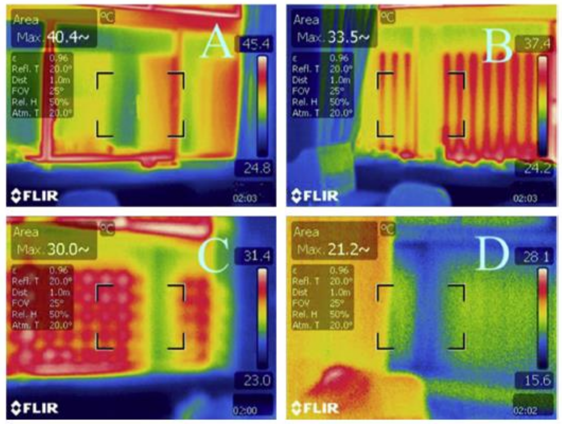

Figure 2.5 Thermal images of the offices (A) base case, (B) vertical fins, (C) egg crate and (D) diagonal fins. (Freewan, 2014)

Another study for (Al-Taamimi & Fadzil, 2011), took place in Malaysia which is a tropical country. Malaysia is a hot humid country with abundant rainfall along the year. The case study has been analyzed using computerized building simulations which is Integrated Environmental Solutions (IES-VE) in order to get accurate outputs. However, various models for external shading devices had been included in the study as shown in Figure (2.6) in order to be compared with the base model as shown in Figure (2.7).

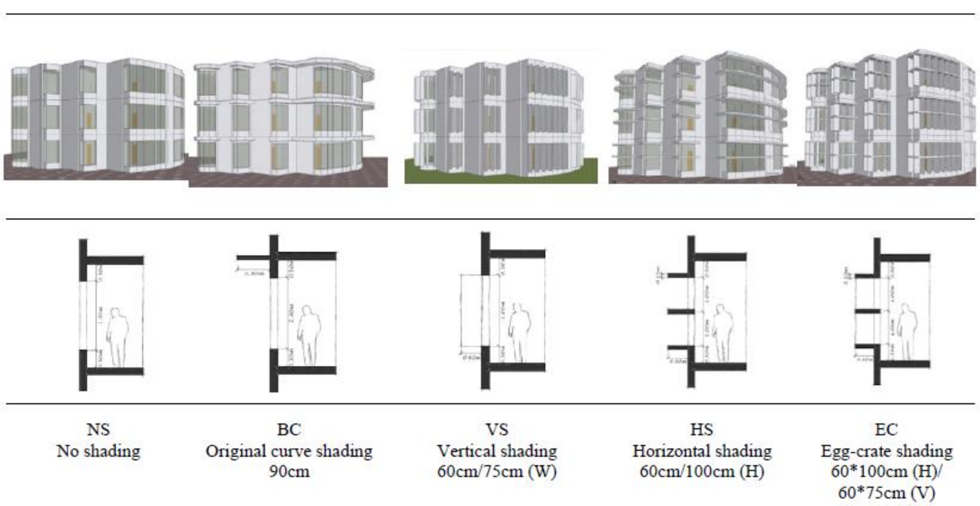

Figure 2.6 The alternative designs for the three types of shading devices. (Al-Taamimi & Fadzil, 2011)

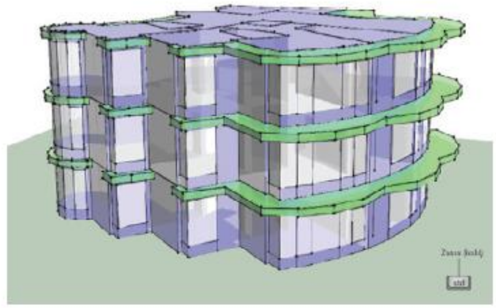

Figure 2.7 Base case model using ISE-VE software. (Al-Taamimi & Fadzil, 2011)

The analysis of shading devices efficiency on the indoor temperature took into consideration the following parameters:

1. The minimum, maximum, and mean air temperature along the year.
2. The duration of indoor air temperature that recorded above the comfortable temperature in the country.

Tables (2.5 and2.6) and Figures (2.8 and 2.9) below summarize the outputs of the analysis, both tables show the duration of comfort hours and the percentages to the total annual hours. However, the results show a high improvement that reaches up to 117% in the egg-crate shading, while both horizontal and vertical shading devices showed improvement comparing to the base model but does not have that much difference comparing to each other. The study showed that the maximum improvement in the comfort hours was achieved using egg-crate shading device.

Table 2.5 Yearly effect of shading devices on improving indoor temperature in unventilated room. (Al-Taamimi & Fadzil, 2011)

Code	Shading System	Number of Hours < 28.6 °C			% hours of T_c/year		
		Full Day	Daytime	Nighttime	Full Day	Daytime	Nighttime
NS	No Shading	1821	683	1138	20.8%	15.6%	26.0%
BC	Base Case	3135	1098	2037	35.8%	25.1%	46.5%
VS	Ver. Shading	3171	1135	2036	36.2%	25.9%	46.5%
HS	Hrz. Shading	3319	1184	2135	37.9%	27.0%	48.7%
EC	Egg Crate	3947	1408	2539	45.1%	32.1%	58.0%
	T_o	5969	2366	3603	68.1%	54.0%	82.3%

Table 2.6 Yearly effect of shading devices on improving indoor temperature in ventilated room. (Al-Taamimi & Fadzil, 2011)

Code	Shading System	Number of Hours < 28.6 °C (Tc)			% hours of Tc/year		
		Full Day	Daytime	Night time	Full Day	Daytime	Night time
NS	No Shading	5295	1674	3621	60.4 %	38.2 %	82.7 %
BC	Base Case	5619	1850	3769	64.1 %	42.2 %	86.1 %
VS	Ver. Shading	5655	1877	3778	64.6 %	42.9 %	86.3 %
HS	Hrz. Shading	5848	1995	3853	66.8 %	45.5 %	88.0 %
EC	Egg Crate	5868	1949	3919	67.0 %	44.5 %	89.5 %
T_o		5969	2366	3603	68.1 %	54.0 %	82.3 %

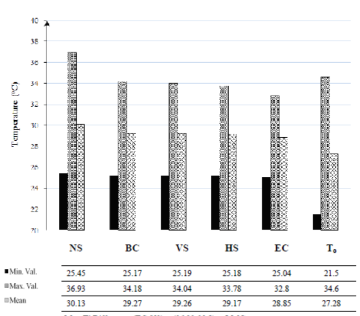

Figure 2.8 Yearly minimum, maximum and mean temperatures with different shading devices in unventilated room. (Al-Taamimi & Fadzil, 2011)

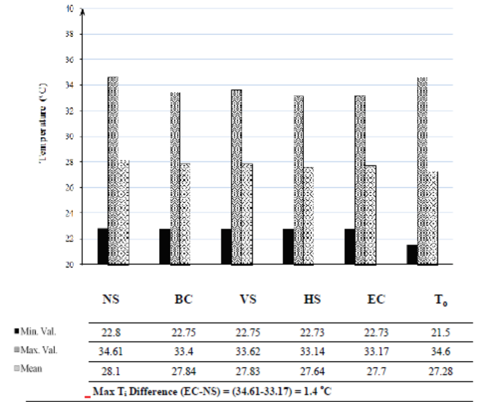

Figure 2.9 Yearly minimum, maximum and mean temperatures with different shading devices in ventilated room. (Al-Taamimi & Fadzil, 2011)

Therefore, shading devices like egg-crate, lovers and overhangs must be encouraged as essential architecture elements in order to protect the indoor environment, building envelopes and occupants from excessive solar radiation especially in hot regions.

2.8.4. Insulations

In the last century, building's energy demand for heating and cooling has been increased all over the world (Nematchoua, et al., 2015). According to (Biswas, et al., 2016), taking commercial buildings into account, 29% of the energy used on site is consumed for space cooling and heating. Therefore, buildings should improve it thermal resistance in order to reduce heating and cooling loads. Thus, some construction materials with low thermal conductivity have been appeared such as insulations (Moretti, et al., 2016). Using insulation materials in buildings is an effective technique to reduce energy consumption for cooling and heating. At the same time, it limits building's negative environmental impact. According to (Uygunoglu, et al., 2016), in cases were buildings are properly designed and constructed, insulation materials can contribute to energy savings up to 60% for cooling and heating loads.

A study for (Uygunoglu, et al., 2016) in Turkey examined four types of insulation materials which are; rock-wool (RW), gray- expanded polystyrene foam (gray-EPS or graphite added EPS), white-EPS and extruded polystyrene (XPS) since they are the mostly used ones in Turkey. However, Table (2.7) below represents the characteristic properties of these insulation materials.

Table 2.7 Properties of EPS, XPS and RW. (Uygunoglu, et al., 2016)

Properties	Grey-EPS	White-EPS	XPS	Rock-Wool
Thermal conductivity, W/m K	0.035	0.035	0.034	0.040
Density, kg/m^3	16	16	25	15
Compressive strength, kPa	60	60	200	1.0
Water vapor diffusion resistance, μ	40	40	100	1.0
Water absorption, %	5.0	5.0	3.0	12.0
Building material class (EU)	B1	B1	B1	A

Afterwards, these insulation materials have been exposed to cold and hot environments that had been set to be 0° C and 40° C respectively for three days. Coefficient of thermal conductivity (U) that has a unit of (W/m^2 K).and thermal resistance (R) that has a unit of (m^2 K/W) have been measured using Equations 1 and 2 as shown below. While after 28 days, the four samples were subjected to flame testing.

$$R = R_i + R_n + R_e \tag{1}$$

$$U = 1/R \tag{2}$$

The results of the experiments showed a number or results; first, that the different types of tested insulation have different adhesion strength of the mortar in the plaster, these differences are related directly to the thickness of the plaster as shown in Figures (2.10 and 2.11) below.

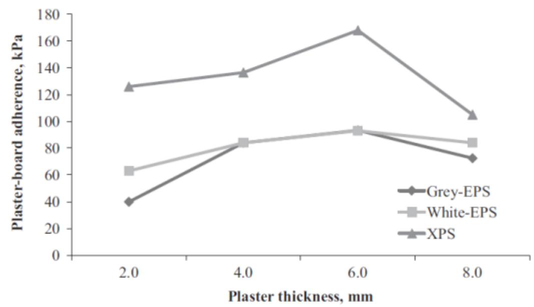

Figure 2.10 Adherence of plaster on insulation board. (Uygunoglu, et al., 2016)

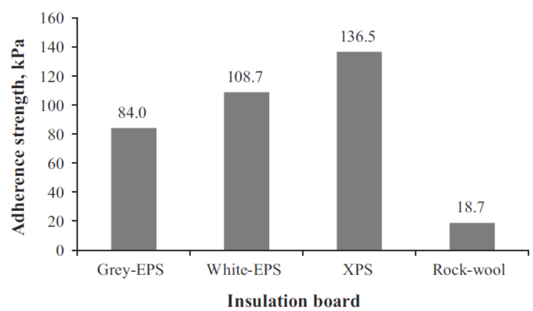

Figure 2.11 Comparison of adherence strength for each insulation board. (Uygunoglu, et al., 2016)

The second result was that as low as the coefficient of thermal conductivity is, as high as thermal resistance of the insulation is. Table (2.8) below represents the measurements of the different tested insulation boards.

Table 2.8 Thermal performance of insulated walls. (Uygunoglu, et al., 2016)

Wall-coating	Wall thickness, m	Thermal resistivity, R (m^2 K/W)	Thermal transmittance (Exp.), U (W/m^2 K)	Thermal transmittance (TS 825), U (W/m^2 K)
Uncoated	0.19	0.485	2.06	2.11
White EPS	0.25	2.06	0.48	0.542
Grey EPS	0.25	2.12	0.471	0.52
XPS	0.25	2.31	0.43	0.497
Rock-wool	0.25	2.10	0.476	0.531

The third result was that fire durability is related directly to the thickness of the plaster for the different types as shown in Figures (2.11 – 2.15).

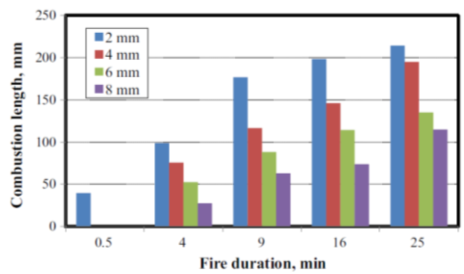

Figure 2.12 Combustion length of plastered white EPS after fire. (Uygunoglu, et al., 2016)

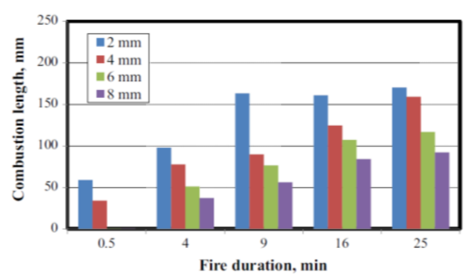

Figure 2.13 Combustion length of plastered grey EPS after fire. (Uygunoglu, et al., 2016)

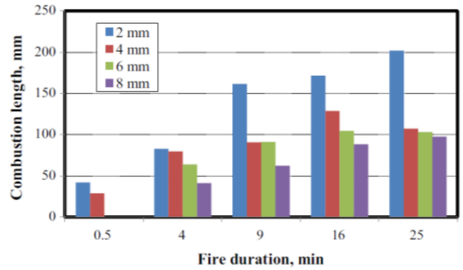

Figure 2.14 Combustion length of plastered XPS after fire. (Uygunoglu, et al., 2016)

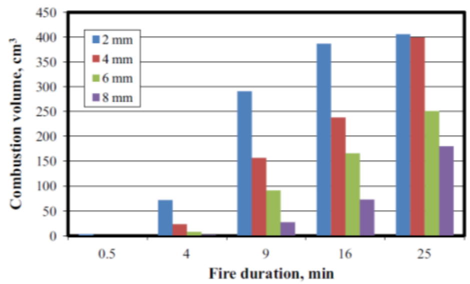

Figure 2.15 Combustion volume of plastered white EPS after fire. (Uygunoglu, et al., 2016)

2.8.5. Solar Heat Gain Coefficient (SHGC) of Glazing

Windows are considered as an essential element in the building because it provides air ventilation, day lighting, vision, passive solar gain and escape opportunity in emergency situation. However, windows play a major role in energy consumption for buildings due to it high U-values in contrast to other building's elements. Therefore, the ability to reduce the U-value of the windows means the ability to decrease heat transmission into the building, and this could be achieved using efficient technologies for windows (Cuce & Riffat, 2015). Heat exchange between occupants and windows occurs in three ways which are;

1. Long-wave: where the heat exchange takes place between the window inside surface and the human body.

2. Short-wave: in other term solar radiation which penetrates out of the layers of the glass and hits the human body.

3. Cold air leakage from windows.

(Mingotti, et al., 2013) compared both single glazed window and double glazed window, Figure (2.16) below shows heat transfer process through both types of glazing. However, the study showed that in colder season, single glazing has more convictive heat loss from the inner space to the outer spaces while in warmer season, it has more convictive heat gain form outer spaces to the inner due to the smaller thermal buffering when comparing to double glazing as shown in Figure (2.17).

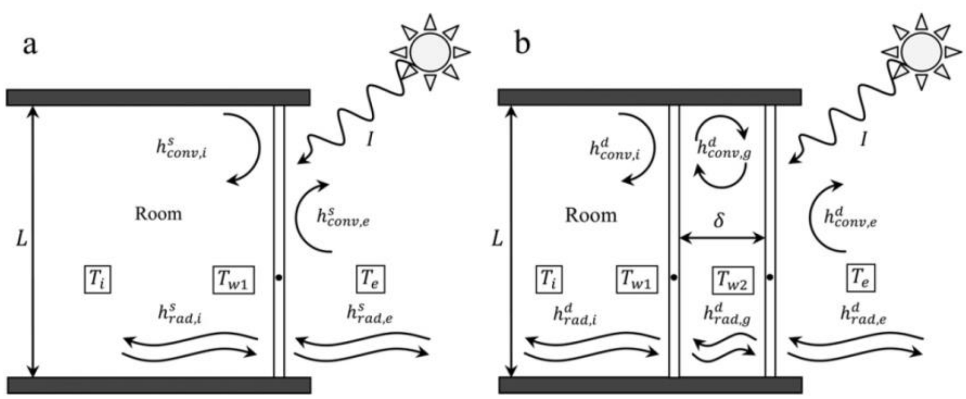

Figure 2.16 Heat transfer processes; (a) single glazed and (b) double glazed. (Mingotti, et al., 2013)

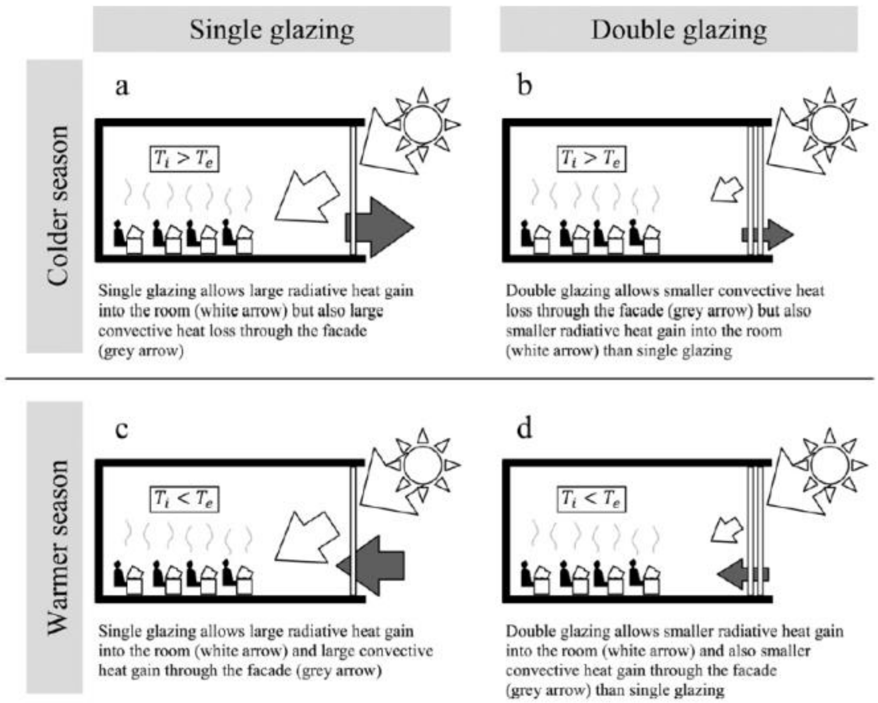

Figure 2.17 Relative heat fluxes through single glazed and double glazed in colder and warmer seasons. (Mingotti, et al., 2013)

According to (Cuce & Riffat, 2015), there are different parameters that affects the performance of the windows as shown in Figure (2.18).

