Exploring the potential of applying Sustainable Retrofitting Policies & Regulations for existing low-rise small-scale Residential Buildings (Villas) in Dubai, UAE

استكشاف إمكانية فرض لوائح و قوانين مستدامة لإعادة تهيئة المباني السكنية الصغيرة الخاصة (الفلل) و القائمة في دبي، الإمارات العربية المتحدة.

by

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Abstract

Green retrofit for existing buildings has now become as one of the effective options to decrease energy consumption worldwide. It is crucial to develop sustainable retrofitting policies and regulations for the existing old villas since there is lack of regulations to retrofit old existing low scale residential buildings like villas in Dubai.

This study aims to discover the possibility of providing regulations to retrofit old villas in Dubai. Six recommended retrofit measures were collected and interviews conducted to investigate the impact of applying them in an old villa using the IES software. A simple payback period was calculated to compare the energy saving with the time of the payback period to know if it is economically feasible.

The highest energy savings were achieved from changing the AC set point 5.61%. While the lowest energy savings comes from adding external shadings with 0.87%. Therefore, applying these retrofit measures as one of the regulations will not be that effective. Due to the different electricity rates for locals and non-locals, mandating these measures will not be economically feasible and the time of the payback period is too long. However, in nonlocal families, mandating more than only one retrofit measure can be effective as it is shown when combing changing the AC set point and adding roof insulation which leads to savings that can be paid back in less than two years.

Overall, providing mandatory regulations and policies to retrofit old villas in Dubai will not be possible in the local family because of the economical challenge. However, it would be possible to mandate the regulations to non-local families. Providing attractive intensives from the government to nonlocal owners with different business plans can help set such regulations. Otherwise, the longtime of payback period will not be convening to owners.

نبذة مختصرة عن البحث

أصبحت إعادة تهيئة المباني القديمة و القائمة الآن أحد الخيارات الفعالة لتقليل استهلاك الطاقة في هذه المباني في جميع أنحاء العالم. لذلك فإنه من المهم القيام بتطوير سياسات و قوانين و لوائح تحديثية مستدامة للفلل القديمة القائمة حاليا نظرا لقلة وجود هذه اللوائح للمباني السكنية القديمة كالفلل في دبي.

تهدف هذه الدراسة إلى استكشاف مدى إمكانية توفير مجموعة من السياسات و القوانين لإعادة تهيئة الفلل القديمة في دبي و التي لا تلبي متطلبات قوانين المباني الخضراء الحالية في المدينة. تم جمع ستة استراتيجيات تم تكرارها في عدة أبحاث سابقة و مستمدة من المقابلات التي أجريت للتحقق من مدى فعاليتها لتقليل الطاقة المستهلكة في الفيلا باستخدام برنامج ال IES. كما أنه تم حساب فترة استرداد مبلغ تكلفة الاستثمار و مقارنته مع نسبة التوفير في استهلاك الطاقة لكل استراتيجية على حدى لمعرفة ما إذا كان ذلك ممكن اقتصاديا.

تم تحقيق أعلى توفير للطاقة من خلال تغيير نقطة ضبط التيار المتردد 5.61٪. بينما كان أقل توفير للطاقة من تطبيق استراتيجية إضافة تظليل خارجي بنسبة 0.87٪. لذلك ، فإن تطبيق استراتيجية التعديل التحديثي لمثل هذه الاستراتيجية لن يكون فعالا. نظرًا لاختلاف أسعار الكهرباء للسكان المحليين وغير المحليين ، فإن فرض هذه الإجراءات لن يكون مجديًا اقتصاديًا ووقت فترة الاسترداد سيكون طويل جدًا. ومع ذلك ، فإنه من الممكن فرض أكثر من إجراء تعديل تحديثي واحد فعالاً عند تطبيقه على الفلل للسكان الغير المحليين كما يظهر عند تغيير نقطة ضبط التيار المتردد وإضافة عزل للسقف مما يؤدي إلى توفيرللطاقة و الذي يمكن سداده في أقل من عامين.

بشكل عام ، من الممكن توفير قوانين وسياسات إلزامية لإعادة تأهيل الفلل القديمة في دبي في المنازل التي تقطنها أسر غير محلية، في حال تم التمكن من التغلب على تحدي رئيسي و هو التحدي الاقتصادي. من الممكن أن يكون توفير حوافز جذابة للملاك الغير المحليين مع توفير خطط سداد مريحة لأصحاب الفلل مفيدًا جدًا في وضع اللوائح و القوانين الخاصة بإعادة تهيئة الفلل القديمة. بدون ذلك فإن فترة استرداد مبلغ الاستثمارستكون طويلة جدا و غير مقنعة للملاك.

Dedication

To my father who always believed in me.

To my mother who has always been there for me and supported me even with my independence.

To my incredible friends and colleagues who offer me endless support and encouragement when I feel the urge to give up. They all gave me the love and foundation to go all the way until I was able to finish my dissertation.

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Finally, none of this would have been possible without my parents, family members, friends and colleagues for always believing in me and pushing me to work harder. Without their continuous support and encouragement, I would not have been able to finish this research. I am grateful for having them all in my life.

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List of abbreviations

Word	Definition
BIM	Building Information Modeling
BCA	Building and Construction Authority
BREEF	Building Retrofit Energy Efficiency Financing
COP	coefficient of performance
DIES	Dubai Integrated Energy Strategy
DSCE	Dubai Supreme Council of Energy
DSM	Dubai Demand Side Management Strategy
ECMs	Energy conservation measures
ECO	Energy Company Obligation
EEMs	Energy Efficiency Measures
EPS	Expanded polystyrene
ESCOs	Energy Service Companies
ESM	Energy saving measures
EUI	Energy Utilization Index
GBRS	Green building regulations and specifications
GHG	Greenhouse gas
IEA	International Energy Agency
IESVE	Integrated Environmental Solutions Virtual Environment
LEED	Leadership in Energy and Environmental Design
LPD	lighting power density
MBIS	Mandatory Building Inspection Scheme
MENA	Middle east and north Africa regions
MOEI	Ministry of Energy and Industry
MWIS	Mandatory Window Inspection Scheme
nZEBs	Nearly zero energy buildings
REmap	Renewable energy roadmap
USGBC	U.S. green building council

Chapter One: Introduction

1. Introduction

1.1 Overview

Nowadays, there is a global imperative to reduce both gas (GHG) emissions and fossil fuel consumption. Drastic reduction in CO_2 emissions is essential to combat climate change, thus, major changes are needed to reduce society's energy consumption (Gram-Hanssen et al. 2018). The building stock itself represents approximately 34% of the total energy use worldwide in 2010. Specifically, 24% of that energy is directly related to GHG emissions (Trencher et al. 2016). Furthermore, this sector is accountable for about 33% of the electricity consumption worldwide (Rakhshan & Friess 2017). The huge amount of energy consumption can have a bad impact on the environment resulting in 40% of the carbon dioxide emissions coming from the buildings' sector only (Michael, Zhang & Xia 2017). In 2014, the buildings' sector solely accounted for nearly 40% of the primary energy consumption globally (Krarti 2015).

In fact, buildings in the Middle East and North Africa regions (MENA) have a higher rate of main energy consumption compared to other countries in the world. The high demand of energy in the Arab region buildings is predicted to keep on growing until the next decade because of the high growth rate of the population, as well as, due to urbanization. As a result of both fast population growth and urbanization, the growing in the building sector is very fast in the region. Moreover, while both, the global population as well as the economic development, are growing rapidly, the demand for achieving thermal comfort in the buildings, without having a negative impact on the environment, is fundamental (Rakhshan & Friess 2017). For that reason, many countries in the MENA region have started to consider providing significant subsidies for reducing energy consumption from buildings. For example, the United Arab Emirates (UAE) is considered one of the top countries globally for the energy consumption subsidies per person, with about $4172/person (Krarti 2015). There are many existing technologies nowadays that can be helpful to accomplish these demands and to reduce the emissions. The correct implementation of these technologies is primarily dependent on the enforcement of regulations and policies (Rakhshan & Friess 2017). The governments of cities are expected to start to innovate and come up with a new set of regulations and policies to control GHG emissions and fossil fuel consumption, especially in buildings, since they significantly contribute in this part (Trencher et al. 2016).