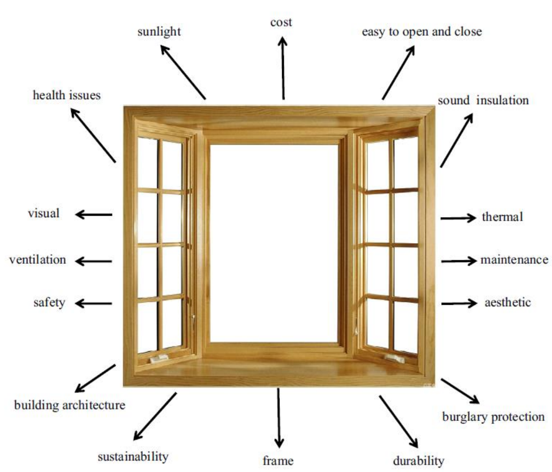

Figure 2.18 Parameters that affect the window design and performance. (Cuce & Riffat, 2015)

However, (Cuce & Riffat, 2015) in their paper summarized various types of glazing with their specific properties as shown in Figure (2.19) and Table (2.9) below.

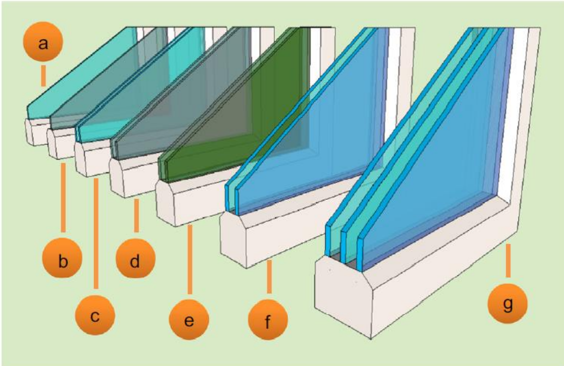

Figure 2.19 Different types of glazing for windows; (a) single clear glass, (b) single glazing with gray tint, (c) double clear glass, (d) double glazing with gray tint, (e) double glazing with selective tint, (f) double glazing with low-e and (g) triple glazing with low-e. (Cuce & Riffat, 2015)

Table 2.9 Performance parameters for different types of glazing. (Cuce & Riffat, 2015)

Window	Glazing type	*U*-value (W/m^2 K)	SHGC	VT
A	Single, clear	0.84	0.64	0.65
B	Single, tint	0.84	0.54	0.49
C	Double, clear	0.49	0.56	0.59
D	Double, tint	0.49	0.47	0.44
E	Double, high performance tint	0.49	0.39	0.50
F	Double, high solar gain, low-e	0.37	0.53	0.54
G	Double, moderate solar gain, low-e	0.35	0.44	0.56
H	Double, low solar gain, low-e	0.34	0.30	0.51
I	Triple, moderate solar gain, low-e	0.29	0.38	0.47
J	Triple, low solar gain, low-e	0.28	0.25	0.40

While taking a double glazed window into consideration, it has good acoustic and thermal properties and might considered as the best option in many cases. Although more than three layers of glazing could be used, it could be impractical due to it high cost, weight and increased size. However, Figure (2.20) below represent heat transmission through double glazed window.

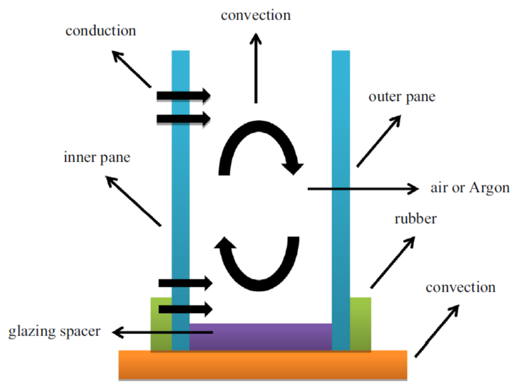

Figure 2.20 Schematic for a double glazed window. (Cuce & Riffat, 2015)

However, as shown in Figure (2.18) earlier, the frame of the window is one of the parameters that affect the performance of the window. Therefore (Cuce & Riffat, 2015) studied and summarize the properties of the frames as shown in Figure (2.21) and Table (2.10).

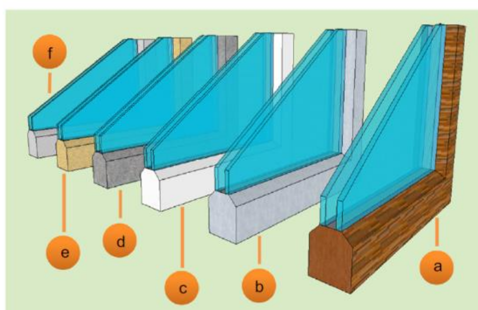

Figure 2.21 Different types of window's frame; (a) wooden frame, (b) aluminum frame, (c) Vinyl frame, (d) clad frame, (e) hybrid frame and (f) fiberglass frame. (Cuce & Riffat, 2015)

Table 2.10 Performance parameters of different types of frames. (Cuce & Riffat, 2015)

Window	Glazing type	Frame type	*U*-value ($W/m^2 K$)	SHGC	VT
A	Double, low solar gain, low-e	Aluminum	0.59	0.37	0.59
B	Double, low solar gain, low-e	Aluminum break	0.47	0.33	0.55
C	Double, low solar gain, low-e	Wood/wood clad	0.34	0.30	0.51
D	Double, low solar gain, low-e	Vinyl	0.34	0.30	0.51
E	Double, low solar gain, low-e	Insulated fiberglass	0.26	0.31	0.55

Furthermore, (Cuce & Riffat, 2015) studied advanced glazing types such as; multi-layer glazing, suspended films, vacuum glazing. Different types of each category have been studied and summarized with their specific properties as shown in Tables (2.11 – 2.13).

Table 2.11 Performance parameters for different types of multilayer glazed windows. (Cuce & Riffat, 2015)

Multilayer glazing type	*U*-value ($W/m^2 K$)	SHGC	VT
AGC GlassUK Top N^+	0.70	0.50	0.48
GURDIAN Flachglas Gmbh ClimaGuard N^3	0.72	0.49	0.54
GURDIAN Flachglas Gmbh ClimaGuard N	0.71	0.50	0.53
INTERPANE Glas Industrie AG Iplus 3CE	0.71	0.49	0.47
INTERPANE Glas Industrie AG Iplus 3CL	0.72	0.53	0.55

Table 2.12 Examples for suspended glazing and their properties. (Cuce & Riffat, 2015)

Manufacturer	Product	*U*-value ($W/m^2 K$)	SHGC	VT
Serious materials	1125 Picture window	0.28	0.17	0.23
Visionwall Solutions Inc.	Series 204 4-Element Glazing System	0.62	0.30	0.50

Table 2.13 Thermal characteristics of SPACIA-21 vacuum glazing. (Cuce & Riffat, 2015)

Manufacturer	Product	*U*-value ($W/m^2 K$)	SHGC	VT
Pilkington	SPACIA-21	0.70	0.32	0.53

1.7. Active design strategies

2.9.1. Photovoltaic (PV) cells

Since the mid of 1950s, solar photovoltaic energy has been decisive relevance application when scientist built the first solar panels in the United States with an efficiency of 5% to 6% (Meneguzzo, et al., 2015). However, the amount of energy generated in form of heat and electricity from solar energy has been doubled in the period between 1990 to 2000 (Rodziewicz, et al., 2016).

Solar energy is an unbounded reservoir of energy. Solar radiation emissions has a power of 4×10^{20} MW while the averaged value of the solar radiation intensity reaching the upper atmosphere of the earth is 1367 W/ m^2, which means that 10^{18} kWh/year reaches the earth which is greater than the energy produced by the fossil energy resources. As shown in Figure (2.22) below, when comparing reserves if fossil fuels with energy consumption, fossil fuels are limited and can be depleted in short period of time which ranges between three to four generations only. Therefore, in order to cover the demand of energy, human-kind should search for other sources of energy. However, Figure (2.22) shows that renewable resources of energy are much greater that our consumption, at the same time, these resources have much higher potential than our needs although the efficiency of such types of resources is sometimes about 10% (Rodziewicz, et al., 2016).

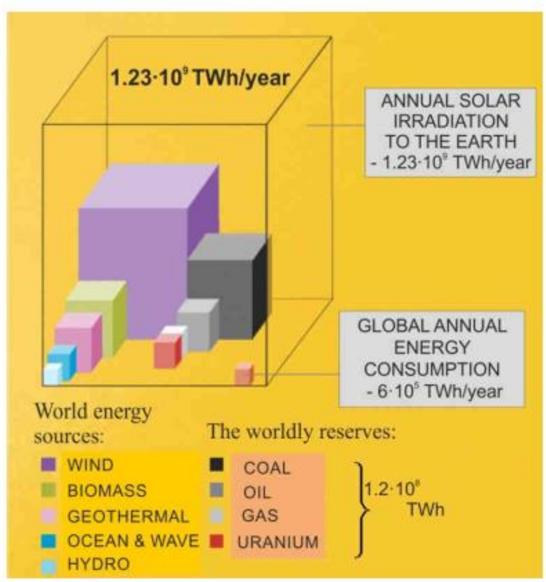

Figure 2.22 Available energy resources. (Rodziewicz, et al., 2016)

2.9.1.1. Types of PV

A comparative study for (Vieira, et al., 2016) compares between static and mobile PV panels. Static PV panels used to be positioned with a certain angle depending on the location, while after introducing mobile PV cells the power generation have been improved through the system by 50%. Solar trackers mainly comes in two types based on the freedom and degrees of movement, either single-axis tracker or dual-axis tracker. However, the study took place at Mossoro city in Brazil. The city is located in semi-arid region with very hot and dry weather conditions in summer. As mentioned above, the paper analyze two types of PV; a fixed solar panel and a sun tracking solar panel using one-axis tracking system that moves on east-west direction. Figure (2.23) below represents the two analyzed solar systems. As shown in the figure, both generate current, voltage, solar radiation and temperature. The collected data is directly sent to the controller where it stored and sent to a computer. While in sun tracking system, in case if the controller didn't captures the maximum solar radiation, it sends a signal to the motor installed in order to measure the variables and re-position the panels.

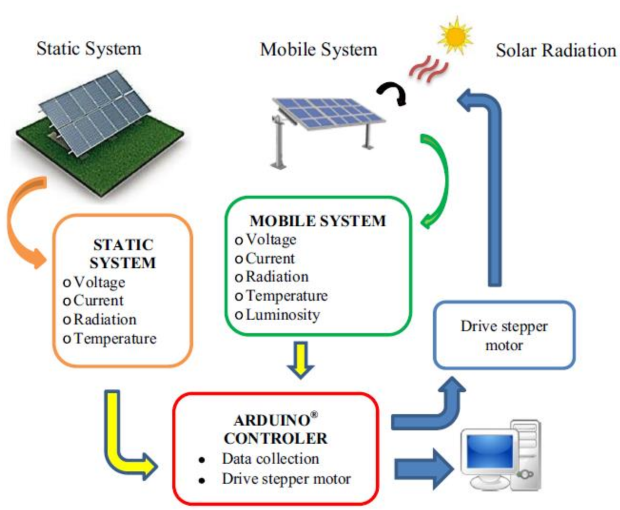

Figure 2.23 Analyzed system layout. (Vieira, et al., 2016)

Moreover, another study for (Visa, et al., 2016) compares five types of PV modules while taking into consideration the efficiency, electrical input and efficiency's relative loss based on temperate climate parameters. The five types of PV modules which are; mono-crystalline, poly-crystalline, Cadmium Telluride (CdTe), Copper Indium Selenide (CIS) and Copper Indium Gallium Selenide (CIGS) have been mounted for over fourteen months on two platforms; P2 and P4, close to a number of buildings as shown in Figure (2.24).

Figure 2.24 Platform P2 with five types of PV modules. (Visa, et al., 2016)

Furthermore, the five types of PV modules were installed with Standard Testing Conditions (STC) parameters as shown in Table (2.14) below. While both platforms which have been used to install the PV modules on, were oriented 47° from the S-axis as shown in Figure (2.25).

Table 2.14 STC parameters of the five types of PV modules. (Visa, et al., 2016)

	p-Si	m-Si	CIGS	CdTe	CIS
Manufacturer	LDK	Heliene	Solibro	Calyxo	Avancis
Product code	LDK-250P-20	HEE215M	SL2-120	CX3 80	Powermax Strong 125
Peak power P_{max} [W]	250 (±3%)	250 (±3%)	120 (+4%)	80 (±5%)	125 (+4%)
Maximum voltage Vm [V]	30.2	30.8	76.9	47.0	43.8
Maximum current Im [A]	8.28	8.12	1.56	1.72	2.85
Open circuit voltage Voc [V]	37.5	37.4	97.6	62.8	59.1
Short circuit current Isc [A]	8.59	8.67	1.69	2.01	3.24
Nominal Efficiency [%]	17.12	17.94	13.54	11.89	13.04
Photovoltaic area of a module [m^2]	1.46	1.39	0.89	0.673	0.96
STC temperature coefficient of P_{max}, Eq. (7) β [$°C^{-1}$]	0.0045	0.0044	0.0038	0.0025	0.0039
No. of modules in a group	1	1	2	3	2
No. of modules on a platform	2	2	2	3	2

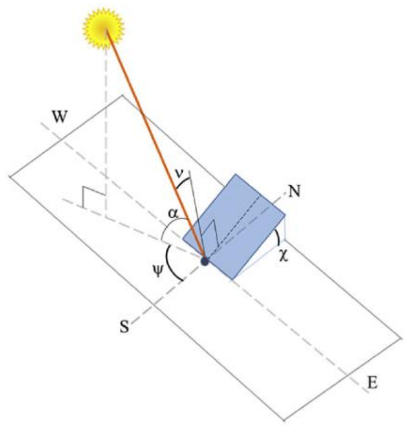

Figure 2.25 Angles used in the calculation process. (Visa, et al., 2016)

However, when taking the annual variation of the photovoltaic output into account, the results of the experiment showed that the electrical energy and solar input are matching with larger amounts during summer period comparing to winter period as shown in Figures (2.26a and 2.26b), while Figure (2.26c) indicates high efficiency values for both mono-crystalline and poly-crystalline while lower efficiencies for the rest as shown. And finally Figure (2.26d) which shows the relative losses in efficiency showed that for the three thin-film PV modules (CIS, CIGS and CdTe) have a relative constant efficiency, but only the CIGS readings indicates performance close to the nominal values. At the same moment, both CIS and CdTe have a relative loss that exceeds 15%. While both mono-crystalline and poly-crystalline readings showed small losses that ranges between 5% -10%.

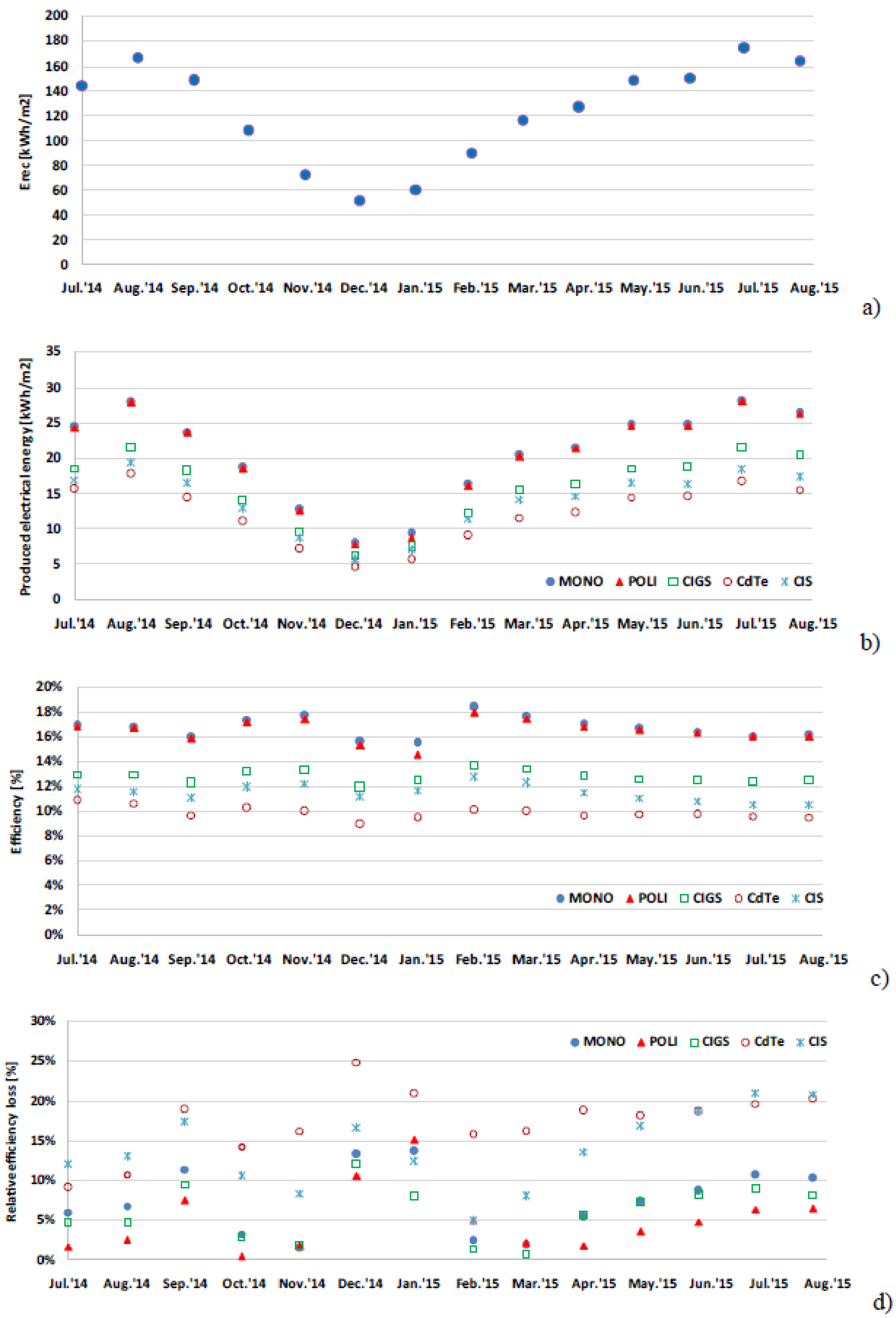

Figure 2.26 Monthly variation of the; (a) input solar energy, (b) output electrical energy, (c) outdoor conversion efficiency and (d) relative efficiency loss. (Visa, et al., 2016)

Moreover, the experiment proves that using PV modules that track the sun enhance the outputs. According to Figures (2.27 and 2.28), when comparing the results of static and dynamic panels, it shows that tracking increases the power outputs. In addition, it increases the constancy of the conversion efficiency values. This enhancement makes the system more predictable.

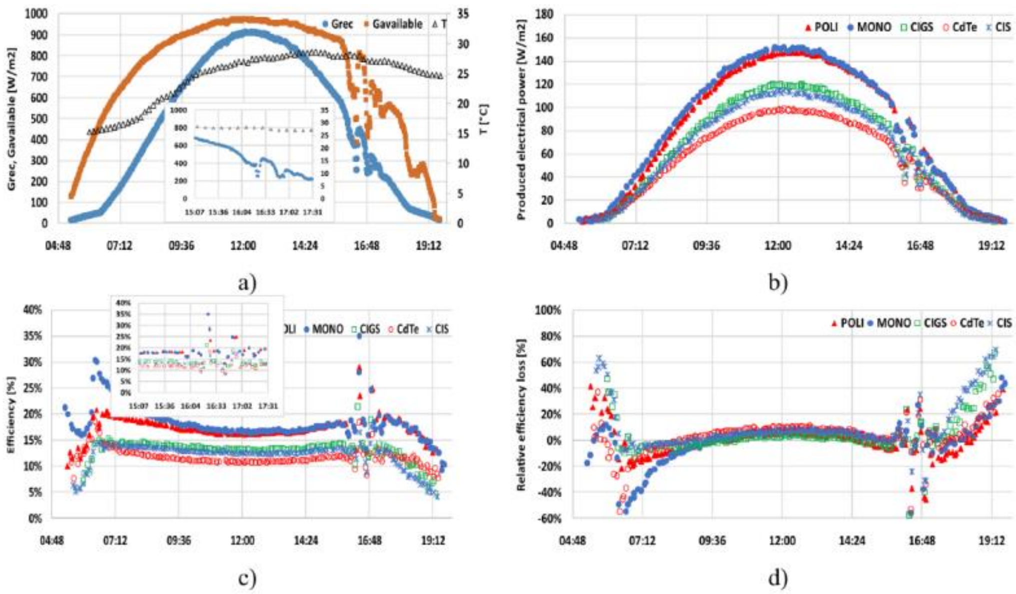

Figure 2.27 Instantaneous variation during 1 August 2014 of the; (a) incident/available solar irradiance and ambient temperature (b) photovoltaic power output, c) conversion efficiency and (d) relative efficiency loss. (Visa, et al., 2016)

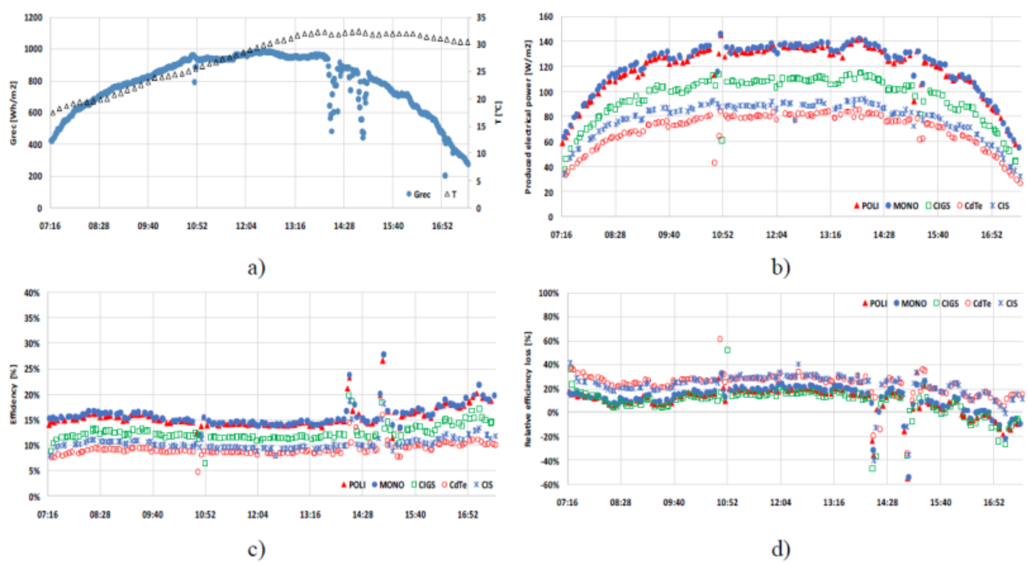

Figure 2.28 Instantaneous variation during 19 September 2015 of the; (a) incident/available solar irradiance and ambient temperature (b) photovoltaic power output, c) conversion efficiency and (d) relative efficiency loss. (Visa, et al., 2016)

2.9.2. Solar Domestic Water (SDW)

Using solar systems for water heating in a house is considered as one of the most effective ecological strategies. A study in South Eastern region of Romania by (Spiru, et al., 2000) resulted that using solar energy covers about 35% to 50% of the demanded thermal energy for water heating for the periods from January to April and October to December, while in the period from May to September it reaches 80% to 100%. This method reduces the costs for electricity used in water heating up to two thirds the traditional methods. Domestic Hot Water supply (DHW) is a perfectly viable solution, (Spiru, et al., 2000) described it as simple, ecological, reliable, inexhaustible and non-polluting. The features of SDW supply facilitate positive impacts such as energy savings and producing clean energy without waster or emissions.

SDW supply has been developed in order to serve different functions such as; individual residential buildings, complex of residential buildings, cultural buildings, accommodation buildings and swimming pools. Moreover, the structural schemes of the system are drawn up in a way that makes it easy to respond to a different series of characteristics, users' requirements and criteria that are related to the building it serves, while the most important characteristics are as follow; the needs of hot water, location, climate, heat demand for the building, available equipments and financial resources. However, due to the increased cost of energy and taking into consideration the fact that the resources of fossil fuel are limited, the concept of using solar energy as renewable source of energy have become popular around the world since consumers realized the benefits of solar heating. A study for (Spiru, et al., 2000) shows a comparison between conventional systems and solar water heating systems as shown in Table (2.15).

Table 2.15 Comparison between solar water heating systems and conventional system. (Spiru, et al., 2000)

	Solar Water Heater	Gas or Electric Water Heater
Initial Investment	€1650 - €2600	€200 - €400
Annual Operating Costs	€30 - €45	€350 - €470
Typical Lifetime	15 - 40 Years	8 - 20 Years
Lifetime Operating Cost	€400 to €1600	€3000 to €9500
Total Lifecycle Cost	€2100 - €4300	€2800 - €9800
Emissions	Zero	Fossil Fuel Emissions
Return on Investment	10 to 30%	None

Since there are different types of solar systems, developers or consumers should select the system that suits their characteristics the best. (Spiru, et al., 2000) selected to study Junkers solar collector due to it high efficiency. Junkers FCB-1S solar collectors can ensure a minimum temperature of 45°C for domestic hot water. The type of system contains a solar collector plane, two pumps, reservoir for hot water storage, heat exchanger and an electric resistance that keeps the temperature of the tank 60°C minimum through the year. The two pumps are equipped with a temperature regulator that monitors the difference in water temperature in the heat exchanger (collector) and in the storage tank. The main parameters of the solar system are shown in Table (2.16).

Table 2.16 Specific parameters for Junkers collector. (Spiru, et al., 2000)

Junkers FCB-1S	Azimuth-South position	Optical efficiency η_0=0.69	Tilting 30°
Dimensions:	Length 2,023 mm	Width 1,030 mm	Thickness 75 mm
Loss coefficient k_1=4, k_2=0.17 in W/m^2K	Tank volume 200 l	Tank surface 2.7m^2	Collector surface 2.08m^2
Inlet temperature - collector 15°C	Outlet temperature 65°C	External temperature 15°C	Fluid flow 0.020kg/s per m^2

While a study for (Khan, et al., 2010) that took place in Bangladesh, chose 'Box-type flat plate collector'. The process of heating the water in this solar system is simple and effective. The collector receives the incident radiation, then converts it into heat and transfers it into working fluid.

Chapter 3
Methodology

3. Methodology

3.1. Introduction

Generally, the research begins by either worries or interests and then raising questions regard it. The types of questions besides how to collect, to analyze, to interpret and to answer the questions, all depends on the preferences and preconceptions such as the topic, the reason to study it, access to data, the context, the available resources, the determined energy to invest and the scheduled time. Substantially, there is no formula that fit all of these parameters in writing a research; almost any methodology can answer any question raised. However, distinguishing between ways to collect data and methods is needed. Ways to collect data are such as interviews, surveys and observation, while methodologies are the principles that influence and guide the choices. Therefore, methodology is concern about how the research is done, how the process of finding out things is done and how the knowledge and information have been gained (Hyland, 2016). Moreover, according to (Hyland, 2016) there are four major methods to collect data which are often used in all processes of the research as shown in Table (3.1) below, the table represents the method and it definition briefly.

Table 3.1 Major methods used in research writing. (Hyland, 2016)

Elicitation:	Ways of prompting self-report and performance data
Introspection:	Ways of collecting verbal or written reports by text users
Observation:	Direct or recorded data of 'live' interactions or writing behaviour
Text samples:	Collections of naturally produced samples of writing

3.2. Types of methodologies

The use of different options for research methodologies in a research can determine and improves the results of the paper. (Salzmann, et al., 2005) used different research options in order to seek for justification for sustainable strategies in the organizations ; they adopted literature review methodology to establish a theoretical framework, instrumental studies in order to either prove or disapprove the theory, descriptive studies for examination and finally using different tools. Moreover, (Wahyuni, 2012) discussed the different available research methodologies which enable the author to answer different research questions. The paper discusses in details the main elements of the case study besides the required data and methods to analyze the collected information. The paper helps researchers to determine which multi-methods could be considered in the research.

3.2.1. Literature reviews methodology

Literature review methodology could be approached in various ways and for various purposes. According to (Hyland, 2016), Literature review is about looking at different choices with different systems, practices and ideologies, then linking it with other papers. Broadly, literature reviews can be analyzed in two different ways. The first way is to look at as systems of forms and taking into account the pattern and the grammatical items to have a better understanding about the regularities found in the text. The second way which is commonly used, texts are handled as discourse, or based on how it work to communicate in such framework. In this case, the texts are handled as resources that will be able to achieve author’s goals (Hyland, 2016).

However, (Luederitz, et al., 2016) states that literature review methodology have step by step guide which consists of six phases; project initiation, project framing, review procedure, data analysis, results framing and article finalization. Figure (3.1) below summarize the definition and the responsibilities of each phase.

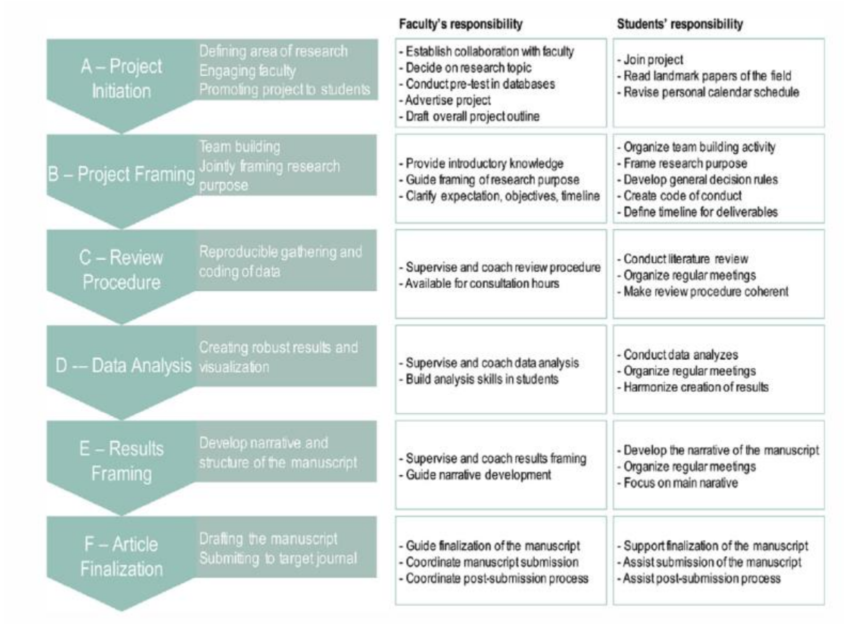

Figure 3.1 Six phases for organizing student-driven literature review projects. (Luederitz, et al., 2016)

Many researches adopted literature review methodology in defining ZEBs. (Marszal & Heiselberg, 2011) defined different definitions for ZEBs using literature review methodology, the paper discussed different definitions of ZEBs written by different authors previously and then defining the main four different definitions of NZEBs which are Net Zero Site Energy, Net Zero Source Energy, Net Zero Energy Cost and Net Zero Energy Emissions, and finally stating the advantages and the disadvantages of each type. As will as (Pless & Torcellini, 2009) whom also defined the four types of NZEB using literature review methodology. The paper also discussed different countries' point of view regard NZEBs and the actions they are planning to take regard it. Another paper for (Pless & Torcellini, 2010) investigates the classification of NZEB based on the renewable energy supply option; wither it is on site or off site, besides explaining examples, the techniques, the advantages and the disadvantages. Moreover, (Marszal, et al., 2010) adopted literature review methodology in reviewing national building codes for eight different countries in Europe and then discussed the different methodologies they are adopting regard generating renewable energy.

3.2.1.1 Pros and cons of Literature reviews methodology

Literature reviews methodology can provide a generous knowledge and a wide background regard the research question; it helps in defining different terminologies and problems that are related to the research.

However, since literature reviews are usually found in books, theses, journals, publications, websites and conferences, sometime it is difficult to find these references especially when the research question is very specified like addressing certain problem in certain area and time or when the research question is new or looking forward to the future. Therefore, the lack of resources could be a disadvantage for such type of methodology. Moreover, since literature review usually comes in theoretical format, it is very likely to have a problem with plagiarism.

3.2.2.Experimental methodology

Experimental methodology is used to discover the impact of specific thing on another thing. This methodology is a constructive method where the researcher interferes in order to examine a theory by studying and insulating a monocular feature under streaked conditions. In a simple way, the methodology involves stratifying some remediation to one of two groups while keeping the other factor as constant. After that, both groups are tested to check wither the effect of the remediation and the statistical examination are showing a variation between the experimental groups and the control are significant or not. However, using examination measurements has to be monitored carefully in order to increase the accuracy and to minimize the threats to the reliability which will affect the validity of the research consequently (Hyland, 2016).

(Lenior, et al., 2011) experimented NZEB in the French tropical Island of La Reunion which is located in the Indian Ocean. The experiment investigated the air-speed, visual and thermal comfort in the island. (Uygunoglu, et al., 2016) experimented the performance of four different types on insulations in Turkey. The experiment showed how far the conductivity and the thickness of each type of insulation material impacts the heat gain and fire resistance. (Mingotti, et al., 2013) experimented two types of windows which were single glazed and double glazed. The experiment showed how much does the number of layers impact heat loss and heat gain. (Cuce & Riffat, 2015) investigated how does the number of layers for a window and the type of the used frame affect heat loss and heat gain through a window using experimental methodology.

3.2.1.1 Pros and cons of experimental methodology

Experimental methodology can help in proving the author point of view. During the experiment, the researcher has a control over the variables and it can be combined with different methods for better improvement. In addition, it could be much specified in some cases since it examine a certain object under a specified conditions like the time and location.

However, experimental methodology does have disadvantages that could reduce it credibility in some cases such as human errors, producing artificial results, the difficulty to measure human response and intruding the researcher’s personal perspective. Moreover, in some cases it might be difficult to replicate on other situations (ColoradoStateUniversity, 2016).

3.2.3.Case studies methodology

According to (Hyland, 2016), a case-study is an instance in action’ which means characterizing what a particular condition is seems to be by understanding the reality of entrants’ thoughts and experiences about a specific situation. Typically, a case study combines methods to discover specific bounded phenomena. Most of the case studies are aiming to gain more clear understanding regard process, context, person, group or situation rather than referring to generalizations, although it is allowed to be used. Essentially, this type of methodology combines a rich characterization of events with illustrative analysis that takes into account participants' perspective.