Existing buildings are considered as one of the main sources of energy consumption, hence it is necessary to retrofit the old buildings in country, in order to help to achieve the global target of reducing CO_2 emissions (Salem et al. 2018). Every year, 1-3% of existing buildings are replaced with new ones. This can lead to negative environmental impacts, resulting in 45% to 65% of solid waste from the demolished buildings (Michael, Zhang & Xia 2017). Since most of the buildings were built before the need for environmentally-friendly buildings were apparent, and the buildings require decades to replace, the need to have strict regulation for both new and existing buildings is essential. Especially existing old buildings, since they represent the largest segment of the building sector (Trencher et al. 2016). Moreover, most of the existing old buildings do not meet the current sustainable environmental standards, therefore, the need to decrease the carbon dioxide emissions from these old buildings, is an urgent task (Michael, Zhang & Xia 2017). Thus, the decarbonization of existing buildings still has a big challenge that needs to be taken into account to achieve the global target of reducing CO_2 emissions (Salem et al. 2018).

Regulations and policies for building energy can enhance the retrofitting in the building in a positive way. Saving energy through the retrofit of existing buildings represents an important approach and strategies for the governments, in order to reduce fossil fuels, which is one of the primary implementations of the national policies for climate change. Many programs and policies are initiated at a global level to use sustainable building retrofit as one of the ways that can help increase energy saving from existing buildings (Pampuri, Caputo & Valsangiacomo 2018).

1.2 Motivation for the study

Green retrofitting for existing old buildings has now become essential and efficient solutions to decrease energy consumption in buildings globally. However, when the retrofit is related to energy efficiency, and we compared it to it, we find that it is harder and more complicated, since we need to have comprehensive research and analysis of the many things in the existing buildings. For example, the report should include the local habits in that specific area within that community function as well as the government policies and regulations in that region and much more. Another challenge in sustainable retrofit for existing buildings, especially the residential buildings, is lack of the regulations and policies in this area and lack of new technologies that can help to achieve sustainable or green retrofit (Li et al. 2017). Currently, many effort and initiatives from many countries around the world in this area in order to achieve sustainable retrofit. Also, there is many guidelines and strategies that have been used and implemented in many existing buildings around the world. However, the mechanism of implementing these strategies still need to be enhanced by setting up clear laws and regulations to achieve the sustainable and green retrofit and to force the owners and stockholders to retrofit all the old buildings (Tan et al. 2018).

Lately in the United Arab Emirates, there have also been efforts to retrofit existing buildings, but on a more significant and larger scale like hotels, commercial and governmental buildings. In 2015, the Emirates Green Building Council (Emirates GBC) cooperated with the Supreme Council of Energy, and they established a technical guideline for retrofitting the existing buildings in the UAE. This guideline has five key parts that need to be taking into consideration while retrofitting the building in the country. The five areas are water, energy, indoor air quality, materials and waste, and innovation and building management. It also consists of the 31 main retrofit methods that can be implemented to existing buildings in the country. (EmiratesGBC Technical Guidelines for Retrofitting Existing Buildings. 2015). Even though there are guidelines in the UAE to retrofit or renovate existing old buildings, optionally, there are no strict and direct regulations to enforce people to retrofit their old existing residential villas. Moreover, the UAE is trying to achieve goals that were set by The World Green Building Council for all new buildings and existing ones since this sector is responsible for about 40 % of the world's carbon emissions. One of the goals is to make all the existing buildings work at zero carbon by 2050. This requires efforts in the deep retrofit of all the existing building stock, that includes villas, to be enhanced (Al Abbar 2019). This paper will help assess the possibility of providing a set of policies and regulations to retrofit old existing villas in Dubai. It will also set a baseline and suggest a framework in order to set some mandatory regulations to retrofit the old existing residential villas in Dubai, which do not meet the current green building system requirements.

1.3 Aims and objectives

In the UAE, the initiatives regarding retrofitting for the existing building were initiated in the last few years by providing a technical guideline with many methods that can be implemented in the existing old buildings to retrofit them. The guideline also contains many tools and processes that can be applied in the existing buildings by the owner of the stockholder decision to improve the building efficiency as well as reduce the environment pollution.

Lack of the regulations for existing buildings, especially for the small-scale residential buildings (villas) is the concern in this paper. Therefore, the primary purpose of this study is to find out whether it is possible to develop a set of regulations to achieve sustainable retrofit for the small-scale existing, residential buildings (villas) in Dubai in a sustainable way, taking in consideration the energy aspect.

The study will conduct an approach to investigate the existing old residential buildings, mainly villas, in Dubai that were built before the new green building code, that ensure buildings are built per the sustainable requirements. It will then analyze is effect on reducing the used energy in the villa. This will be accomplished by collecting data about old existing villas in the city, by considering the used material of the building, for example. All these data will lead to suggesting some of the policies and developing the sets of policies and regulations in one framework, in order to achieve a green retrofitting for this type of buildings in Dubai. To assess the proposed retrofit measures for villas which can be mandatory, a case study will be used to assess the effect of these strategies in reducing the consumption of the energy in the villa. Also, the impact of these strategies in the cooling load will be assessed. Moreover, an estimated cost for implementing the selected measures will be analyzed with simple economic analysis to determine the most appropriate measures to create a balance between energy consumption and cost. In order to achieve all these aims and objectives of this study, the following should be included:

1- Understanding the term of sustainable retrofit by gathering information about its types, factors, benefits, success and challenges
2- Collecting data about the polices and regulations of the sustainable retrofit worldwide
3- Gathering information about sustainable retrofit regulation in Dubai for villas and the challenges that may be faced, by interviewing some experts in the city from different sectors
4- Collecting data about both actual size and the age of the old existing residential buildings in Dubai with more specific details about them like the year of construction, to have a real case study that represents most of the old existing villas which do not meet any green building requirements in Dubai
5- Providing recommended policies and retrofit strategies for Villas from the energy aspect
6- Select the most appropriate strategies and retrofit options and evaluate them based on the energy savings and estimated cost and payback period, to select the most appropriate and effective ones that could be enforced as regulations in all old existing villas
7- Analyzing all the gathered data to explore whether providing these polices and regulations can be effective in retrofitting villas.

1.4 Research outline

The following is the list of what will be be covered in this dissertation:

- The first chapter is the introduction, which provides an overview of the topic (sustainable retrofitting). Followed with the aims and objectives of the dissertation study and concludes with the research outline.

- The second chapter is about the literature review, which covers multiple topics that are related to green retrofitting, such as the definition of this term, its types, benefits, the key issues, factors of the green retrofit, characteristics, success of the sustainable retrofit and the challenges to have a better understanding of this term. Moreover, it also covers the building energy codes, and its relation to the green retrofit as well as the initiatives in green retrofit worldwide and, in the UAE, specifically. It also reviews the policies with their types of green retrofit worldwide.

- The third chapter is the methodology. This chapter covers what is the best research method that can be used in order to achieve the main objectives and goals of this study. It also highlights the importance of using the selected research methodology in this dissertation by illustrating how previous research within the same topic as this dissertation was used to achieve the research aims and objectives. Also, it provides the pros and cons of each research method to help to choose the most appropriate methodology with a clear justification for that. This chapter also illustrates a detailed layout of how this research is to be conducted.

- The fourth chapter is Interviews and case study. This chapter has two main section. The first section is the qualitative research method which is the interviews. Many interviewees will be interviewed to collect more data specifically in Dubai about the retrofit regulations in the city. Also, to understand the challenge and the improvements that can be done in the retrofit policies to ensure providing a good framework that can be beneficial for the government, as well as refine the proposed measures and strategies to apply them in small-scale residential buildings in Dubai. The second section is the quantitative research method which is the computer simulation. In this section, the selection criteria and the selected case study will be introduced. Also, the selected strategies and retrofit measures for the villas will be applied in the case study using IESVE software. Each section in this chapter will conclude with the main findings.

- The fifth chapter is the Analysis and Discussion. This covers in detail all the different simulations that have been done in the fourth chapter. It shows all the simulation findings and compares the different simulations and results to conclude with an evaluation of all the strategies and measures that were used in the simulation.