However, (Bullis, 2009) investigated Masdar City in Abu Dhabi in The UAE. The study covered almost everything about this green city; such as the master plan and the transportation. (Meltzer, et al., 2014) discussed energy consumption in Qatar and the gulf countries besides discussing alternative renewable energy resources. (Al-Taamimi & Fadzil, 2011) discussed the types of shading devices in a high rise building in Malaysia, and the impact on day-lighting and heat gain, after that the paper continued the discussion further for other recommended shading devices using simulation methodology. (Freewan, 2014) investigated the used types of shading devices in an existing university campus in Jordan and its impact on day-lighting and heat gain inside the offices, the researcher then proved the results using simulation methodology. (Radhi, 2009) studied the impact of global warming on a residential building in Al-Ain in The UAE. The study assesses the impact of global warming on the air conditioning system of the building which will subsequently lead to increase the amount on CO_2 emissions. The researcher also studied the impact of the window area on CO_2 emission. (Elminir, et al., 2006) studies the performance of a solar flat-plate collector on a building in Egypt. The researchers discussed the optimum slope that allows getting the maximum solar energy.

3.2.2.1 Pros and cons of case studies methodology

Case studies methodology can provide a detailed investigation for a certain problem. According to (Hsieh, 2002) case studies methodology is flexible, it allows the researcher to select the topic and then decide the boundaries.

However, in most cases it can't be generalized to a larger scale. In addition, it doesn't conduct empirical research and depends mostly on bias findings. Moreover, the reliability and the validity of the case study are influenced by the researcher's point of view, which means that findings are affected by the researchers and might be differ from one to another (Hsieh, 2002).

3.2.4.Simulation methodology

According to (Belton, 2016), simulation methodology has become a very important method for some types of studies such as, education, industry and engineering; although in most cases there are no evident theoretical frameworks. Moreover, simulation methodology is directly related to computing skills therefore it became an essential skill for some employability. In addition, (Barbaresi, et al., 2014) states that building simulations became a very efficient way to relay on in design decisions since it enables considering different system and materials solutions by optimizing both the energy consumption and the operation cost for buildings.

(Al-Taamimi & Fadzil, 2011) investigated in different types of shading devices on a high-rise building in Malaysia using simulation methodology. The researchers used Integrated Environmental Solutions - Virtual Environment (IES-VE) software in order to find out the minimum, maximum, and mean air temperature and the duration of hours where the indoor air temperature is exceeding the comfort level for each type of shading devices. (Freewan, 2014) supported his theory of the impact of the shading devices used in a university campus in Jordan on day-lighting and heat gain using simulation methodology. The researcher used IES-VE software in order to find the amount of penetrated daylight and heat. (Hammad & Abu-Hijleh, 2010) investigated the impact of external louvers on the energy performance for a building in Abu Dhabi in The UAE. The researchers used IES-VE software to find out the relation of saved energy for the building and the different orientation of the louvers.

3.2.3.1 Pros and cons of Simulation methodology

Simulation methodology is considered as cost effective since examining an object could be done through a computer model rather than producing it in order to test it. It allows the researcher or the developer to test the object under different conditions freely. In addition, it can also provide a highly detailed model in order to get more accurate results (Davis, 2016).

However, simulations are subjected to errors. The input data are very sensitive and can affect the reliability and the validity of the simulation model directly.

3.3. The selected methodologies

In order to answer the question of the research and to achieve aims and objectives of the research, two main methodologies have been adopted; Literature review and simulations. The research conducted literature review methodologies mostly in the introduction, literature reviews and methodology chapters in order to provide better understanding for the different terminologies discussed in the paper. Moreover, literature review methodology will allows establishing clear framework for the research which will help the author to build the rest of the research besides clarifying the concept and the idea of the research for the readers. In addition, the research is depending highly on the simulation methodology. All the processes starting from analyzing the existing villa to pushing the villa into NZEB will be based on the simulation analysis. Therefore, the selected software to run the simulation should be selected carefully in order to achieve the objective of the research,. while some parts of the paper adopted other methodologies such as; case study methodology and experimental methodology. Some of the literature reviews that have been discussed in this paper earlier adopted case study methodology to provide more clarification and understanding about the concerned topic by discussing a lived experience. While this paper is adopting case study methodology in analyzing the current condition of the existing villa beside the energy consumption, thermal comfort and available passive strategies for the villa. Moreover, the research is adopting experimental methods in analyzing the existing villa in addition to the proposed scenarios. The method will support the comparison process between all the scenarios by isolating different feature each time and testing it then comparing the results. Moreover, experimental methodology had been used a lot earlier in the literature review chapter by different authors to support their point of perspective and to conclude the result.

3.4. Software's

There are different that could be used to analyze the performance of a building besides the energy consumption of a building. However, this research is considering Integrated Environmental Solutions - Virtual Environment (IES-VE) software in the analysis process. The reason of selecting this software is that IES-VE is considered as a world leader in performance analysis. Moreover, it have been used to design many energy efficient buildings globally. Many researchers proved their theories using IES-VE software, the software is able to read and understand many details that affect the performance of the building and the energy consumption.

IES-VE has many features that will help achieving the aims and the objectives of the research. The software will obtain results related to different aspects in each scenario such as;

1. A model for the existing villa will be built using the software; it will take into consideration all the elements in the villa besides the profiles of HVAC and lighting usage.

2. Energy consumption: the software will calculate energy consumption for each scenario which will subsequently help in comparing the results and finds ways of improvements.

3. Daylight and shading: once the software established a daylight and shading diagram, it will be used to set the timings where artificial lights are not needed in each scenario which will subsequently affect the energy consumption directly.

4. Insulations: the software will allow testing different scenarios regard insulations which will consequently affect the heat gain and energy consumption.

5. Energy generated by PV cells: the software is able to determine the generated energy by the selected PV cells. This feature will help in calculating the difference between the consumed and the generated energy which will consequently help in pushing the villa into NZEB.

Chapter 4
Computer Modeling

6. Computer modeling

4.1. Introduction

Achieving the goal of the research requires detailed study of the existing situation of the case study while taking into consideration all the aspects that influence or might influence the case. However, these data should be used to develop the concerned building in order to reach the desirable goal. Therefore in this chapter, a full analysis using IES-VE software will be run on the existing building to figure out the current status which will be used later on to compare with the proposed scenarios. Then, the same analysis will be run on all scenarios which are “AL SA’AFAT” rating system, until reaching the last scenario which is pushing the villa into NZEB.

However, ‘AL SA’AFAT’ rating system has many requirements that could not be implemented on IES-VE software. Therefore, the study will focus on the ones that could be implemented on the software in order to examine the efficiency of it on the building.

4.2. About the case study

The selected villa is located in Al-Qouz area in Dubai, occupied by local family. Table (4.1) below shows a list of information regards the case study. Moreover, Figure (4.1) shows the sitting layout plan for the plot, while Figures (4.2 and 4.3) shows the plans of the villa.

Table 6.1 Building's information

Building’s information	
Location	Al-Qouz , Dubai, United Arab Emirates
Building type	Residential
Year of completion	2012

Occupancy	4 Adults + 3 children
Plot area	1022 sq.m
Built up area	473.08 sq.m (ground floor= 231.03 sq.m , first floor= 242.05 sq.m)
Building height	G+1 (Maximum height = 12.4m)
Rooms	5 Bedrooms + Majlis + Living room + Kitchen

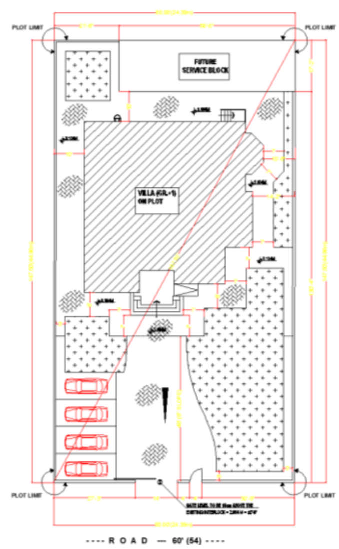

Figure 6.1 Sitting layout plan

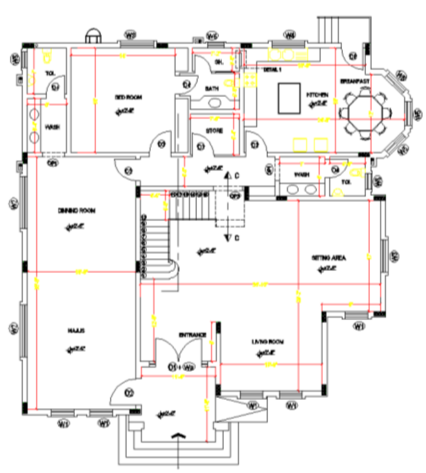

Figure 6.2 Ground floor plan

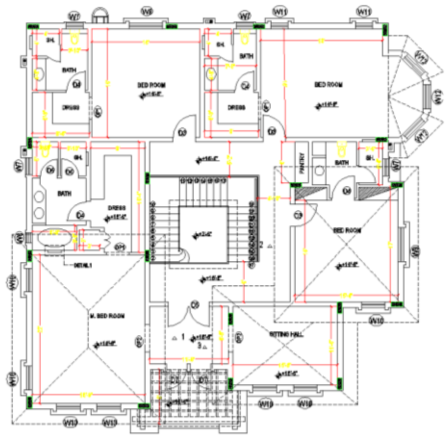

Figure 6.3 First floor plan

4.3. About the site

As mentioned previously, the selected existing villa is located in Al-Qouz area in Dubai. however, Al-Qouz area are divided into four smaller areas named Al-Qouz 1 to 4, and the selected villa is located exactly in al-Qouz 4 which have some features as mentioned below;

4.3.1. Building regulation

Al-Qouz 4 area is classified as a residential area for local families with building's maximum height of G+1 (Ground + 1 storey) and a setback of 3 meters from all directions for the main building which is the villa.

4.3.2.Sky condition

Dubai's sky is almost clear to mostly clear all the year, while it gets cloudiest in winter where the median cloud coverage reaches 25% as shown in Figure (4.4). However, Figure (4.4) shows that only 20% represents partly cloudy to overcast sky (Weather Spark, 2012).

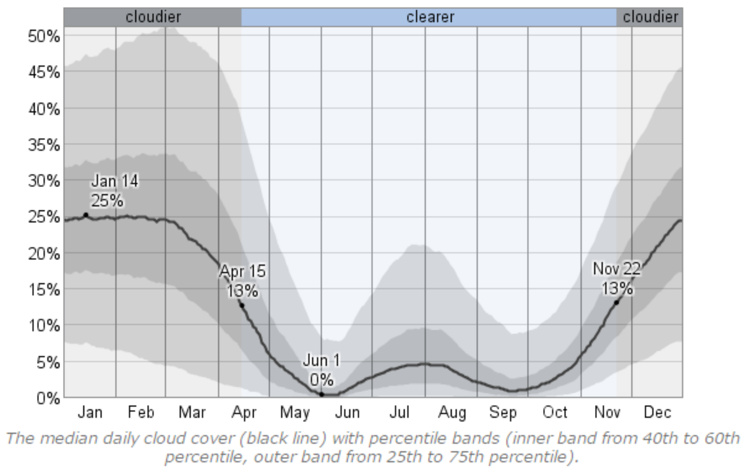

Figure 6.4 Median cloud cover. (Weather Spark, 2012)

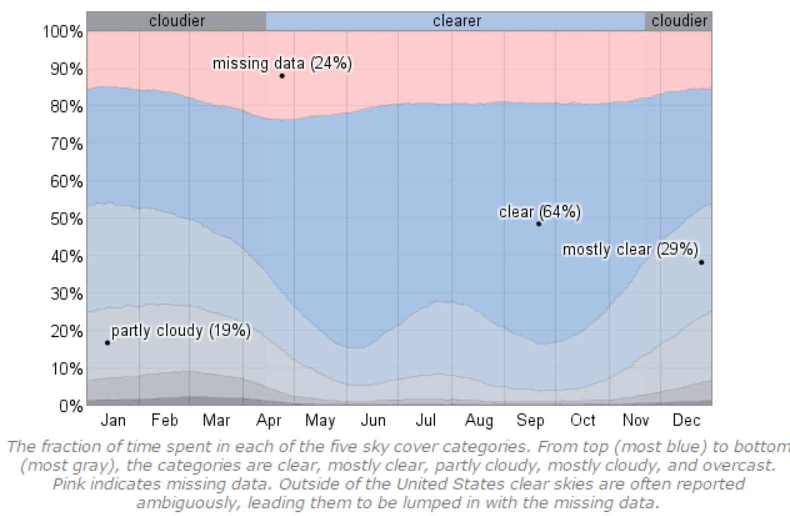

Figure 6.5 Cloud cover types. (Weather Spark, 2012)

4.3.3.Day-lighting

Availability of daylight is usually affected by the season in all climatic zones. Fortunately, in Dubai there is no big difference in the duration. As shown in Figure (4.6), during summer the daylight is available for about 13 hours a day, while in winter is 10 hours and both spring and autumn is 12 hours.

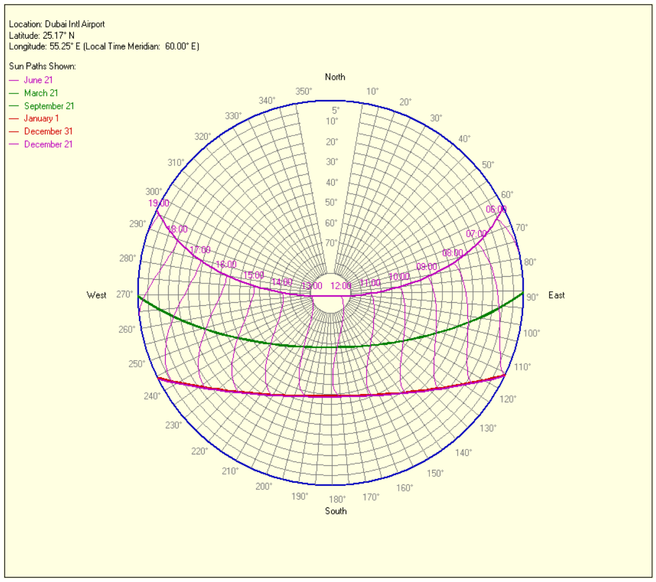

Figure 6.6 Sun path for Dubai (IES-VE).

4.3.4.Landscape and vegetation

Al Qouz 4 area has no special landscape or vegetation, all of the area is flat with the same topography level; only minor variation in the level is there and few vegetations could be found only inside the house yards while the outer spaces are either sand, paving or asphalt roads.

4.3.5.Surroundings

The selected villa is surrounded from three directions by other villas; all of the villas are G+1.

4.4. Scenario 1 – The basic scenario

The first scenario is representing the existing status of the villa. In this scenario, the model will be built in IES-VE as per the existing villa in the site, while taking into consideration the location, materials, walls, openings and slabs. Moreover, the readings of energy demand shown in the software will be compared to the one shown in Dubai Water and Electricity Association

(DEWA) bill in order to make sure that the model is representing the current status of the villa as much as possible. However, this scenario is going to analyze only the energy demand, building's materials, HVAC, day-lighting and shading since there are no passive or active strategies applied yet. All the data will be used later in the next chapter in order to be compared with the other scenarios.

4.4.1. Building's materials

A study for (Al-Badri, 2013) summarized materials properties for a house in Bagdad as shown in Table (4.2). However, according to (Marawi, 2017), most villas in Dubai are built with the same materials properties that are shown in Table (4.2). Therefore, since most of the houses in Dubai and the gulf are built almost with the same materials properties, the same properties are applied on this scenario.

Table 6.2 Materials properties for the existing villa. **(Al-Badri, 2013)**

	Materials	Thickness(M)	Density (kgm2)	Conductivity W/(m.k)	ASHRAE U- Value W/m2 K
Roof	Concrete tiles	0.025	2100	1100	2.0896
	Sand	0.05	0.2080	0.3500	
	Concrete undried aggregate	0.2	2243	1.7300	
	Plaster	0.03	1300	0.5000	
Wall	Cement plaster aggregate	0.030	0.7200	1860	1.7197
	Common brick	0.24	0.7270	1922	
	plaster	0.0300	0.5000	1300	
Floor	Concrete tiles	0.025	1.100	2.1000	2.7322
	Concrete un dried aggregate	0.2000	1.7300	22430	
	Tile bedding	0.0500	1.4000	2.100	
	Materials	Thickness(M)	SHGC	Conductivity (W/m.k)	ASHRAE U-Value
Glazing	Windows	0.0040	0.811	1.0600	5.8744

4.4.2. Day-lighting and shading

The main elevation of the villa is facing northwest, therefore both northwest and northeast elevations has a good chance of shading as shown in Figure (4.7) which shows both sun path and shading in the afternoon.

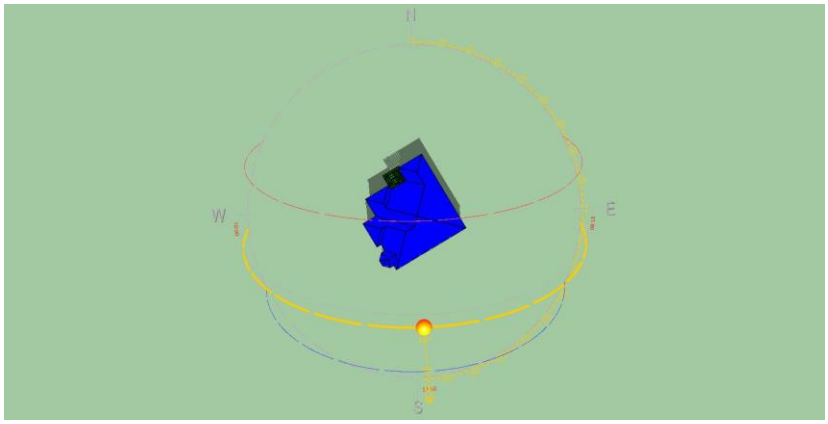

Figure 6.7 Sun path and shading for the villa (IES-VE).

However, there are no many shading devices on the villa, except one wooden pergola located on the first floor on the main elevation and the porch that covers the main entrance of the villa as shown in Figure (4.8), while figure (4.8) showed the computer model which have been created for the villa which has the same main characteristic of the villa.

Figure 6.8 Photo for the villa.

Figure 6.9 Computer model for the villa using IES-VE software.

4.4.3. Energy consumption

Since the villa is located in Dubai which is hot almost all the year, the villa does not have any heating system but it has central air conditioning system which is almost on all the day. However, according to the latest DEWA bill (February 2017) as shown in Figure (4.10), the consumed electricity was 3,360 kWh, while comparing to the model in IES-VE as shown in Table (4.3) it shows a reading of 3,314.8 kWh for the same month of the year which shows that the results are almost similar. Unfortunately, only one DEWA bill has been received from the owner of the villa, which means that the comparison has been done based on this bill only. Although having bills for the rest of the months will proves that the model does match the existing villa strongly, one month is enough to match with since the software is able to understand the weather conditions for each day and the energy consumption during it.

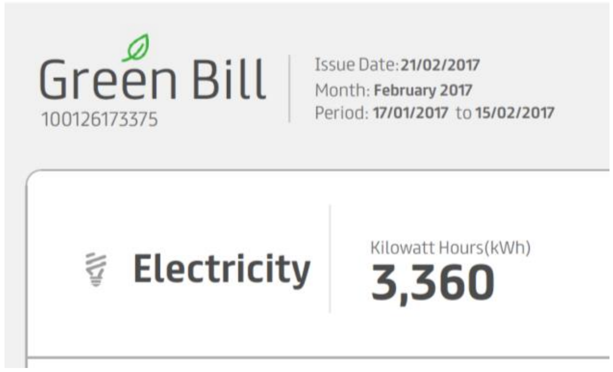

Figure 6.10 Part of DEWA bill that shows the total electricity consumption for the villa from the period 17.1.2017 to 15.2.2017.

Table 6.3 Energy consumption per month for the villa (IES-VE).

	Total system energy (MWh)
Date	scenario 1.aps
Jan 01-31	1.1839
Feb 01-28	3.3148
Mar 01-31	7.3016
Apr 01-30	14.1407
May 01-31	22.1451
Jun 01-30	25.3120
Jul 01-31	28.7261
Aug 01-31	29.3942
Sep 01-30	24.7119
Oct 01-31	18.3416
Nov 01-30	10.2369
Dec 01-31	3.2373
Summed total	188.0461

4.5. Scenario 2 – AL SA’AFAT rating system (Bronze)

In the second scenario, the major requirements of the bronze level in ‘AL SA’AFAT’ rating system will be implemented on the built up model in IES-VE in order to examine and analyze the improvement in energy consumption for the villa. However, as mentioned earlier ‘AL SA’AFAT’ rating system is not only concern about energy consumption, it is also concern about other features related to the buildings’ environment, water consumption and occupants which could not be applied on IES-VE software. Therefore, this study will focus on the requirements that could be implemented on the software which are most of it related to energy consumption in the building.

Therefore, the enhancements that are going to be applied on this scenario as per the bronze SA'AFA requirements are as follow:

a) Introduce day-lighting

b) Shading entrances

c) Treating windows on both south and west elevations

d) Electronic ballasts

e) Demand controlled ventilation

f) Maximum U-Value of 0.30 W/m^2K for roof

g) Maximum U-Value of 0.57 W/m^2K for walls and floors

h) Maximum thermal bridging of 0.4 W/m^2K

i) Minimum SRI value for steep sloped roof of 29

j) Maximum LRV value for wall's painting of 45

k) Minimum AC temperature of 22.5°C and a maximum of 25.5°C

l) Compact fluorescent lamp (CFL)

m) Solar water heaters

n) Glazed elements performance as per table (4.4)

Table 6.4 Glazed element's properties as per AL SA'AFAT rating system requirements. **(Dubai Municipality, 2016)**

Glazed Elements - Fenestration Performance Requirements as per Green Building Regulations & Specifications	Thermal Transmittance -U W/m² K	Shading Coefficient - SC	Light Transmittance - LT
(1) If percentage of total area of external walls that let lights to the external wall area is:			
1-1 Equal or less than 40%	2.10 (max)	0.40 (max)	0.25 (min)
1-2 Between 40% - 60%	1.90 (max)	0.32 (max)	0.10 (min)
1-3 Equal or greater than 60%	1.90 (max)	0.25 (max)	0.10 (min)
(2) For shopfronts and showrooms, other than those at ground floor level:	1.90 (max)	0.76 (max)	
(3) If percentage of glazing portion of a roof to the roof area is:			
3-1 Equal or less than 10%	1.90 (max)	0.32 (max)	0.40 (min)
3-2 Greater than 10%	1.90 (max)	0.25 (max)	0.30 (min)

4.5.1. The model

As per the requirements, windows on both south and west elevations should be treated; therefore shading elements have been added on both ground and first floor as shown in Figures (4.11 and 4.12).

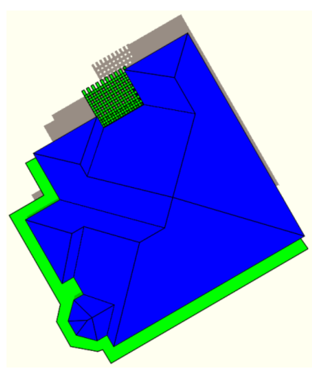

Figure 6.11 Tope view for the model. (IES-VE).

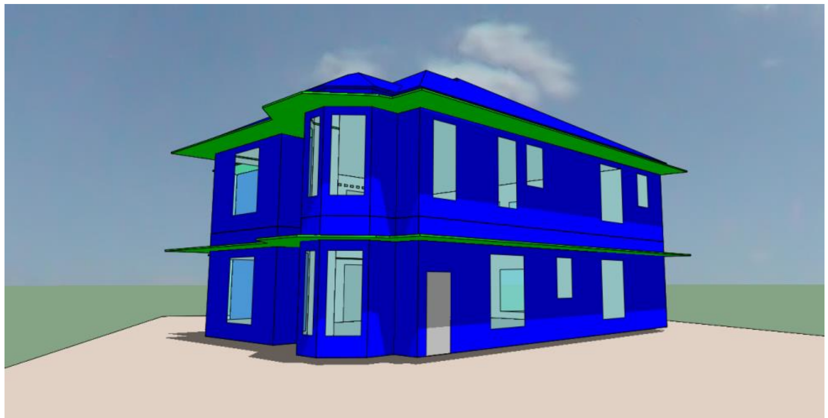

Figure 6.12 Perspective for the model (IES-VE).

4.5.2. Energy consumption

Using IES-VE, timing and duration of turning on\off electrical equipment such as; AC, heaters and lights can be set daily, weekly and annually. This feature will allow rectifying the requirements of the bronze level. Therefore, four different daily profiles have been set as shown below which will be almost the same along the year;

a) Weekdays for HVAC

The villa is occupied by the whole family from 3:00 pm till 7:00 am, while only occupied by the housemaid from 7:00 am till 3:00 pm as shown in Figure (4.13).

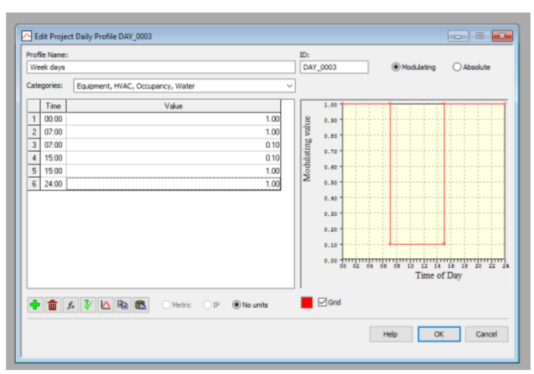

Figure 6.13 Weekdays profile for HVAC (IES-VE).

b) Weekdays for lighting

There is no need for artificial light from 11:00 pm till 6:00 am since all the family members are sleeping, while all the lights are turned on from 6:00 am to 7:00 am at the time of breakfast and preparation for work , then the lights are turned off from 7:00 am to 4:00 pm due to the availability of the daylight, after that in the period between 4:00 pm to 6:00 pm lights are turned on gradually and remain on till 11:00 pm when it is time to sleep as shown in Figure (4.14).

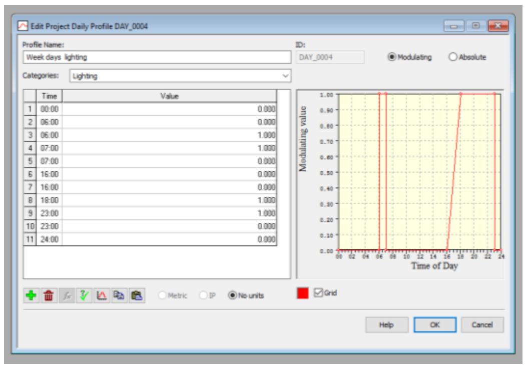

Figure 6.14 Weekdays profile for lighting (IES-VE).

c) Weekends for HVAC.

The villa is occupied by the whole family members from 11:00 pm till 3:00 pm, while it is empty from 3:00 pm till 11:00 pm as shown in Figure (4.15).

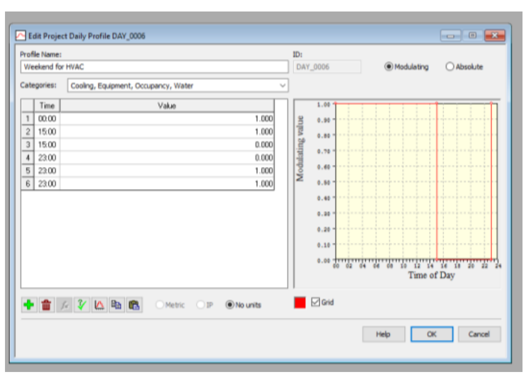

Figure 6.15 Weekends profile for HVAC (IES-VE).

d) Weekends for lighting

Where it is almost turned off all the day till 6:00 pm where only exterior artificial lights turned on automatically, while the interiors one opens only between 10:00 pm to 12:00 am and turned off gradually till 1:00 am while only the exterior ones remains on till 6:00 am as shown in Figure (4.16).

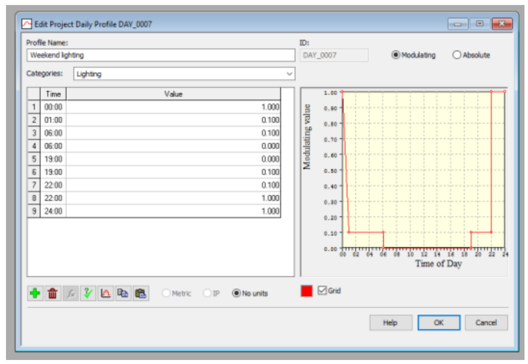

Figure 6.16 Weekends profile for lighting (IES-VE).

After setting daily profiles, two weekly profiles have been set; one for the HVAC while the other is for lighting as shown in Figures (4.17 and 4.18). These profiles have been used to modify the room conditions and the internal gain. However, two major internal gains have been set which are lightings, occupants and equipments.

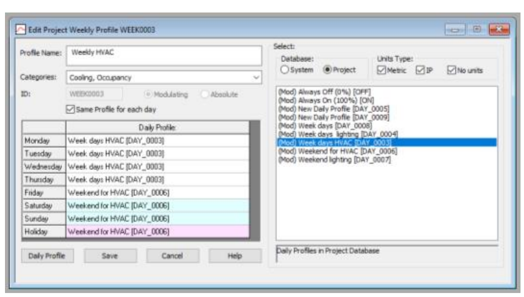

Figure 6.17 Weekly profile for HVAC (IES-VE).

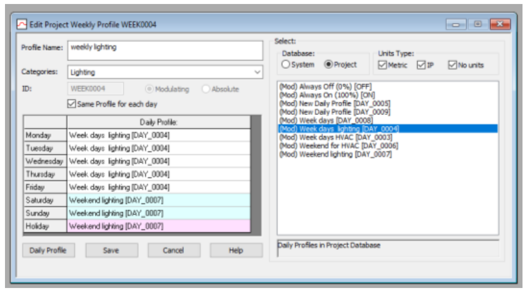

Figure 6.18 Weekly profile for lighting (IES-VE).

Moreover, U-value for roof, floors and walls have been set according to the requirements, besides the properties of the glazed elements. In addition, solar heaters with an area of 8 m² have been set too. The properties of the solar heaters are shown in Figure (4.19) below.

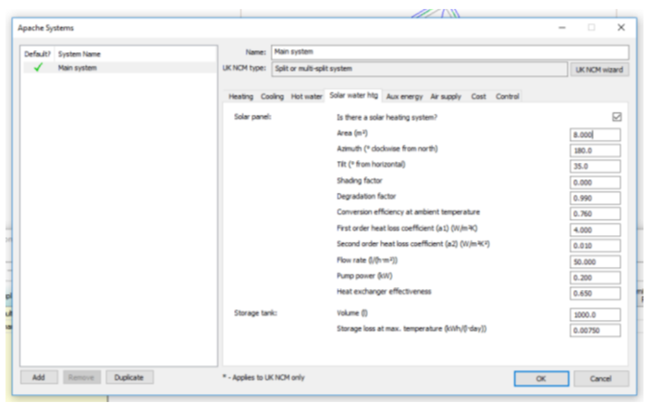

Figure 6.19 Solar heater's properties (IES-VE).

4.6. Scenario 3 – AL SA'AFAT rating system (Silver)

For the third scenario, few additional requirements could be implemented on the model such as;

a) Dimmers

b) Light Emitting Diodes (LEDs)

c) Generating energy using PV panels (minimum 5% of the total consumed energy for the building)

4.6.1. The model

As per requirements, PV panels should be able to generate at least 5% of the total consumed energy. According to the second scenario, the total annual energy consumption is 73.2 MWh, therefore PV panels should be able to generate at least 3.66 MWh. However, the output energy of PV panel is as shown in the equation below

$$E = A \cdot r \cdot e \cdot PR$$

Where;

E = output energy (kWh)

A = total area for the solar panel (m^2)

e = solar panel efficiency (%)

r = annual average solar radiation (kWh/m^2)

PR = performance ration, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

While in this case, the selected type of PV panels is the Monocrystalline Silicon since it has high performance compared to others. However, according to (AZoCleantech, 2016) the efficiency for the Monocrystalline Silicon is ranging between 15% - 24%. Moreover, according to (Hejase & Assi, 2013), the average annual solar radiation in the UAE is about 2285 kWh/m^2. However, according to (World Weather Online, 2017), the average maximum temperature in dubai along the year is 40°C while the average minimum is 24°C which means that the average along the year is 32°C. In addition, according to (BlogActiv, 2013), the efficiency of a Monocrystalline

Silicon at 25°C and irradiance of 1000 W/m² is 20%. Eventually, when substituting in the equation above the required minimum area is as follow

$$3660 = A \cdot (2285) \cdot (0.20) \cdot (0.75)$$

$$A = 3660/342.75$$

$$A = 10.68\ m^2$$

Therefore, a PV panel with dimensions of 3.25m X 3.5m and an area of 11.375 m² has been installed on the roof as shown in Figure (4.20) while Figure (4.21) shows the rest properties of the PV panel.

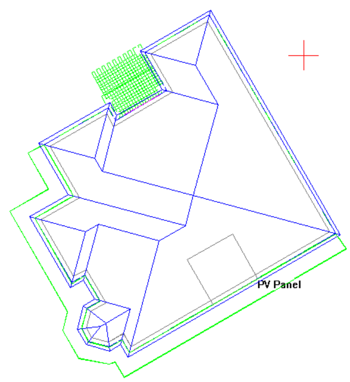

Figure 6.20 Top view for the model with PV panel on the roof (IES-VE).

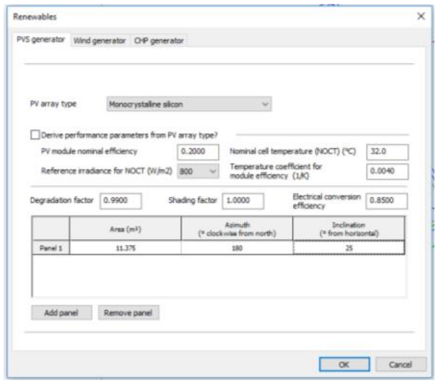

Figure 6.21 Properties of the PV panel (IES-VE).

4.7. Scenario 4 – AL SA'AFAT rating system (Gold and Platinum)

For the fourth scenario, couples additional requirements could be implemented on the model such as;

a) Maximum U-Value of 0.42 W/m²K for walls and floors

b) Generating energy using PV panels (minimum 10% of the total consumed energy for the building)

In order to achieve 10% of total energy consumption, the area of panels should be doubled. Therefore, another PV panel with the same properties and dimensions will be installed next to it which means that the total area will be 22.75 m² as shown in Figures (4.22 and 4.23).

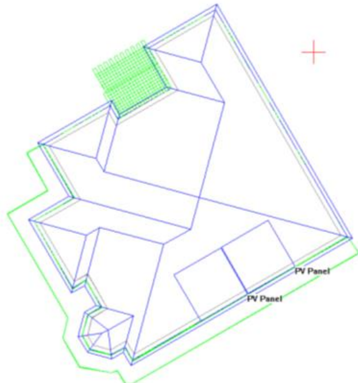

Figure 6.22 Top view for the model with 2 PV panels on the roof (IES-VE).

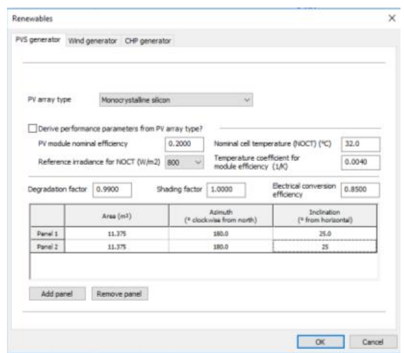

Figure 6.23 Properties of the 2 PV panels (IES-VE).