- Chapter six, the last chapter, is the Conclusion chapter. This chapter follows the results and discussing the findings of the simulation. It contains the initial findings and the revised ones, of the aims and objectives to shows what was achieved and covered by this study. It also consists of research limitations as well as future recommendations that may help in future research and studies.

Chapter two: Literature review

2. Literature review

2.1 Introduction

Building sector is attributes to about 32% of the global energy consumption, for that, reduction of energy consumption in this sector is essential (Cox 2016). Nowadays, there are many actions focused on increasing the energy efficiency of the buildings because of its importance in overall world energy consumption. This has led to setting up many policies and regulations for achieving energy consumption in buildings since the year 2000. Most of these regulations were directly targeting new buildings, and many measures have been taken to enhance energy efficiency (Terés-Zubiaga et al. 2015).

Reducing energy consumption cannot be achieved without reducing the energy from the existing buildings (D'Agostino, Zangheri & Castellazzi 2017). Energy retrofit of the existing old buildings has a huge potential to decrease the energy consumption in the building and reduce carbon dioxide emissions as well (Webb 2017). To support this reduction, there is a minimum energy efficiency standard that needs to be followed in the energy codes of the buildings. These standards may contain the building envelope (HVAC) systems and lightings (Cox 2016). To achieve that, retrofit regulations are important to target a specific energy performance in the existing buildings in particular for the residential buildings (D'Agostino, Zangheri & Castellazzi 2017). The good implementations, energy codes, and regulations may have the ability to support energy cost savings by improving the air quality and increasing the users comfort inside the building as well as reducing greenhouse gas emissions (Cox 2016). Approximately, there are now more than 40 national governments that have building codes for new buildings. Some countries implemented energy codes for the existing residential and commercial buildings as well (Cox 2016). However, there are significantly less codes and policies for existing buildings. There are many efforts from the governments worldwide to implement the retrofit strategies in the existing buildings, especially in the governmental and commercial buildings, but there are still no clear regulations in the sustainable retrofitting of the residential buildings (Webb 2017). One of these efforts is the call to action that was launched by The World Green Building Council for all the existing buildings in the country to operate at net zero carbon by 2050. This call needs to accelerate the efforts in retrofitting the existing buildings to reach the deep retrofit and achieve the target (Al Abbar 2019).

Until now, it still considered a challenge to implement the retrofit strategies in the buildings since there are no clear ideas and policies to evaluate energy retrofit strategies in the existing old buildings

(Webb 2017). Also, achieving a comprehensive implementation of retrofit the existing buildings by renovating them is very challenging (D'Agostino, Zangheri & Castellazzi 2017). The biggest challenge is enhancing the energy efficiency in the existing buildings stock where retrofitting is considered an important aspect to enhance the existing building's energy efficiency (Terés-Zubiaga et al. 2015). In order to develop some regulations and policies to achieve sustainable retrofitting for the existing building, we need first to understand clearly what is the sustainable retrofit.

2.2 Green retrofit definitions

A considerable amount of literature has been published on retrofit and sustainable retrofit. According to one of these studies, retrofit is simply the change of elements or components of the buildings (Tan et al. 2018). The term exactly comes from re-fit some systems or subsystems for a particular purpose, or in some times, adding one or more components to something that did not have this new component or technology when it was manufactured (Hinge 2017). When it comes to buildings retrofitting, building retrofit is improving the energy performance in the existing building that can be achieved through the retrofit. It is summarized as the modification that can be done in the existing building through modifying and improving it is own systems, equipment's, and operation to enhance the overall building energy performance (Webb 2017). In a simple way, energy retrofit for the existing buildings is mainly done exclusively by upgrading the building energy performance (Hinge 2017). For example, the retrofitting can include changing the building thermal insulation, or changing the window frames. It may also use a different type of glazing for the building facade and for windows. In addition, upgrading the HVAC system of the building can be one of the major changes that will help achieve the retrofit to some extent (Webb 2017).

The term retrofit is limited when we talk about green or sustainable retrofit, which is limited to upgrading these elements and components to enhance the overall building environmental performance and decrease the energy use. In other words, the main scope of the green retrofit is to cover the scope of the upgrade. The term retrofit is addressed by many different terms in different studies such as: refurbishments, renovation, improvements, rehabilitation and renewal on the existing buildings (Tan et al. 2018). Additionally, sustainable or green retrofit is defined by the upgrading of the existing building fabric, systems, or the controls in order to enhance the total building energy performance. In other words, the U.S. green building council (USGBC) describes the sustainable retrofit as any type of improving an existing building, regardless wether the upgrade is done entirely or partially for many different aims. These aims are summarized as improving both of the energy and environment performance, reducing the used water in the building, enhancing the comfort of the spaces in terms of using natural lights as well as reducing the noise. Moreover, in any development of the existing building in order to make them green, both of the thermal comfort and the quality of the indoor air must be taken in consideration to achieve the sustainable retrofitting, regardless of the method used to achieve the green retrofit (Zhou et al. 2016). However, it needs to be done in a financially beneficial way to the owners, in order to be considered a green retrofit. For that, finding the balance between both of the used strategies and economic to improve the building environment is essential in sustainable or green retrofit. Given these definitions and explanations, it can be seen that the green or sustainable retrofit can enhance the energy performance of the existing building, satisfying all the services inside the building, in addition to enhance the indoor environment quality of the building (Tan et al. 2018).

2.3 Green retrofit types, benefits, factors, characteristics and challenges

2.3.1 Types of retrofit

The "renovation" term has been used to define a variety range of specific improvements to an existing building, which are considered a retrofit (D'Agostino, Zangheri & Castellazzi 2017). Both renovation and refurbishment are generally synonymous with the retrofit, but the scope of the renovations is more comprehensive (Hinge 2017). Renovation can include any replacement that can be done in the building or upgrading of some or all elements of the building, which have an impact on the energy usage. In addition, it can include any installation of renewable energy systems to decrease energy consumption in the building (D'Agostino, Zangheri & Castellazzi 2017). The term "refurbishment" is also considered a type of retrofit which refers to the basic improvement in the building at periodic intervals. Any work such as painting, repairing, and cleaning can be considered a refurbishment (Hinge 2017). The refurbishment of the building façade like windows and walls can provide a diverse energy level when it compared to the retrofitting of the complete building envelope and building systems like HVAC and lightings.

There are different ranges and levels for the retrofitting of existing buildings, whether it is renovation or refurbishment. The types can be categorized into four main groups: Minor, moderate, deep and nearly zero-energy buildings (NZEB) depending on the involvement and how much it can obtain energy saving. We can notice the difference in the building energy performance by changing or implementing a single measure such as the type of roof insulation and cooling or heating system. Such involvements are stated to as either light retrofit or minor renovation. (D'Agostino, Zangheri & Castellazzi 2017). This kind of retrofit requires low-cost energy efficiency strategies like the installation of pro programmable thermostats (Krarti & Dubey 2018). This type of retrofit can save up to 30% energy by implementing one of the above-mentioned measures. While in contrast, the deep renovation is about leading the refurbishment so it can decrease the delivered and the final energy consumption of the building, which can lead to a very high performance compared to the pre-renovation levels (D'Agostino, Zangheri & Castellazzi 2017). This type of retrofit requires big changes in the building, like replacing the whole cooling system and installing daylight control systems, which is generally considered as a costly option (Krarti & Dubey 2018). In other words, Deep renovation is about applying Energy Efficiency Measures (EEMs) that would be able to change the existing building to reach the net-zero energy buildings (NZEBs) with a more innovative technologies based on the renewable energy source (Penna et al. 2015). The reduction can reach 80% approximately (D'Agostino, Zangheri & Castellazzi 2017). Table (1) below, summarizes all the four types in general and shows the average percentage of the reduced final energy consumption. It also displays examples of the retrofit options that could be implemented in this type during the process, as well as the estimated project cost in AED/m2.