4.8. Scenario 5 – Nearly ZEB

For the fifth and the last scenario, the existing villa is going to be improved in different aspects in order to reach nearly ZEB which the main aim of the study, these improvements should take into account the existing structure and the major elements of the villa such as columns, walls and slabs. However, the enhancement can be done in insulations and plaster layers in addition to the amount of produced energy

4.8.1. Shading devices

As shown in Figures (4.24 and 4.25) below, projections with a minimum of 1.5m width have been added on both floor levels from all sides to provide shade for windows. Moreover, medium to large trees can provide shades for the windows too in order to reduce direct sun radiation and heat gain.

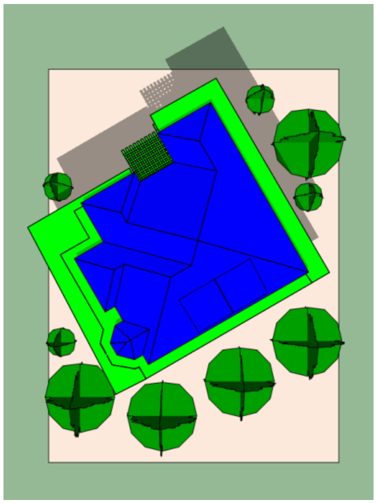

Figure 6.24 Top view for the model (IES-VE).

Figure 6.25 Perspective for the villa (IES-VE).

In addition, external shading devices have been added to all windows with properties as shown in Figure (4.26) below. Besides that, curtains have been selected as inner shading device.

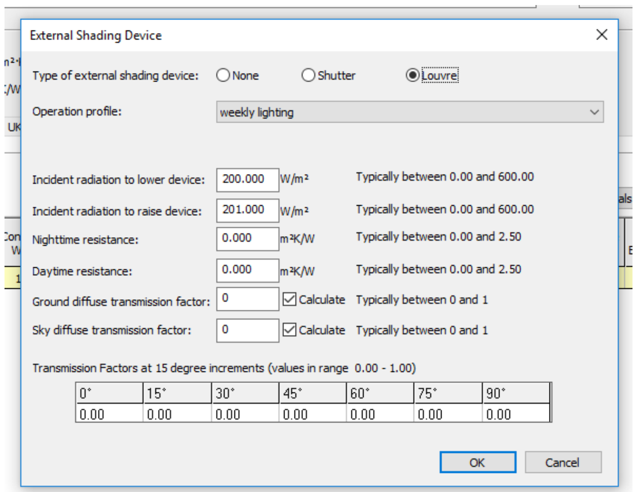

Figure 6.26 Shading device properties (IES-VE).

4.8.2. Glazed elements properties

In order to reduce heat gain through windows, windows with low U-value and shading coefficient and high resistance value have been selected as shown in Figure (4.27).

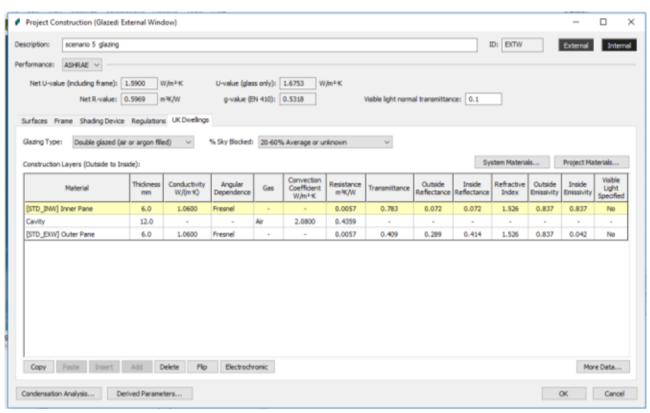

Figure 6.27 properties of the double glazed window (IES-VE).

4.8.3. Materials properties

4.8.3.1. Walls

In order to reduce the affect of convection, polyurethane foam has been selected since it has low thermal conductivity that reaches 0.0213 W/(m.K), Table (4.5) below shows polyurethane foam properties. Moreover, according to (Seyam, 2017), polyurethane has a very weak fire resistance property; therefore it is preferable not to be used in the inner surface of the building.

Table 6.5 polyurethane insulation properties. (Dubai Municipality, 2005)

Property	Unit	Value	Test method / Standard
Thermal conductivity (Max of 35°C and 50% RH)	W/(m.K)	0.0213	ASTM C518 - 1998 or C177
Compressive strength (Min. Value). The specimen is pressed as much as 10% of its original thickness	kpa	280	ASTM 165 or 1621
Density	kg/m^3	45	ASTM D1622
Water absorption	%by vol.	0.1	ASTM C209 - 1998

However, as shown in Figure (4.28) two layers of insulation with a thickness of 100mm have been placed, one on the outer surface while the other is on the inner surface, while as shown in Figure (4.29) only one layer on insulation with a thickness of 200mm have been placed on the outer surface. Usually polyurethane boards comes in 100mm thickness which means that two boards of 100mm will be attached together then placed on the walls. Therefore, the simulation process will run twice in order to examine the performance of the building in each case and the affect on building's energy consumption.

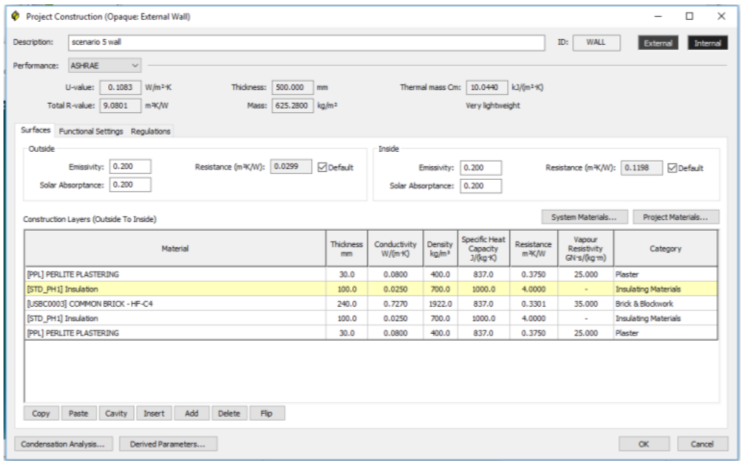

Figure 6.28 Properties of the walls while adding 2 insulation layers (IES-VE).

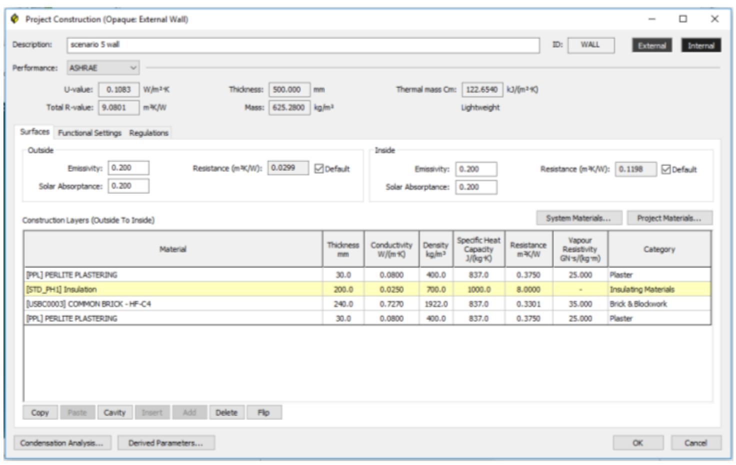

Figure 6.29 Properties of the walls while adding 1 insulation layers (IES-VE).

4.8.3.2. Roof and floors

For roof and floors, the same type of insulation with a thickness of 200mm is placed on the concrete slab.

4.8.4. PV panels

In order to increase the amount of generated power on site, the area of PV panels have been increased. For the first case, four PV panels with a total area of $45.5m^2$ have been placed on the, while for the second case, five PV panels with a total area of $56.875m^2$ is placed on the roof. All the PV panels used have the same properties like the one used in the previous scenarios.

Chapter 5
Results and Discussion

5. Results and discussion

5.1. Introduction

After simulating all the scenarios using IES-VE, the results are ready to be compared, which will allow representing the procedure of improving the building's performance by reducing the energy consumption and the carbon emissions. The compression process will show which features have big influence on the buildings and which are not. At the same time it will show the difference in energy consumption for the different four levels of 'AL SA'AFAT' rating system, and how much more is needed in order to reach nearly ZEB.

5.2. Scenario 1 results

The first scenario which is for the current status of the villa, the results showed high yearly energy consumption due to the continuously on AC and lighting besides other factors as mentioned in the previous chapter. However, Table (5.1) shows the consumed energy per month in addition to the total amount per year.

Table 5.1 Total energy consumption (IES-VE).

	Total system energy (MWh)
Date	scenario 1.aps
Jan 01-31	1.1839
Feb 01-28	3.3148
Mar 01-31	7.3016
Apr 01-30	14.1407
May 01-31	22.1451
Jun 01-30	25.3120
Jul 01-31	28.7261
Aug 01-31	29.3942
Sep 01-30	24.7119
Oct 01-31	18.3416
Nov 01-30	10.2369
Dec 01-31	3.2373
Summed total	188.0461

5.3. Scenario 2 results

The second scenario which examines the performance of the building while applying the requirements of the Bronze SA'AFA shows a significant difference in the energy consumption as shown in Table (5.2). the significant reduction in energy consumption is due to implementing various sustainable features that encourage reducing energy consumption which were listed in the previous chapter.

Table 5.2 Total energy consumption (IES-VE).

	Total system energy (MWh)
Date	scenario 2.aps
Jan 01-31	1.4083
Feb 01-28	2.3024
Mar 01-31	3.7737
Apr 01-30	5.7829
May 01-31	8.3647
Jun 01-30	9.3828
Jul 01-31	10.1367
Aug 01-31	10.1935
Sep 01-30	8.6601
Oct 01-31	6.7525
Nov 01-30	4.2679
Dec 01-31	2.1775
Summed total	73.2029

5.4. Scenario 3 results

The third scenario which examines the performance of the building while applying the requirements of the Silver SA'AFA shows small difference in the energy consumption as shown in Table (5.3) due to installing PV panels that produce 5% of total consumed energy.

Table 5.3 Total energy consumption (IES-VE).

	Total system energy (MWh)
Date	scenario 3.aps
Jan 01-31	1.0842
Feb 01-28	1.9653
Mar 01-31	3.4348
Apr 01-30	5.4450
May 01-31	7.9954
Jun 01-30	9.0370
Jul 01-31	9.7884
Aug 01-31	9.8313
Sep 01-30	8.3006
Oct 01-31	6.3870
Nov 01-30	3.9477
Dec 01-31	1.8727
Summed total	69.0894

However, Table (5.4) below shows the generated energy by the PV panels per month. The negative values are due to the generation process instead of consumption were PV panels generates energy more than the villa consumes. The total produced energy per year is 3906.9 KWh which represents 5.33% of the total consumed energy.

Table 5.4 Total generated energy by the installed PV panel (IES-VE).

	PV generated electricity (MWh)
Date	scenario 3.aps
Jan 01-31	-0.3067
Feb 01-28	-0.3207
Mar 01-31	-0.3211
Apr 01-30	-0.3206
May 01-31	-0.3510
Jun 01-30	-0.3282
Jul 01-31	-0.3304
Aug 01-31	-0.3450
Sep 01-30	-0.3432
Oct 01-31	-0.3485
Nov 01-30	-0.3036
Dec 01-31	-0.2879
Summed total	-3.9069

5.5. Scenario 4 results

The fourth scenario which examines the performance of the building while applying the requirements of both Gold and Platinum SA'AFA shows further reduction in energy consumption as shown in Table (5.5) due to installing PV panels that produce 10% of total consumed energy. While Table (5.6) shows that total produced energy per year is 7680.4 KWh which represents 10.49% of the total consumed energy.

Table 5.5 Total energy consumption (IES-VE).

	Total system energy (MWh)
Date	scenario4.aps
Jan 01-31	0.7105
Feb 01-28	1.5616
Mar 01-31	3.0034
Apr 01-30	5.0065
May 01-31	7.5272
Jun 01-30	8.5866
Jul 01-31	9.3369
Aug 01-31	9.3679
Sep 01-30	7.8463
Oct 01-31	5.9347
Nov 01-30	3.5363
Dec 01-31	1.4875
Summed total	63.9054

Table 5.6 Total generated energy by the installed PV panels (IES-VE).

	PV generated electricity (MWh)
Date	scenario4.aps
Jan 01-31	-0.5862
Feb 01-28	-0.6209
Mar 01-31	-0.6274
Apr 01-30	-0.6407
May 01-31	-0.6974
Jun 01-30	-0.6577
Jul 01-31	-0.6604
Aug 01-31	-0.6838
Sep 01-30	-0.6751
Oct 01-31	-0.6807
Nov 01-30	-0.5929
Dec 01-31	-0.5573
Summed total	-7.6804

5.6. Scenario 5 results

For the fifth scenario, a number of different cases have been examined in order to push the villa to nearly ZEB. These cases have features as follow;

5.6.1. Case 1

a) Two layers of insulation with a thickness of 100mm have been placed, one on the outer surface while the other is in the inner surface

b) Four PV panels with total area of 45.5 m²

The results show noticeable difference in the results in term of reducing energy consumption as shown in Table (5.7) below due to the two layers of insulations beside the two extra PV panels.

Table 5.7 Total energy consumption (IES-VE).

	Total system energy (MWh)
Date	scenario 5.aps
Jan 01-31	-0.9166
Feb 01-28	-0.7150
Mar 01-31	-0.3070
Apr 01-30	0.2222
May 01-31	0.7340
Jun 01-30	1.0571
Jul 01-31	1.3446
Aug 01-31	1.4093
Sep 01-30	1.0595
Oct 01-31	0.5828
Nov 01-30	0.0886
Dec 01-31	-0.4085
Summed total	4.1509

5.6.2. Case 2

a) one layer on insulation with a thickness of 200mm placed on the outer surface

b) Four PV panels with total area of 45.5 m²

The results show very small difference in energy consumption as shown in Table (5.8) below. However, there is a minor difference between this case and the previous one in term of energy consumption.

Table 5.8 Total energy consumption (IES-VE).

	Total system energy (MWh)
Date	scenario 5.aps
Jan 01-31	-0.9585
Feb 01-28	-0.7120
Mar 01-31	-0.2949
Apr 01-30	0.2472
May 01-31	0.7510
Jun 01-30	1.0746
Jul 01-31	1.3600
Aug 01-31	1.4181
Sep 01-30	1.0586
Oct 01-31	0.5740
Nov 01-30	0.0735
Dec 01-31	-0.4244
Summed total	4.1673

5.6.3. Case 4

a) one layer on insulation with a thickness of 200mm placed on the outer surface

b) Five PV panels with total area of 56.875 m²

In this case the villa produce energy more than it consumed during half of the year which resulted in a value that is very close to the zero for total energy consumption as shown in Table (5.9) below which consequently achieves the target of the research.

Table 5.9 Total energy consumption (IES-VE).

	Total system energy (MWh)
Date	scenario 5.aps
Jan 01-31	-1.2516
Feb 01-28	-1.0224
Mar 01-31	-0.6086
Apr 01-30	-0.0731
May 01-31	0.4023
Jun 01-30	0.7458
Jul 01-31	1.0298
Aug 01-31	1.0762
Sep 01-30	0.7210
Oct 01-31	0.2337
Nov 01-30	-0.2229
Dec 01-31	-0.7030
Summed total	0.3271

5.7. Comparison

5.7.1. Comparison between the three cases

Taking the four cases as shown in Table (5.11) into account, case 3 showed the best results which describes and achieves the main aim of the research, therefore it will represent the fifth scenario which is pushing the villa to nearly ZEB.

Table 5.10 Total yearly energy consumption for each case.

Case	Total yearly energy consumption (MWh)
Case 1	4.15
Case 2	4.16
Case 3	0.32

5.7.2. Comparison between the five scenarios

As shown in Figure (5.1) below, scenario 1 showed very high values in term of energy consumption when comparing to other scenarios. However, there was a huge jump on energy consumption shown in scenario 2 after implementing the bronze level of 'AL SA'AFAT' rating system. In other hand, scenarios 2, 3 and 4 are somehow close from each others. Finally, the last scenario shows another big jump in the performance of the building where values are almost close to zero which achieves the aim of the research.

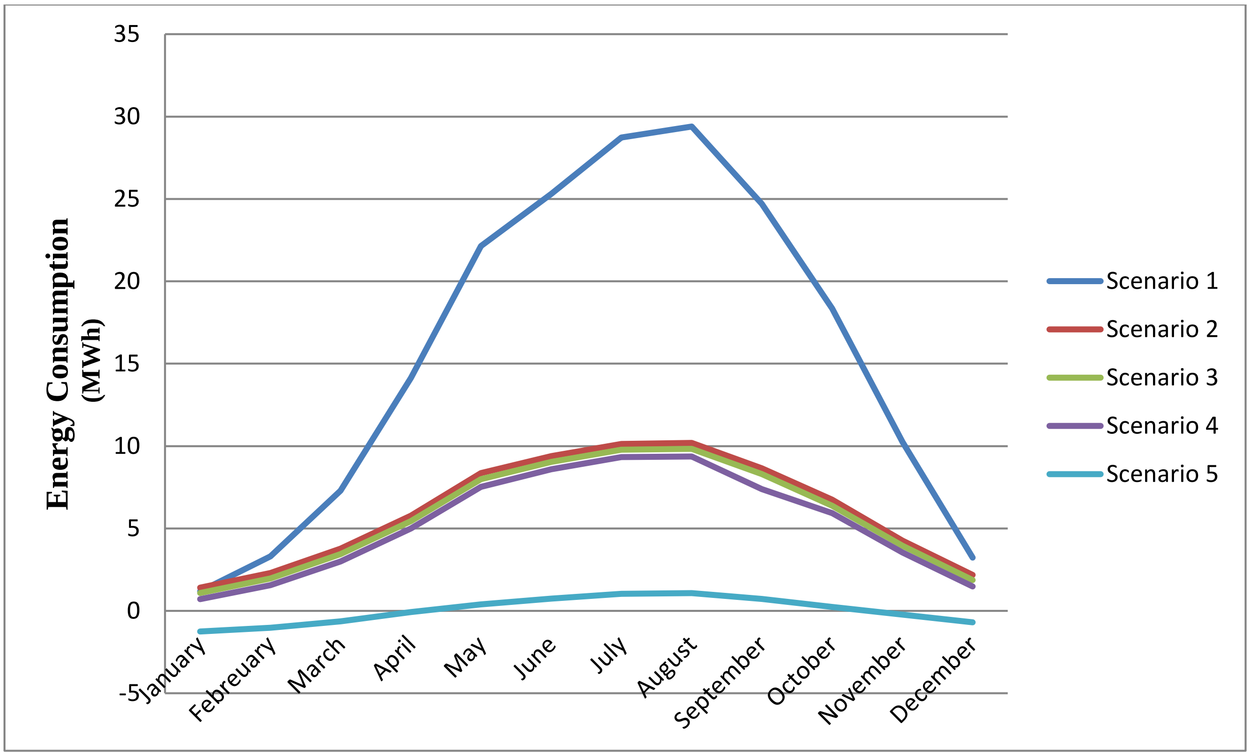

Figure 5.1 Energy consumption for the 5 scenarios.