Table 1: Retrofit types summary (Author 2019)

Type of retrofit	Energy reduction	Examples of the options taken during the process	Average total cost (AED/m^2)
Minor	Decrease final energy consumption by 30%	Applying one to three retrofit strategies like replacing the lighting system	220 AED/m^2
Moderate	Reduce the energy consumption in the range between 30%–60%	Implementing three to five retrofit measures and it includes replacing all the lighting and HVAC system as well as replacing all the doors and windows	514 AED/m^2
Deep	Total reductions in the energy consumption in the range between 60%–90%	Adopting the retrofit as a set of strategies and all of these strategies working together like replacing or adding roof and wall insulation and using all the measures from the minor and moderate types	1212 AED/m^2
NZEB	It can reduce up to 90% of the total energy consumption	Type of retrofit that has a significant energy performance using all the previous retrofit measures	2130 AED/m^2

2.3.2 Benefits of green retrofit

One of the main advantages to retrofit the existing building is that it is considered as a low-cost method when compared to demolishing the building and rebuilding it. It can increase the building efficiency if it is done in the right way (ElGohary & Khashaba 2018). When we compare the retrofitting of existing buildings and demolishing and rebuildling existing buildings, we find that green retrofitting is more beneficial to some extent. The advantage of the sustainable retrofit for the existing buildings can be categorized by three main structures or levels. The three levels are the environment, society and the economy (Tan et al. 2018).

Previous studies demonstrate that green retrofit can have a big role to improve the existing buildings energy efficiency, which is important to promote for the sustainable environments. From the social aspect, sustainable of green retrofit is considered to be an important solution because it helps to preserve the culture of a particular region, as well as preserving the heritage values of the aged buildings. As a matter of fact, retrofitted existing buildings are more livable and much more comfortable depending on the building activities. This has happened because the improvements that have been done to the buildings contributes in promoting good indoor air quality (Tan et al. 2018). As a result, it can increase the occupants' productivity as well as reduces the negative impacts of buildings on the occupants. Moreover, green retrofit offers much healthier living environments depending on the level of retrofitting, as well as increases air ventilation. It also increases the daylight in the space and replaces the toxic finishes and materials (ElGohary & Khashaba 2018).

For the economic part, the advantages of sustainable retrofit can rise the value of the building. For example, it has been found in previous studies that the property value of retrofitted buildings has seen improvements of no less than 9% when compared to the un-retrofitted buildings in the same place (Tan et al. 2018). Also, it can have many benefits to owners, tenants, investors and even contractors. For the owners, there are many significant benefits that can be grouped into two main categories; the first category is about increasing the income because of increasing the rental rates which can lead to a higher occupancy and rental growth. While the second category is about lowering the cost because of lowering both, the operational and maintenance costs (ElGohary & Khashaba 2018).

2.3.3 Factors affecting green retrofit

Green retrofit for existing buildings can be the solution to decrease both of the total energy consumption in buildings and GHG emissions. To promote green retrofit and how buildings that have been retrofitted can have a good performance with the less used energy, there is a need to some extent new polices and technologies (Tan et al. 2018). The factors that can influence the energy performance should be taken into consideration when providing any kind of policies and regulations. One of the major factors that affect energy performance is the climate characteristic of the building area and location during the year (AlFaris, Juaidi & Manzano-Agugliaro 2016). Another factor is the initial conditions of the building, like its orientation and characteristics of the building envelope. These are essential factors to be considered when applying the green retrofit (AlFaris, Juaidi & Manzano-Agugliaro 2016).

To develop the existing buildings in order to make them green ones, thermal comfort as well as indoor air quality are essential. Moreover, the availability of advanced technology is considered one of the factors that can affect the green retrofit directly (Tan et al. 2018). Additionally, economic validity is another critical factor that has a huge impact while retrofitting any building. Economic validity can be analyzed by using tools such as calculating the payback period. (Zhou et al. 2016).

2.3.4 Characteristics, Success and case studies of green retrofit

Green retrofitting can play a crucial role in order to achieve the sustainable development. The retrofit effectiveness of the existing building can be affected by two board factors. The two factors are: the management and the technology used to retrofit the building (Zhou et al. 2016). Two key characteristics that will help identify is a building needs to be retrofitted or not. These characteristics are the building’s physical and conservation characteristics. The physical one is related to building shapes and geometry and it is more concerned with buildings that have complex shapes and designs. It also can be related to buildings that have no types of insulation. In addition, it is also concerned with buildings that use non-standardized materials, with no kind of indoor climate strategies, like natural ventilation and thermal mass (Webb 2017).

Applying the green retrofit in a building can be done in many ways, but its success depends on several factors. One of these factors is related to the retrofit awareness as well as the readiness of owners to retrofit their old buildings. In addition, the retrofit costs may directly affect the success of the building retrofit. The cost, in turn, affects the kind of technology that are used in the same building. Furthermore, the availability of different kinds of technology in each country is also considered one of the key factors. Similarly, the presence of the governmental support through imposing some laws and regulations to support and ensure that the green retrofit is successful. Among these factors, people's awareness about green retrofit and participants the public in sustainable retrofit can be enhanced through the government's guidance and policies (Tan et al. 2018).

There are many cases that prove the success of the green retrofit in residential buildings, internationally and locally. For example, an old existing house in New Mexico that was constructed in 1964. The house is 1500 square feet with three bedrooms and two baths, with a concrete block facility and a sloped roof. Before retrofitting the house, there was a retrofitting plan that was established based on the criteria of the green buildings in New Mexico (Amirhosein et al. 2014). The plan shows the priority of the retrofit activities as well as the process of retrofitting starting from the basic and least expensive strategies (Amirhosein et al. 2014). Figure (1) summarizes all the plan retrofit activities for the selected house.

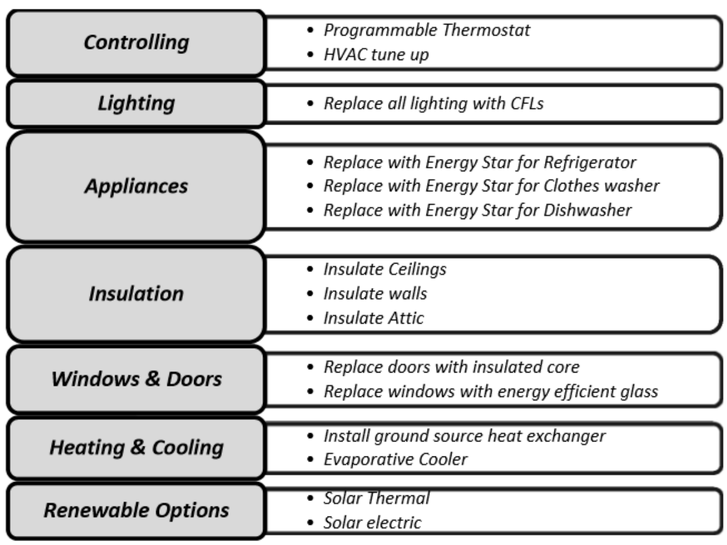

Figure 1: Planned retrofit activities (Amirhosein et al. 2014)

The results show that applying these measures could reduce the environmental impact, in terms of the harmful emissions from the building operation, by more than the half (Amirhosein et al. 2014). Moreover, the results illustrated that the lighting is considered as low-cost activity and replacing the insulation is a medium-cost activity. The Renewable Options are high-cost activity since it has a positive environmental impact during the house operation (Amirhosein et al. 2014).

One of the retrofit options that have been used in many countries is installing solar thermal water heating systems. In residential buildings, water heaters usually represent approximately 30% of the present-day electricity consumption. Installing a thermal hot water system in the building, can help reduce electricity consumption by nearly 15%. A case study on several residential buildings in Palm Jumeriah occupied 2800 m^2 of gross surface area. In this case, a supplier Viessmann installed a solar thermal heating system and it allowed the client to save 471,000 m3 in yearly gas consumption as well as avoiding 1,070,000 kg in CO2 emissions (EmiratesGBC Technical Guidelines for Retrofitting Existing Buildings. 2015).

Another example of the green retrofit success is one of the studies in the UAE, on the effectiveness of the retrofit measure that can reduce the final energy consumption in the buildings, which is by thermal insulation. According to a study by Rochester institute of technology, it is estimated that the existing buildings without any type of external insulation in the Middle East region use nearly 30% more energy needed for their air conditioning systems, especially in the summer months (EmiratesGBC Technical Guidelines for Retrofitting Existing Buildings. 2015). It can be avoided by adding thermal insulation to the existing building to avoid both energy consumption and reduce energy cost (EmiratesGBC Technical Guidelines for Retrofitting Existing Buildings. 2015).

A survey of the existing residential buildings (villas) was conducted to investigate the success and effectiveness of one of the retrofit measures - wall insulation. The study was mainly to analyze the effect of adding wall insulation on the energy efficiency for a small existing residential villa that was built in 2009 in the UAE (EmiratesGBC Technical Guidelines for Retrofitting Existing Buildings. 2015). This study identified the total energy saving in the villa which reached up to 30% depending on the insulation type that was installed.

There is another example that ensures the success of green retrofit in the UAE. A survey and site visit of ten typical villas in Abu Dhabi was conducted (AlFaris, Juaidi & Manzano-Agugliaro 2016). Several energy conservations measures (ECMs) have been implemented in this villa. All the ECMs that have applied in theses villas monitored for one year show the potential to improve the performance of the energy in the housing sector. By using different measures, energy efficiency increased by 25.1% implementing low and medium strategies (AlFaris, Juaidi & Manzano-Agugliaro 2016). The percentage of savings in these villas differs from 14.4% to 47.6% of the total electricity in each house. The percentage was varied because of the different occupant behaviors in each villa, as well as the difference individual operating conditions, which opens up a new perspective to retrofit the housing sector (AlFaris, Juaidi & Manzano-Agugliaro 2016).

2.3.5 Challenges and barriers of green retrofit

These policies and guidance that can provide from the government can be very helpful for implementing the green retrofit work in the existing buildings in an easy and effective way to ensure that the retrofit implementation will be a successful retrofit (Tan et al. 2018). However, there are many challenges and difficulties that may affect the success of green retrofit. The challenges in sustainable retrofitting lie in identifying the barriers that could stand in the way to reach sustainable retrofitting and how to overcome these obstacles through providing some policies and regulations that act as a motivation to retrofit the existing buildings. Also, the challenge lies in identifying what are the real motivators to retrofit the existing building to the owners, stakeholders, investors and contractors (ElGohary & Khashaba 2018).

The real and main challenge is how to achieve the desired achievement while respecting the budget which can be considered as a sustainable retrofitting (ElGohary & Khashaba 2018). When it comes to the implementation of the retrofit, the economic issues are considered as one of the main challenges that discourage the old building owners from implementing the building's retrofit (Tan et al. 2018). For the stakeholders, it is difficult to quantify the profits from the different sustainable retrofit alternatives (Wang & Holmberg 2015). The cost problems can be solved by selecting the most appropriate retrofit technology for each building by considering it is size, building users, etc. For example, by choosing the most appropriate system to reduce the payback period.

The availability of technology is counted as the baseline to enhance the existing building energy performance. However, the retrofit definitions emphasize that technical intervention is the prime measure to enhance building performance. The adoption of advanced technology and the innovation that is related to these technologies can be determined by economic growth, user satisfaction as well as the impact of the environment, which can be challenging in some regions (Tan et al. 2018).

Regardless of the benefits of the green retrofit in the existing buildings, there are many barriers that do not ease applying the green retrofit measures. These barriers can decrease the growth of building retrofit and renovation. The first barrier is a contribution to the high initial investment cost. The green building construction costs less in the first stage of designing compared to the green retrofits that need to be integrated in old and existing buildings. In addition to the high cost of the new systems and technologies that need to be implemented, the long payback periods can also be considered as the main barrier, especially for the public and for owners. Furthermore, lack of financial incentives or removing the tax incentives as well as the subsidies and not unifying them can be one of the barriers of implementing retrofit strategies and regulations (Jagarajan et al. 2017).

Another barrier is the lack of awareness about the sustainable retrofit advantages and the difficulty of understanding the codes and regulation, especially for the public and for clients. An additional barrier is also splitting the benefits. The tenants who pay the bills are not always the people who are benefiting from it. This can result in losing interest in investing in the green retrofit, since the owners are getting the most benefits. In other circumstances, tenants are not able to pay for retrofits in a residence that is not their own. Risk and uncertainty about the payback period and the building performance over time is a concern for people retrofitting their buildings. Moreover, the lack of experienced workforce and product information are also considered as barriers (ElGohary & Khashaba 2018).

2.3.6 Green retrofit measures and strategies

Building type, environment, its specific use and characteristics play a significant role in identifying the appropriate retrofit options for a building (Tan et al. 2018). Different environments, political and economic situations can influence the applicable retrofit measures for each community (Tan et al. 2018). The used retrofit measures and techniques can be categorized into three main groups: building services, building envelopes and renewable energy. Each category has a group of retrofit technologies relating to different parameters (Tan et al. 2018). In lighting, for example, it is more feasible to replace traditional lights with new ones, as the first stage of the green retrofit. Replacing the conventional lightings lamps in China with low energy lamps like T5 fluorescent lamps can save energy (Tan et al. 2018). For the same building service, replacing the old lighting bulbs with CFL/LED lighting, which has a better lighting power density (LPD) than the conventional one, is used as one of the energy measures (Krarti 2015). Based on a lighting survey that was conducted during a study to improve the energy efficiency for 10 villas in Abu Dhabi, it was found that replacing old lights with new LED bulbs can be 50% better than old bulbs. Hence, the heat generated by the traditional lamps will reduce (AlFaris, Juaidi & Manzano-Agugliaro 2016). Replacing both, the interior and exterior lighting fixtures, with high efficiency lights with occupancy sensors and controls is considered one of the retrofit techniques in sewed by Wang and Holmberg 2015. Using efficient equipment and adding motion and temperature sensors, as well as switches, have proven their effectiveness in reducing energy consumption (Tan et al. 2018).

From the building envelope category, there are different parameters, like roof, walls, windows and airtightness. Adding insulation in walls, whether internal or external, is one of the retrofit measures (Tan et al. 2018). Also, adding external insulation for the roof can contribute to reducing energy consumption and is considered as one of the measures (Penna et al. 2015). AlFaris, Juaidi and Manzano-Agugliaro approved that a cool roof system or roof coating by using reflective materials in arid climates can be sufficient to cool down the roof because of its effectiveness in increasing the solar reflectance factor. For windows, the US Department of energy approximations that inefficient window glazing performance is responsible for one-third of the cooling load (AlFaris, Juaidi & Manzano-Agugliaro 2016). Providing good shading, as well as replacing the existing window glazing with higher thermal performance can be useful in reducing the total energy consumption (Penna et al. 2015). Besides, replacing the frame with improving them by adding thermal breaks is considered as a retrofit measure (Penna et al. 2015). Also, for the building envelope, improving the airtightness is one of the retrofit measures that can reduce the waste of cooling energy. This improvement can be made by sealing the gaps around doors and windows (AlFaris, Juaidi & Manzano-Agugliaro 2016).

Improving the air conditioning systems (AC) efficiency in the building has a high impact on the potential to decrease the total electricity consumption for a villa by up to 41% (Krarti 2015). Oversizing machines in the AC system to cope with the extreme conditions leads to consuming more energy in cooling than needed. The typical AC system operates continually until the temperature of the room is met, while at the same time, a compressor will run in order to produce a higher power for cooling, which will make the compressor continue consuming energy without benefit. Providing a controller with software that can detect this kind of issue in the AC is recommended to be installed as one of the retrofit measures. The controller will help switch the composer off when it is not needed to maximize savings (AlFaris, Juaidi and Manzano-Agugliaro 2016). Also, installing a thermostat, to change the set point of the AC and reset it automatically, can be considered as one of the measures. Another retrofit measure is improving the coefficient of performance (COP). The percentage of annual savings for improving the COP of the HVAC system for an existing house in Kuwait reached up to 30% (Krarti 2015).

The last category in the green retrofit measures and technology is the renewable energy. It includes providing solar water heating as one of the measures. Many scholars highlight the value of using renewable energy to achieve a high performing building. However, some studies pointed out that the use of these measures is not feasible since the payback period is very long (Tan et al. 2018).

2.4 Building energy codes and green retrofit

Energy codes for the buildings are one of the controlling tools that define the minimum energy efficiency standards for the buildings. Generally, the codes mandate specific energy features for the technology that is used in the buildings. Also, the outcomes based on the building energy codes aligned with the performance of the used technology in the building can deliver a specific target for the used energy levels in the whole building (Cox 2016). Mainly, the building energy codes were established to build green buildings, that are defined as healthy facilities that are using ecologically-based principals that are designed in a resource-efficient way. These green buildings have been used to regulate some policies that helped to face the issues associated with the environment and climate change. Nowadays, there are many rating tools for the building in generals like LEED and BREEAM (Zhou et al. 2016).