However, Figure (5.2) below shows the total energy consumption for each scenario. It is very clear that scenario 1 is much higher while scenarios 2, 3 and 4 are very close from each other. The small difference between these three scenarios is related to the availability of the PV panels. Scenario 2 does not have any PV panel, while scenario 3 have one PV panels with an area of 11.375m² which produce energy that represents 5.33% of the total consumed energy, while scenario 4 have two PV panels with an area of 22.75m² which produce energy that represents

10.49% of the total consumed energy. Furthermore, the last column in the graph which represents scenario 5 is showing a value that is very close from the zero which is 0.32 KWh.

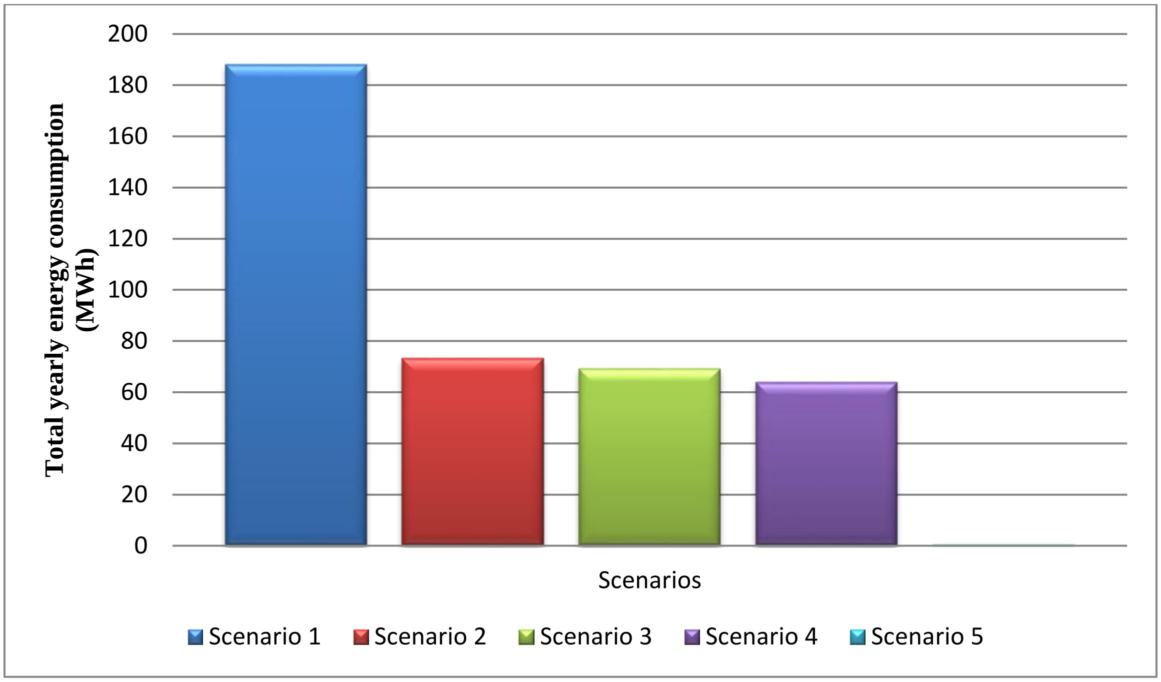

Figure 5.2 Yearly energy consumption for all 5 scenarios.

The percentage values shown on Figure (5.3) below represents how much percent energy does each scenario consumes comparing to the basic scenario. However, scenario 5 consumes 0.0017% energy of the total consumed energy by the basic scenario.

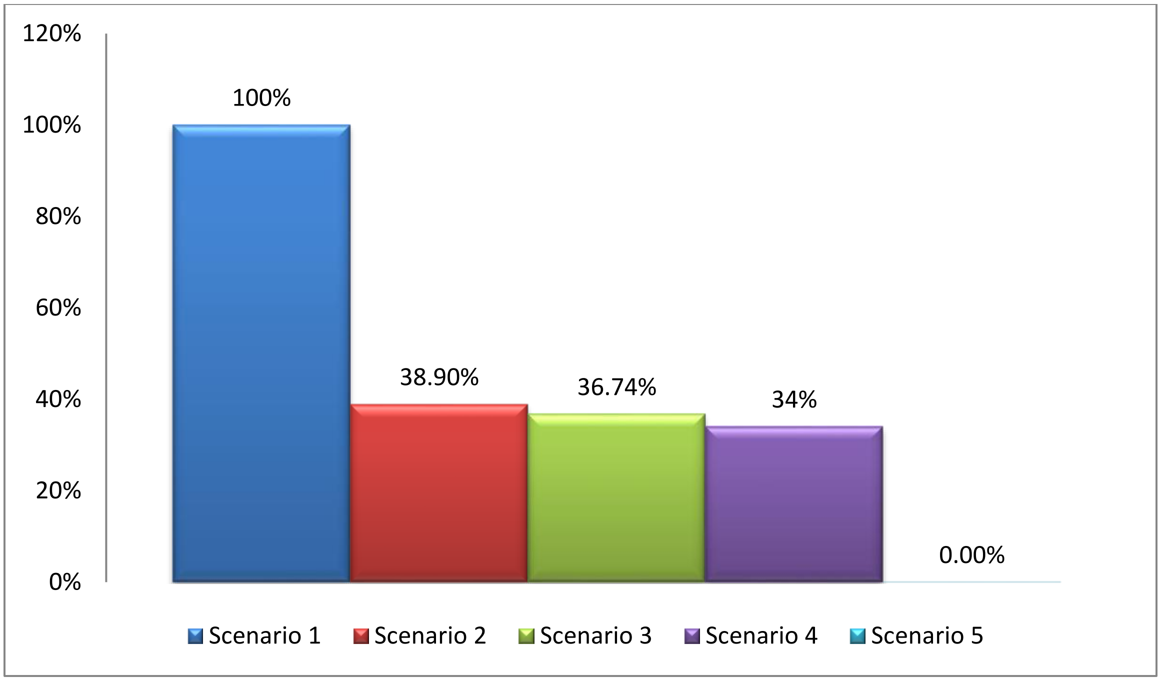

Figure 5.3 Percentages of energy consumption comparing to the basic scenario.

According to these values, the percentage of saved energy for each scenario comparing by the basic scenario is as follow;

a) Scenario 2 (The Bronze) saves 61.1% from the current consumed energy

b) Scenario 3 (The Silver) saves 63.26% from the current consumed energy

c) Scenario 4 (The Gold and The Platinum) saves 66% from the current consumed energy

d) Scenario 5 (Nearly ZEB) saves 99.9983% from the current consumed energy

5.8. Discussion

Obviously, there is a big gap between scenario 1 and the other scenarios since it is not adopting any sustainable technique. However, the minor difference between the three scenarios 2, 3 and 4 does not mean that 'AL SA'AFAT' rating system has a small enhancement between the four levels. But it is due to a number of reasons. The main reason is that some of the requirements are not possible to implement on IES-VE software. Another reason is that the bronze level is the most suitable one for villas since energy consumption is not that much when comparing to other large projects. The other levels of ‘AL SA’AFAT’ rating systems will work better on large scale projects because energy saving will be much greater, and applying all the requirements of silver, gold or platinum level will not be a waste of money because the amount of saved energy worth it. Moreover, Dubai Municipality takes into account the cost of the requirements of the building regulations which should not exceed 5% of the total cost of the building. However, the requirements of the bronze level are mandatory for all types of new buildings according the buildings regulations that set by Dubai Municipality. Therefore, the villa has been pushed to NZEB using the requirements of the Bronze level, in addition to proper glazing and insulation. Since the villa is an existing building and the same structure was kept, proper layers of insulations have been added. Although 200mm seems very thick to be applied in a villa, but since it is an existing villa it will be the best option, otherwise the owner will have to demolish the existing walls in order to replace them will different insulated bricks. Therefore, it will be easier for new villas to implement the techniques of ZEB since everything will be considered from the early stage. Nowadays, concrete blocks are made hollow in order to accommodate insulating material inside it, which enables having walls with less thickness. Moreover, one of the main elements that enable the villa to be pushed to NZEB is the installed PV panels on the roof and the solar water heater system which will save most of the current consumed energy.

Moreover, examining the difference between case 1 and case 2 in the 5th scenario showed a minor reduction in energy consumption for the two layers of insulation. However, the two main reasons of selecting one layer of insulation instead of the two layers although the two layers of insulations showed better results in term of energy consumption is that installing two insulation layers on both sides of the walls will cost the owner more during the renovation process and will as consuming more time at the same time. However, the selected type of insulation was polyurethane foam which has low thermal conductivity but has a weak fire resistance at the same time, which makes using it on the outer surface of the villa safer. In addition, the outer surface of the villa will need to be covered by a high fire resistance material in order to prevent disasters. According to (Seyam, 2017), the best option is to have stone claddings on the elevations in order to protect the insulation and the building from the fire.

Chapter 6
Conclusion and recommendation

6. Conclusion and recommendation

After defining, analyzing, collecting and discussing the results, the research was able to achieve the main aim and finally conclude some points besides recommending other points for future studies as below.

6.1. Conclusion

The research was aiming to push an existing villa to nearly ZEB passing through 'AL SA'AFAT' rating system, and that is what has been achieved in the previous couple chapters through adopting a number of sustainable techniques. However, some of these techniques already became mandatory according to Dubai Municipality which is the concerned organization in Dubai of giving building permits that allows contractors to start their work at the site. All the requirements of the bronze level that have been mentioned in the previous chapters are mandatory such as the solar heaters which is already started to be used widely across the city, the properties of the walls, floors, roofs and glazed elements, providing shadings for the entrances, controlling the AC as per demand, adopting daylights and selecting the proper type of artificial lights.. In addition to all of these techniques, some techniques was optional, yet it have been adopted in order to reach ZEB such as using Monocrystalline Silicon PV panels which has high efficiency comparing to other PV panels, using polyurethane foam for insulations due to its low thermal conductivity and providing enough shading devices for all the openings.

Moreover, the research examined the influence of using single glazed windows and double glazed windows, which showed a noticeable difference in the results. Double glazed windows reduce energy consumption by 38.3 In addition to that, the research also examined the difference in the performance of using one thick layer of insulation on the outside surface of the building and using two thin layers of insulation; one on the outer surface while the other on the inner surface. However, the results showed a minor difference in reducing energy consumption where the two layers of insulation showed a reduction of 0.99%. However, there were a couple of reasons that led to choose the one layer of insulation on the outer surface which are the cost and safety.

Furthermore, the results of the analysis shows a huge reduction in energy consumption between the 1st scenario which is the current status of the villa and the 2nd scenario which is applying the bronze level, the reduction in energy consumption reached 61.1%, later on after implementing the 3rd and the 4th scenario which are applying the rest levels of 'AL SA'AFAT' rating system, the results showed reduction of 63.26% for the 3rd and 66% for the 4th in energy consumption, while the 5th scenario which is pushing the villa to nearly ZEB showed another huge reduction that reached 99.9983% .

Eventually, the research was able to achieve the main aim which is pushing the villa to nearly ZEB. Actually, in case of increasing one more PV panel, the total yearly energy consumption will be less than zero, which means that the villa will generates energy more than it consumes. But for sure that will cost the owner more and will occupy larger space on the roof of the villa.

6.2. Recommendations

During the process of analyzing and discussing the results of the study, some issues and questions have been raised. These issues and questions could be studied later in future researches in order to get proper problem definition and answering the questions. However, the recommendations are as follow;

a) The alternatives spaces for installing PV panels in case there is no enough space on the roof of the building while taking into account the shading profile in order to ensure the highest possible performance for the PV system.

b) Studying the pros and cons of using insulation materials inside, outside or both in the building while taking into consideration the thermal conductivity, thickness and fire resistance with finding alternatives that takes into account the type and the location of the building.

c) Studying the influence of using single, double and triple glazed windows using different methods while taking into account the cost and the type of the building.

d) The possibilities of making the requirements of ZEB mandatory for all new buildings in Dubai

e) Implementing the same scenarios on different types of buildings to check wither the percentages of saved energy for each scenario is the same or not.

List of references

Al-Badri, N., 2013. *Grid electricity Demand Reduction through Applying Passive and Active Strategies for a House in Baghdad - Iraq,* s.l.: s.n.

Al-Taamimi, N. & Fadzil, S., 2011. The potential of shading devices for tempreture reduction in high-rise residential buildings in the tropics. *Procedia Engineering,* Volume 21, pp. 273-282.

AZoCleantech, 2016. *AZO Cleantech.* [Online]
Available at: http://www.azocleantech.com/article.aspx?ArticleID=603#2
[Accessed 27 April 2017].

Barbaresi, A., Torreggiani, D., Benni, S. & Tassinari, P., 2014. Underground cellar thermal simulation: Definition of a method formodelling performance assessment based on experimental calibration. *Energy and Buildings,* Issue 76, pp. 363-372.

Belton, D., 2016. Teaching process simulation usingvideo-enhanced and discovery/inquiry-basedlearning: Methodology and analysis within atheoretical framework for skill acquisition. *Education for Chemical Engineers,* Issue 17, pp. 54-64.

Biswas, K., Shrestha, S., Bhandari, M. & Desjarlais, A., 2016. Insulation materials for commercial buildings in North America:An assessment of lifetime energy and environmental impacts. *Energy and Buildings,* pp. 256-269.

BlogActiv, 2013. *BlogActiv.* [Online]
Available at: https://energypub.blogactiv.eu/2013/04/07/increasing-solar-panel-efficiency/
[Accessed 27 April 2017].

Bullis, K., 2009. A Zero-Emissions City in the Desert. *Technology Review*, April.

ColoradoStateUniversity, 2016. *Writing@CSU.* [Online]
Available at: http://writing.colostate.edu/guides/page.cfm?pageid=1368&guideid=64
[Accessed 5 November 2016].

Cuce, E. & Riffat, S., 2015. A state-of-the-art review on innovative glazing technologies. *RenewableandSustainableEnergyReviews,* Issue 41, pp. 695-714.

Davis, S., 2016. *eHow.* [Online]
Available at: http://www.ehow.com/info_12138886_advantages-disadvantages-simulation-models.html
[Accessed 5 November 2016].

DeKay, M. & Brown, G. Z., 2014. *Sun, Wind & Light: Architectural design strategies.* 3rd ed. New Jersey: Jhon Wiley & Sons.

Dubai Municipality, 2005. *Guide For Thermal Insulation In Buildings.* 1st ed. Dubai: Dubai Municipality.

Dubai Municipality, 2016. *AL SA'FAT: Green Buildings Evaluation System.* 1st ed. Dubai: Dubai Municipality.

Dubai.com, 2016. *City Guide & Bookings: Dubai Geography.* [Online]
Available at: http://www.dubai.com/v/geography/
[Accessed 16 July 2016].

Elminir, H. et al., 2006. Optimum solar flat-plate collector slope: Case study for Helwan, Egypt. *Energy Conversion and Management,* 47(5), pp. 624-637.

Freewan, A., 2014. Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions. *Solar Energy,* Volume 102, pp. 14-30.

Gatto, M., 1995. Ecological Applications. In: E. S. O. AMERICA, ed. *Sustainability: Is it a well defined concept?.* s.l.:John Wiley & sons, pp. 1181-1183.

Goodhew, S. & Griffiths, R., 2005. Sustainable earth walls to meet the building regulations. *Energy and Buildings,* 37(5), pp. 451-459.

Hammad, F. & Abu-Hijleh, 2010. The energy savings potential of using dynamic external louvers in an office building. *Energy and Buildings,* 42(10), pp. 1888-1895.

Hejase, H. & Assi, A., 2013. Global and Diffuse Solar Radiation in the United Arab. *International Journal of Environmental Science and Development,* 4(5), pp. 470-474.

Hemandez, P. & Kenny, P., 2010. From net energy to zero energy buildings: Defining life cycle zero energy buildings (LC-ZEB). *Energy and Buildings,* 42(6), pp. 815-821.

Hsieh, C.-e., 2002. Strengths and Weakness of Qualitative Case Study Research. Issue 15, pp. 87-116.

Hyland, K., 2016. Methods and methodologies in second language writing research. *System,* Issue 59, pp. 116-125.

Hyland, K., 2016. Methods and methodologies in second language writing research. *System,* Issue 59, pp. 116-125.

Joanna, A. & Heiselberg, P., 2011. Zero energy building definition - a literature review.

Khan, M., Abdul-Malek, A., Mithu, M. & Das, D., 2010. Design, fabrication and performance evaluation of natural circulation rectangular box-type solar domestic water heating system. *International Journal of Sustainable Energy,* 29(3), pp. 164-177.