Most of the building energy codes are designed for the new residential buildings to achieve the green buildings, where this term has been growing rapidly during the last 10 years around the world (Zhou et al. 2016). Applying the energy codes can be mandatory in some countries where it can be voluntary in others and frequently it can be complemented by some other energy efficiency building motivations (Cox 2016). Since the existing buildings are considered as a part of the building sectors, sustainable retrofitting of theses building can play an important role to achieve the goals of the green building. Some of the rating tools that are made specifically to transform the existing old buildings into green buildings are: LEED-EB and CASBEE-EB. Building energy rating varies based on the environmental conditions in each region and country. However, all of them share the same three main categories: energy efficiency, indoor and ecological environment (Zhou et al. 2016). Adjusting the energy codes to be suitable to applied in the existing residential buildings can be helpful to provide a new regulation to retrofit the existing residential building in the area.

2.5 Initiatives in green retrofit worldwide

Governments around the world have policies and regulations to improve energy performance and reduce environmental pollution. In this regard, green retrofit of the existing building provides a possible solution for the reduction of GHG emissions as well as energy consumption issues in the old existing buildings. A large and growing body of literature has investigated building retrofit in general but the number of these kinds of literature that is related directly to the sustainable is less. However, the related literatures have been carried out the green retrofit from numerous aspects. For example, the refurbishment of the existing buildings measures such as new technologies for envelope renovation of the existing building, solutions for refurbishing the air conditioning systems, and using green roofs and regulations (Tan et al. 2018).

By virtue of all the green retrofit benefits, the sustainable retrofit in the existing buildings with it is different types has been carried out in many countries around the world, which has led to provide some guidelines to retrofit the existing old buildings (Tan et al. 2018). There are many countries started some policies to motivate the buildings energy efficiency, which considered as one of the main factors that contribute to retrofitting the existing old buildings (Zhou et al. 2016). In the United States, the federal government has conducted a plan that will lead to retrofitting the existing buildings in the country. This plan is about the refurbishment of the existing building and its aim is to improve energy productivity by 2030. Similarly, most of the existing residential buildings that were built before 1980 in Germany were renovated by installing new energy-efficient systems for heating and cooling in these buildings (Tan et al. 2018). While in Japan, the PV systems are highly recommended and encouraged by the government to be used in all the existing buildings there which can be helped to produce electricity from the solar PV systems (Zhou et al. 2016). In Switzerland, they launched some new policies and regulations to support and to promote the existing building retrofit such as tax incentives. They also provide some financial assistance to help owners to retrofit their buildings. In Australia, some obligatory policies were adopted by the Australian government to support the green retrofit. For example, owners of big commercial office buildings were enforced to provide all the details and information about the energy efficiency of the buildings to the potential buyers or lessees in the building (Tan et al. 2018).

Similarly, there are many schemes around the world which were established to help homeowners make improvements in the energy-saving in their homes. For instance, Renewable Heat Incentive is based in the UK, which is mainly a financial incentive from the government to encourage people to switch the used energy in the buildings towards renewable energy. Similarly, there is the Energy Company Obligation (ECO) which is a governmental energy efficiency scheme that is used in Great Britain countries. Similarly, in Singapore, there is a scheme that offers financing to the owners of the buildings for energy retrofit which is Building Retrofit Energy Efficiency Financing (BREEF). In Hong Kong, two mandatory schemes were implemented in 2012: Mandatory Building Inspection Scheme (MBIS) and Mandatory Window Inspection Scheme (MWIS). These two schemes provide the chance to promote the green retrofit of the old buildings (Tan et al. 2018).

In the United Kingdom, the government has a strategy that aims to achieve a reduction of 80% in the country’s carbon emissions by 2050 (El-Darwish & Gomaa 2017). For example, the United States makes significant efforts, through the Department of Energy, to promote energy-efficient upgrades. The department sets mandatory requirements for reducing air infiltration. Stricter regulations for metal building roofs and walls, as well as improved clarity of exterior walls, seek to enhance energy consumption. The U.S aims to ensure an estimated 75% of its buildings are new or renovated by 2035 (El-Darwish & Gomaa 2017). Retrofit measures in China also provide examples of the new policies and regulations seeking to enhance energy efficiency. China's fabric approach to retrofitting supports the installation of solar thermal systems and solar P.V. systems (Zhang 2018). The fabric retrofit also provides opportunities for building airtightness to enhance cost saving and improve indoor living quality (Zhang 2018). The launch of the Building and Construction Authority (BCA) Green Mark scheme also provides insights into the new policies and regulations meant to evaluate sustainability in the existing buildings in Singapore. The initiative goal is to promote the development of green buildings that incorporate increased natural light, efficient ventilation systems, and the use of photovoltaic cells in the building (Siva, Hoppe & Jain 2017). Therefore, Singapore is in the position to rely on green building rating tools that emphasize on achieving energy efficiency through added insulations, low emissivity windows, and new heating systems. The various policies and regulations adopted by nations across the world reveal the desire by communities, governments, and institutions to support reducing energy consumption as well as the quality of living.

With excessive energy demand worldwide, the demand for retrofitting strategies is high. Retrofitting seeks to provide comfort in structures without interfering with functional needs. The components of retrofitting strategies include thermal and visual features that reduce energy consumption. Plans include airtightness, solar shading, and insulation to reduce energy consumption (El-Darwish & Gomaa 2017). Energy-efficient renovations strategies such as added insulation, efficient lighting systems, and new heating systems enhance energy efficiency. Landscaping is also one of the aspects considered to lower energy consumption. It creates a suitable microclimate that reduces the amount of energy needed for a sustainable indoor environment (El-Darwish & Gomaa 2017). The Green Investment Bank in the U.K. is among the initiatives embraced by the government to support green retrofitting projects. The institution encourages the installation of measures such as solar thermal panels and biomass boilers (Shan, Hwang & Zhu 4). Additional strategies involve relying on a building form that increases the ability of the structure to harness solar light and heat and support natural ventilation (Shan, Hwang & Zhu 4). Table (2) summarizes the various initiatives, policies, and strategies that have been used by different countries around the world.

Table 2: Summary of the initiatives, policies, and strategies that have been implemented worldwide (Author 2019)

Country	Initiatives, Requirements & strategies
United States	- Federal government has conducted a plan to refurbishment the existing building and it is aim is to improve energy productivity by 2030 - Set mandatory requirements for reducing air infiltration. - Tighter regulations for metal building roofs and walls - Improved clarity of exterior walls
Germany	- Renovated most of the existing residential buildings that were built before 1980 by installing new energy-efficient systems for heating and cooling - Use of renewable energy such as solar energy - Requirements for sufficient ventilation - Add Insulating to the floors
Japan	- The government encouraged owners to use PV systems in all the existing buildings to help generate electricity
Switzerland	- Launched new policies and regulations to support and to promote the existing building retrofit such as tax incentives. - Provide some financial assistance to help owners to retrofit their buildings
Australia	- The government enforcing owners of large commercial office buildings to provide all the details and information about the energy efficiency of the buildings to the potential buyers or lessees in the building
United Kingdom	- Providing government financial incentives to encourage people to replace the used energy in the buildings with renewable energy - Energy Company Obligation (ECO) which is a government energy efficiency scheme to help reduce carbon emissions - Installation of solid wall and floor insulation to reduce emissions - Whole-home retrofit to deliver high energy performance standards - Replacement of the older doors and windows with modern and efficient ones
Singapore	- Scheme that provides financing to building owners for energy retrofit which is called Building Retrofit Energy Efficiency Financing (BREEF) - Building and Construction Authority (BCA) Green Mark scheme which provides insights into the new policies and regulations meant to evaluate sustainability in the existing buildings - Increased natural light, efficient ventilation systems, and the use of photovoltaic cells - Use green building rating tools that emphasize on achieving energy efficiency through added insulations, low emissivity windows, and new heating systems
China	- Two mandatory schemes were implemented which they are Mandatory Building Inspection Scheme (MBIS) and Mandatory Window Inspection Scheme (MWIS) - support the installation of solar thermal systems and solar P.V. - Central heating system for residential buildings

In the UAE, the total electricity consumption is one of the largest consumptions in the world.

Since the building sector in the UAE has a huge potential to save energy, the Ministry of Energy and Industry (MOEI) started to work with both of the federal and local authorities to reduce energy consumption (The UAE state of energy report. 2019). In 2017, the Ministry launched a Federal Buildings Retrofit Program in the country which targets the energy efficiency in the building sector. This program is mainly about developing a federal framework for regulations and policies to control Energy Service Companies (ESCOs). The program has multiple phases. The first phase is targeting the energy audits for federal government buildings in all emirates using specialized ESCOs to identify energy conservation measures (ECMs) (The UAE state of energy report. 2019).

Dubai has started to roll out some standards to retrofit the older buildings since they consume a high amount of energy. There is a retrofitting program by Dubai Municipality, Dubai Supreme Council of Energy (DSCE) and Etihad ESCO which targets improving the energy performance of more than 30,000 existing governmental, industrial and commercial buildings by 2030 (The UAE state of energy report. 2019). However, there is no clear frame-work for the existing residential buildings and villas and it is not a mandatory until now.

All these efforts from the governments of different countries around the world indicate and emphasize the importance of the green retrofit for the existing buildings. Not to mention all the other efforts from the governments in many other countries to promote the green retrofit and apply the measures that will help to reduce the used energy.

2.6 Green retrofit in residential buildings

The building sector can be considered as one of the biggest energy consumers and it contributes largely to GHG emissions globally (Zhou et al. 2016). Energy used in buildings has increased by the comparable of million tons of oil in the last two decades. This number is bound to continue growing unless we have enough energy-saving measures that are conducted efficiently (Wang & Holmberg 2015). Many previous studies showed that the building sector itself is accountable for over nearly 30% of the global GHG emissions. Moreover, it is responsible for almost 40% of the primary energy consumption. Meantime, this sector consumes around 72% of the global electricity and produces around 67% of the solid waste (Tan et al. 2018).

Building retrofitting is considered as one of the valuable ways to speed up the low-energy transformation of housing (Wang & Holmberg 2015). Among all the buildings types, residential buildings are considered an important building category and limited efforts have been made to retrofit these buildings. It is essential to pay more attention to the existing old residential buildings and identify a clear green retrofit technology. Furthermore, it is also necessary to develop relevant sustainable retrofit regulations and policies for the residential buildings specifically in the line with some criteria, like the characteristics of the building and the climate (Tan et al. 2018). The existing retrofit solutions for residential buildings nowadays tend to be as highly specific cases and all the available retrofitting cases and models in the housing sector from many countries are mainly based on the local energy codes for the buildings, in that specific country, with a specific retrofit target. In the Italian residential building sector. for example, the retrofit strategy that was used in order to save the energy was mainly by replacing the windows, as well as the roofs and walls with thermal insulations (Wang & Holmberg 2015).

More recently, attention has focused on the provision of green retrofit in the residential buildings from the stockholder’s point of view and perceptions. These studies show that there are varied stakeholder’s perceptions of the green retrofit. For instance, house owners prefer to pay for the heat pumps to retrofit their house while the lessees prefer to pay more for the floor insulation. Some of the house occupants, whether the owner or the tenants, are unwilling to retrofit the building because of the lake of insurance that can be provided to them to ensure that the energy will be saved more after the green retrofit. The uncertainty in energy-saving makes them hesitant to retrofit their houses. Moreover, the owners lack of understanding about what the green retrofit really is, as well as lack of recognition the long payback time (Tan et al. 2018).

2.7 Green retrofit in the UAE

Building sector energy consumption, in the UAE, is a priority for the government because it has been found that the buildings in the UAE are consuming up to 70-80% of the overall electricity generation in the country. Inefficiency in the country-built environment is a result of the existing old buildings in the country. For instance, 25% of the existing buildings in Dubai are considered inefficient. Referring to the Dubai Supreme Council of Energy (DSCE), they have the potential for high energy savings if retrofitted well (Dubai Supreme Council of Energy 2018). Some research has evaluated the potential to improve the energy in the existing buildings and the result shows that the potential saving in the UAE public houses can reach up to 30.8% (Fayyad & John 2017). Moreover, previous studies show that applying the level one of green retrofit, which is a minor or light retrofit option, can have an average saving up to 8% approximately in the UAE for all building types. While applying level two of green retrofit measures, which is the moderate retrofit type, can have average savings of 23% for the residential buildings only in the UAE. On the other hand, applying level three of green retrofit measures, which is the deep retrofit option, can provide high savings in energy use that can reach more than 50% in the UAE (Krarti & Dubey 2018).

Existing residential buildings are contributing to high energy consumption. The renewable energy roadmap (REmap) emphasized that the residential buildings sector in the UAE is one of the major consumers of the primary energy responsible for nearly 29% of Dubai city total energy consumption (Abu-Hijleh & Jaheen 2019). The sustainability report also showed that the residential buildings in Dubai were the largest users of electricity b consuming up to 73.68% of the total generated electricity in the city of Dubai (Abu-Hijleh & Jaheen 2019). The 2030 Dubai Integrated Energy Strategy (DIES) aims to reduce the power consumed by 30% by the year 2030. In order to achieve that reduction, the Dubai government started the Dubai Demand Side Management Strategy (DSM). The DSM strategy comprises of eight different programs, each one of them is planned to address multiple aspects of electricity, energy and water source in Dubai. One of these programs is building retrofit, initiated by the Dubai Government, in 2013. From 2016 until 2018, 2531 buildings were retrofitted successfully in Dubai (Dubai Supreme Council of Energy 2018).

Retrofitting the residential villas to achieve a higher standard of energy can generate significant savings in the building energy and reduce the CO2 equivalent emissions since the total CO_2 equivalent emissions for UAE have been reported to be 175.4 Mt in 2014. The CO_2 equivalent emission only from the residential buildings is 27 Mt and the cooling of these buildings produces approximately 12.7 Mt of CO_2 equivalent emissions yearly. These high levels CO_2 emissions in the UAE are because of the large residential buildings in the country that were built before any green and sustainable codes. This increases the importance of finding effective ways to retrofit the existing residential buildings (Rakhshan & Friess 2017). In 2011, both Dubai Municipality (DM) and Dubai Energy and Water Authority (DEWA) established the green building regulations and specifications (GBRS) for the new buildings to be sustainable buildings. However, a big part of the existing buildings was not built on these specifications of the green buildings (Abu-Hijleh & Jaheen 2019). For that, it is essential to renovate the existing residential buildings that were built before 2011.

The experience of retrofitting the existing buildings worldwide can be used as a reference for all the decision-makers when it comes to applying the sustainable retrofit in the buildings especially in the countries that do not have any schemes regarding the retrofit of old existing buildings.

Nevertheless, some individual features can make implementing green retrofit from the accumulated experience around the world not applicable in some countries like the UAE. These distinctive features could be climatic features or could be from the different architectural characteristics in the UAE. Moreover, it could be the construction of materials and standards that were used while constructing these buildings. All these factors may affect and make the world experience unfeasible for the application in the UAE (Tan et al. 2018).

2.8 Polices and regulations of the green retrofit

Over the last decades, many executive related factors have received a high level of attention when it comes to building retrofitting. For example, the regulation and policy instruments that need to be forced to facilitate the building of retrofit practices in the country. Also, the energy performance of the building where the consultant is involved to ensure that the building retrofit is effective and sustainable. Similarly, to the professional consultants, the users of the building should have a decision about the building retrofit since their perspective and their comfort is essential (Zhou et al. 2016). Throughout the world, there was many specific technologies and green retrofit policies that have been applied in old buildings. However, these policies are still not well known and not applied in many countries around the world because of the little attention that has been paid from some governments in a particular region to identify clearly the practicable sustainable retrofit policies and technologies (Tan et al. 2018). For that, it is important to shift government priorities like developing regulations to retrofit the existing buildings and maintaining them is essential (Jagarajan et al. 2017).