Kirimtat, A., Koyunbaba, B., Chatzikonstantinou, I. & Sariyildiz, S., 2016. Review of simulation modeling for shading devices in buildings. *Renewable and Sustainable Energy Reviews,* pp. 23-49.

Lenior, A., Thellier, F. & Garde, F., 2011. Towards Net Zero Energy Buildings in Hot Climate, Part 2: Experimental Feedback. *ASHRAE Transactions,* Volume 117.

Luederitz, C. et al., 2016. Systematic student-driven literature reviews in sustainability science - an effective way to merge research and teaching. *Journal of Cleaner Production,* Issue 119, pp. 229-235.

Marawi, N., 2017. *Building materials used in Dubai for typical villa* [Interview] (29 January 2017).

Marszal, A. et al., 2010. *Net Zero Energy Buildings - Calculation Methodologies versus National Building Codes.* [Online]
Available at: http://www.task41.iea-shc.org/data/sites/1/publications/Task40a-Net_Zero_Energy_Buildings_Calculation_Methods_and_Input_Variables.pdf
[Accessed 27 April 2017].

Marszal, A. J. & Heiselberg, P., 2011. Zero Energy Building definition – a literature review.

Meltzer, J., Hultman, N. & Langley, C., 2014. *Low-Carbon Energy Transitions in Qatar and the Gulf Cooperation Council Region.* 1st ed. Doha: Brookings.

Meneguzzo, F., Ciriminna, R., Albanese, L. & Pagliaro, M., 2015. The great solar boom: a global perspective into the far reaching impact of an unexpected energy revolution. *Energy Science & Engineering,* pp. 499- 509.

Mingotti, N., Chenvidyakarn, T. & Woods, A., 2013. Combined impacts of climate and wall insulation on the energy benefit of an extra layer of glazing in the facade. *Energy and Buildings,* Issue 58, pp. 237-249.

Moretti, E., Belloni, E. & Agosti, F., 2016. Innovative mineral fiber insulation panels for buildings: Thermal and acoustic characterization. *Applied Energy,* pp. 421-432.

Nematchoua, M. et al., 2015. Study of the economical and optimum thermal insulation thickness for building in a wet and hot tropical climate: Case of Cameroon. *RenewableandSustainableEnergyReviews,* pp. 1192-1202.

NJ Green Building Manual, 2011. *Green Building Manual.* [Online]
Available at: http://greenmanual.rutgers.edu/newcommercial/strategies/buildingorientation.pdf
[Accessed 22 August 2016].

NZEB, 2016. *Net Zero Energy Buildings.* [Online]
Available at: http://www.nzeb.in/knowledge-centre/passive-design/vegetation/
[Accessed 29 August 2016].

Ochoa, C. E. & Capeluto, I. G., 2008. Strategic decision-making for intelligent buildings: Comparative impact of passive design strategies and active features in a hot climate. *Building and Environment,* 43(11), pp. 1829-1839.

Östman, B. & Källsner, B., 2011. *National building regulations in relation to multi-storey wooden buildings in Europe.* [Online]
Available at:
https://www.researchgate.net/profile/Bo_Kaellsner/publication/267222079_National_building_regulati

ons_in_relation_to_multi-storey_wooden_buildings_in_Europe/links/558bdc6508ae591c19d8d417.pdf [Accessed 26 April 2017].

Pan, W. & Garmston, h., 2012. Building regulations in energy efficiency: Compliance in England and Wales. *Energy Policy,* Volume 45, pp. 594-605.

Pless, S. & Torcellini, P., 2009. Getting to Net Zero.

Pless, S. & Torcellini, P., 2010. *Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options,* Colorado: National Renewable Energy Laboratory.

Radhi, H., 2009. Evaluating the potential impact of global warming on the UAE residential buildings – A contribution to reduce the CO2 emissions. *Building and Environment,* 44(12), pp. 2451-2462.

Rasmussen, B., 2010. Sound insulation between dwellings – Requirements in building regulations in Europe. *Applied Acoustics,* 71(6), pp. 373-385.

Rodriguez-Ubinas, E. et al., 2014. Passive design strategies and performance of Net Energy Plus Houses. *Energy and Buildings,* Volume 83, pp. 10-22.

Rodziewicz, T., Zaremba, A. & Waclawek, M., 2016. *PHOTOVOLTAICS: SOLAR ENERGY RESOURCES AND THE POSSIBILITY OF THEIR USE,* s.l.: s.n.

Runde, T., 2015. Net Zero Energy Buildings: An Introduction for Valuation Professionals. *The Appraisal Journal,* pp. 141-149.

Seyam, N., 2017. *How to select a proper insulation in dubai* [Interview] (6 April 2017).

Seyam, N., 2017. *How to select the proper insulation in Dubai* [Interview] (6 April 2017).

Spiru, P., Catalin-Bogdan, M. & Simona, P., 2000. DOMESTIC SOLAR WATER HEATING POTENTIAL IN THE SOUTH- EASTERN REGION OF RO<ANIA. *Constanta Maritime University's Annals,* Volume 18, pp. 139-142.

Torcellini, P., Pless, S. & Deru, M., 2006. *Zero Energy Buildings: A Critical Look at the Definition.* California, National Renewable Energy Laboratoty.

Uygunoglu, T., Özgüven, S. & Çalıs, M., 2016. Effect of plaster thickness on performance of external thermal insulation cladding systems (ETICS) in buildings. *Construction and Building Materials,* pp. 496-504.

Vieira, R., Guerra, F., Vale, M. & Araujo, M., 2016. Comparative performance analysis between static solar panels and single-axis tracking system on a hot climate region near to the equator. *Renewable and Sustainable Energy Reviews,* pp. 672-681.

Visa, I. et al., 2016. Comparative analysis of the infield response of five types of photovoltaic modules. *Renewable Energy,* pp. 178-190.

Voss, K., Sartori, I. & Lollini, R., 2012. Nearly-zero, Net zero and Plus Energy Buildings - How definitions & regulations affect the solutions. *REHVA Journal,* pp. 23-27.

Weather Spark, 2012. *Weather Spark.* [Online]
Available at: https://weatherspark.com/averages/32855/Dubai-United-Arab-Emirates
[Accessed 19 February 2017].

Wilson, G., 2006. *Rashid's Legacy.* London: Media Prima.

World Weather Online, 2017. *World Weather Online.* [Online]
Available at: https://www.worldweatheronline.com/dubai-weather-averages/dubai/ae.aspx
[Accessed 27 April 2017].

Appendix A

الجامعة البريطانية في دبي
The British University in Dubai

APPENDIX A

STUDENT DISSERTATION RECEIPT

Programme	MSc Sustainable Design of the Built Environment	Submission Date	30th . April . 2017
Student ID	2014217073	Supervisor Name	Prof. Bassam Abu-Hijleh

DECLARATION

I confirm that I have read and understood the University Policy on Academic Honesty and that the work contained in the attached dissertation is my own work. Any assistance, of any type, has been acknowledged in my bibliography.

I also understand that the university may use plagiarism detection software on any submitted work, whether plagiarism is suspected or not.

I **do hereby consent/ do not consent (delete as applicable)** that my work is submitted into the plagiarism detection software to check the originality of my work.

Signature

30th . April 2017
Date

Note: Please complete the following section for final dissertation submission

PART A (to be completed by student)

Changes recommended by Supervisor have been made ☐ Yes ☐ No ☐ Not applicable
English and Arabic abstracts added ☐ Yes ☐ No
Spine and front cover printed in standard format ☐ Yes ☐ No
Dissertation Release form completed and attached ☐ Yes ☐ No
Soft copy submitted to library ☐ Yes ☐ No

Signature

Date

PART B (to be completed by Supervisor)

The dissertation is approved for submission to the library ☐ Yes ☐ No

Supervisor Signature

Date

PART C (For Library use only)

Student ID:
Received by:
Official Stamp:

Date of submission:
Signature:

Appendix B

102.05 Verification of Implementing Green Building Regulation

(a) Evidence of compliance for all applicable Green Building measures shall be provided to the Competent Authority. Specific requirements for information that demonstrates compliance are included within the practice guide and the associated implementation flow chart.

(b) Alternative methods of documentation shall be acceptable (with appropriate discretion) when the Competent Authority finds that the proposed alternate documentation is satisfactory to demonstrate substantial conformance with the intent of the proposed Green Building measure.

Table no. (1) General Requirements

Serial	Section	Chapter	Regulation No.	Regulation Title
1	Ecology and Planning 300	Chapter 01 - 301: Access and Mobility	301.02	Enabled Access
2		Chapter 4 - 304: Microclimate and Outdoor Comfort	304.02	Heat Rejection Equipment Installation
3			304.04	Colours on the Outside of Buildings
4		Chapter 5 - 305: Environmental Impact Assessment	305.01	Environmental Impact Assessment
5	Building Vitality 400	Chapter 1 - 401: Ventilation and Air Quality	401.01	Minimum Ventilation Requirements for Adequate Indoor air quality
6			401.02	Air Quality During Construction
7			401.03	Air Inlets and Exhausts
8			401.04	Isolation of Pollutant Sources
9			401.05	Openable Windows
10			401.07	Indoor Air Quality Compliance – Existing Buildings
11			401.09	Inspection and Cleaning of HVAC Equipment
12			401.10	Parking Ventilation
13			401.11	Environmental Tobacco Smoke
14		Chapter 2 - 402: Thermal Comfort	402.01	Thermal Comfort
15		Chapter 4 - 404: Hazardous Materials	404.01	Low Emitting Materials: Paints and Coatings
16			404.02	Low Emitting Materials: Adhesives and Sealants
17			404.03	Carpet Systems

Table no. (1) General Requirements				
Serial	Section	Chapter	Regulation No.	Regulation Title
18	Building Vitality 400	Chapter 5 - 405: Day lighting and Visual Comfort	405.01	Provision of Natural Daylight
19			405.02	Views
20		Chapter 6 - 406: Water Quality	406.01	Legionella Bacteria and Building Water Systems
21			406.02	Water Quality of Water Features
22		Chapter 7 - 407: Responsible Construction	407.01	Impact of Construction, Demolition and Operational Activities
23	Resource Effectiveness: Energy 500	Chapter 1 - 501: Conservation and Efficiency: Building Fabric	501.03	Air Conditioning Design Parameters
24		Chapter 2 – 502: Conservation and Efficiency: Building Systems	502.03	Elevators and Escalators
25			502.07	Electronic Ballasts
26			502.09	Control Systems for Hotel Rooms
27			502.14	Maintenance of Mechanical Systems
28		Chapter 4 - 504: Onsite Systems: Generation & Renewable Energy	504.01	On-Site Renewable Energy – Small to Medium Scale Embedded Generators
29			504.02	Outdoor Lighting
30	Resource Effectiveness: Water 600	Chapter 3 - 603: Onsite Systems: Recovery and Treatment	603.02	Water Consumption for Heat Rejection Including Cooling Towers
31	Resource Effectiveness: Materials and Waste 700	Chapter 1 - 701: Materials and Resources	701.03	Asbestos Containing Materials
32			701.04	Lead Containing Materials
33			701.05	Ozone Depletion Potential (ODP) Material Management

Table no. (2) - Bronze Sa'fa Requirements Required in addition to the General Requirements				
Serial	Section	Chapter	Regulation No.	Regulation Title
1	Building Vitality 400	Chapter 1 - 401: Ventilation and Air Quality	401.06	Indoor Air Quality Compliance – New Buildings
2	Resource Effectiveness: Energy 500	Chapter 1 - 501: Conservation and Efficiency: Building Fabric	501.01	Minimum Envelope Performance Requirements
3		Chapter 2 - 502: Conservation and Efficiency: Building Systems	502.02	Demand Controlled Ventilation
4			502.04	Lighting Density Interior
5			502.05	Lighting Power Density - Exterior
6			502.10	Exhaust Air Energy Recovery Systems and Condensation water
7		Chapter 4 - 504: Onsite Systems: Generation & Renewable Energy	504.03	On-Site Renewable Energy– Solar Water Heating System
8	Resource Effectiveness: Water 600	Chapter 1 - 601: Conservation and Efficiency	601.01	Water Efficient Fittings
9	Resource Effectiveness: Materials and Waste 700	Chapter 1 - 701: Materials and Resources	701.01	Thermal and Acoustical Insulation Materials

* Apply this table and read with Article no. 101.18

Table no. (3) - Silver Sa'fa Requirements Required in addition to Bronze Sa'fa requirement				
Serial	Section	Chapter	Regulation No.	Regulation Title
1	Ecology and Planning - 300	Chapter 1 - 301: Access and Mobility	301.01	Preferred Parking
2			301.03	Bicycle Storage
3			301.04	Charging Facilities for Electrical and Hybrid Vehicles
4		Chapter 2 - 302: Ecology and Landscaping	302.01	Local Species
5		Chapter 3 - 303: Neighborhood Pollution	303.01	Exterior Light Pollution and Controls
6		Chapter 4 -304: Microclimate and Outdoor Comfort	304.01	Urban Heat Island Effect
7			304.05	Orientation of Glazed Facades
8			304.06	Hardscape
9			304.07	Shading of Public Access Areas
10	Building Vitality - 400	Chapter 3 - 403: Acoustic Comfort	403.01	Acoustical Control
11	Resource Effectiveness: Energy - 500	Chapter 1 - 501: Conservation and Efficiency: Building Fabric	501.02	Thermal Bridging
12			501.04	Air Loss from Entrances
13			501.05	Air Leakage
14			501.10	Surrounding Shadow Factors
15		Chapter 2 - 502: Conservation and Efficiency: Building Systems	502.01	Energy Efficiency – HVAC Equipment and Systems
16			502.06	Lighting Controls
17			502.08	Control Systems for Heating, Ventilation and Air Conditioning (HVAC) Systems
18			502.11	Pipe and Duct Insulation

Table no. (3) - Silver Sa'fa Requirements Required in addition to Bronze Sa'fa requirement				
Serial	Section	Chapter	Regulation No.	Regulation Title
19	Resource Effectiveness: Energy - 500	Chapter 2 - 502: Conservation and Efficiency: Building Systems	502.12	Thermal Storage for District Cooling
20			502.13	Ductwork Air Leakage
21		Chapter 3 - 503: Commissioning and Management	503.01	Commissioning of Building Services – New Buildings
22			503.02	Re-Commissioning of Building Services – Existing Buildings
23			503.03	Electricity Metering
24			503.04	Air Conditioning - Metering
25			503.05	Central Control and Monitoring System
26		Chapter 4 - 504: Onsite Systems: Generation & Renewable Energy	504.04	On-Site Renewable Energy– Electricity Generation
27	Resource Effectiveness: Water 600	Chapter 1 - 601: Conservation and Efficiency	601.02	Condensate Drainage
28			601.03	Condensate Recovery
29			601.04	Water Efficient Irrigation
30		Chapter 2 – 602: Commissioning and Management	602.01	Water Metering
31	Resource Effectiveness: Materials and Waste 700	Chapter 1 - 701: Materials and Resources	701.02	Certified Timber
32			701.06	Recycled Content
33			701.07	Regional Materials
34			701.08	Composite Wood Products
35		Chapter 2 - 702: Waste Management	702.01	Construction and Demolition Waste
36			702.02	Bulk Waste Collection
37			702.03	Waste Storage
38			702.04	Waste Collection
39			702.05	Recyclable Waste Management Facilities

* Apply this table and read with Article No. 101.18.
* In case of Graywater use inside the building or Treated Sewage Effluent, all requirements of Article No. 603.01 are mandatory.
* If the green roof provides 30% of the total surface area of the building, it will be exempted from the requirements of Article No. 304-01.

Table no. (4) - Gold Sa'fa Requirements Required in addition to Bronze and Silver Sa'fa requirements				
Serial	Section	Chapter	Regulation No.	Regulation Title
1	Ecology and Planning - 300	Chapter 4 - 304: Microclimate and Outdoor Comfort	304.03	Green Roof
2	Building Vitality - 400	Chapter 1 - 401: Ventilation and Air Quality	401.08	Sealing Doors and Window Frames
3		Chapter 4 - 404: Acoustic Comfort	403.02	Sound Insulation
4			403.03	Extended Breaks and Prevention of shaking
5		Chapter 7 - 407: Responsible Construction	407.02	Ensuring Quality and Safety for construction activities
6	Resource Effectiveness: Energy - 500	Chapter 1 – 501: Conservation and Efficiency: Building Fabric	501.06	Air Leakage Test
7			501.07	Thermal Storage
8			501.09	Innovative Techniques to Enhance Building Thermal Envelop Performance
9		Chapter 2 – 502: Conservation and Efficiency: Building Systems	502.15	Control of Air Flow
10			502.18	Cooling of Corridors and Public Areas
			502.19	Air Conditioning and Ventilation of Parking Areas
11			502.21	Cooling Water Purification to Enhance Cooling Efficiency
12			502.22	Heat Exchangers
13		Chapter 3 – 503: Commissioning and Management	503.06	Pollutants Control and Pressure Assessment
14			503.07	Cost of the Expected Performance Assessment
15			503.09	Sustainable Awareness
16	Resource Effectiveness: Water - 600	Chapter 3 – 603: Onsite Systems: Recovery and Treatment	603.01	Wastewater Reuse

Table no. (5) - Platinum Sa'fa Requirements Required in addition to Bronze, Silver and Gold Sa'fa requirements				
Serial	Section	Chapter	Regulation No.	Regulation Title
1	Resource Effectiveness: Energy 500	Chapter 1 - 501: Conservation and Efficiency: Building Fabric	501.08	Heat Dissipation
2		Chapter 2 - 502: Conservation and Efficiency: Building Systems	502.16	Control of Chilled Water
3			502.17	Control of Air Conditioning Zones
4		Chapter 3 - 503: Commissioning and Management	503.08	Performance and Commissioning Reports

* Apply this table and read with Article no. 101.18