Retrofitting of the existing residential buildings is a main concern of national energy policies globally. Identifying the regulations and policies that would able to achieve the green retrofit by renovating the existing old building in a cost-effective way is essential. The regulations suggest to firstly decrease the energy needs in the building and then adopt more suitable advanced solutions with suitable costs (Penna et al. 2015). In order to develop mandatory polices recommend technologies, the polices of refurbishment and renovation were reviewed. There are many policies that are connected to the refurbishment and renovation of existing old buildings worldwide. Based on the International Energy Agency (IEA), there are more than 500 polices in more than 29 countries. All the polices were collected and categorized in six main groups that are summarized with their distribution around the world in figure (2) below (Tan et al. 2018). Table (3) defines each type of retrofit policy worldwide with a short brief about each one.

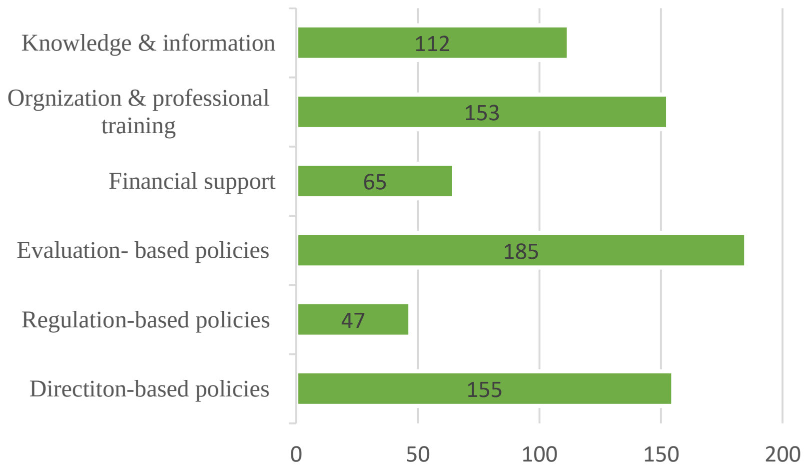

Figure 2: Polices of building retrofit type and it is distribution worldwide (Tan et al. 2018)

Table 3: Types of building retrofit polices (Tan et al. 2018)

Category	Definition & Brief
Direction-Based policies (DP)	Polices that are related to the future plans, strategies and roadmaps. It can provide a long term an idea about the direction in the long time to achieve the target and help the building's owners and developers to have an idea about the future market and trends
Regulations-based policies (RP)	Policies that are related to the green retrofit promoting which may consist of lows, codes and standards. Providing the regulation to set the minimum requirement for retrofitting the existing building since that the mandatory regulation can accelerate the progress of the building retrofit
Evaluation-based polices (EP)	Policies that are related to the labels of the buildings stars or buildings rating systems like Leadership in Energy and Environmental Design (LEED). This type of polices are essential because it help people to know the assessment criteria's and inspire them to accomplish the high energy efficiency level
Financial support polices (FP)	This type is considered as a supplement to mandatory green retrofit regulation policies. They are relatively more effective in the short term. Financial support policies to stakeholders are necessary since it can enhance the implementation of the green retrofit. Financial incentives can support developing and implementing new retrofit technologies. Subsidies like income tax reduction can used as drivers of energy efficiency retrofit existing building investment. Moreover, research funds, tax reduction and low interest rate for the retrofit strategies can support the retrofit market
Organization and professional training (OP)	These kinds of policies are related to the research and development that can help to develop and innovate new retrofit technologies as well as solving problems of the green retrofit. Providing training and professional skills are essential for the green retrofit developments
Knowledge & information (KI)	An alternative program that are supplements to mandatory RP and FP. Lack of awareness and knowledge of the people regarding the sustainable retrofit can limit the implementation of green retrofit to some extent, hence the need for KI is essential

2.9 Polices and retrofit measures for villas in Dubai

Based on the statistics from the Dubai Statistics Center, it shows that private villas are considered as the biggest type of buildings as shown in figure (3). As a consequence of increasing the population in Dubai, the number of existing private villas in the city increased too by the years. As illustrated in figure (4), the total number of the residential buildings (private villas) that built in 1993 were 15,655 villas, while in 2010, it was 32,580 villas only, in Dubai (Housing and Building 2019).

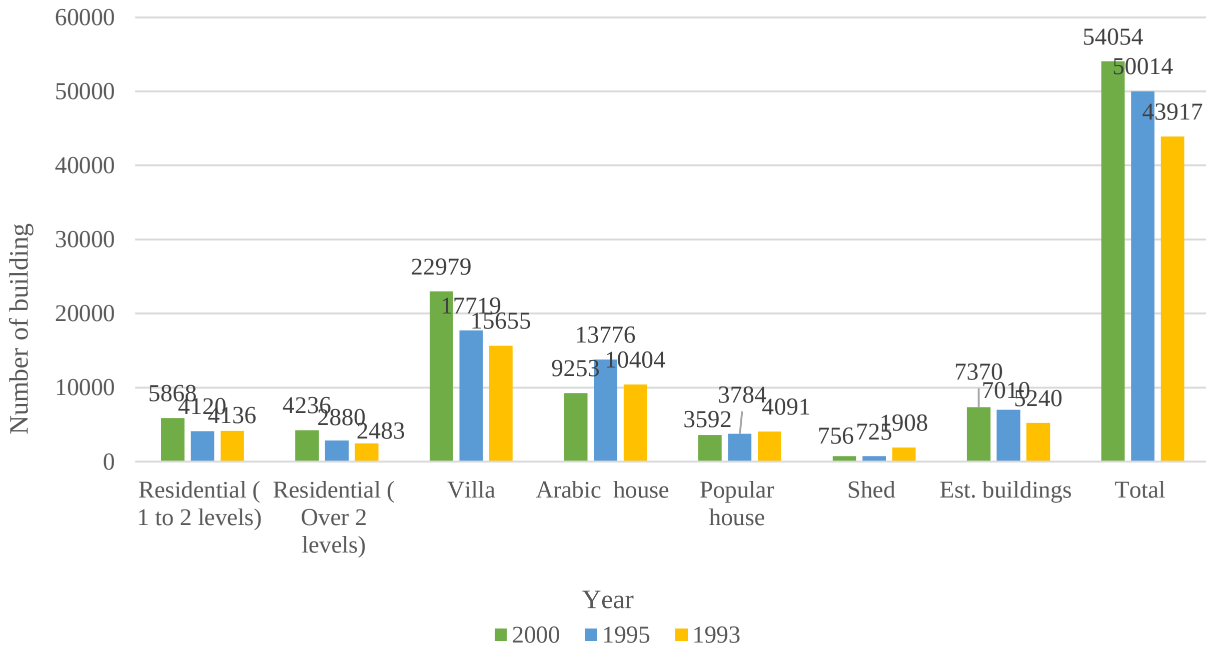

Figure 3: Completed buildings distribution by type in Dubai in 2010 (Housing and building 2019)

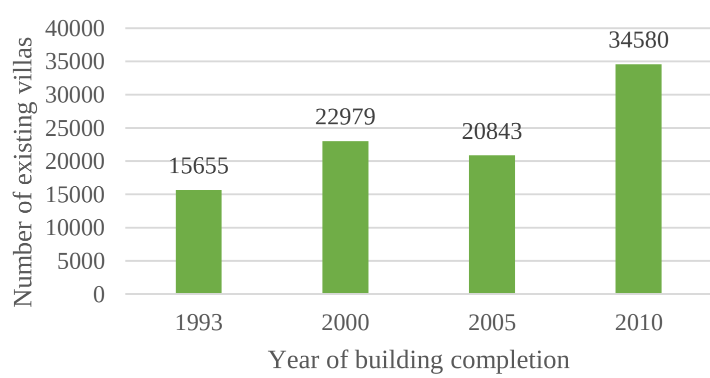

Figure 4: Number of existing private villas in Dubai in 2010 and before (Housing and building 2019)

From these statistics, we notice that a large part of the existing villas in Dubai do not incorporate any energy efficiency considerations. These villas were built before applying any green building regulation in 2011 while applying for permits for the villas (Rakhshan & Friess 2017). Figure (5) shows the estimated building energy use for residential buildings in the UAE. From the pie chart, it is shown that the majority of the building use is related to the space cooling consuming 46% of the total energy use (Abi Saab 2018). This high percentage is because of the excessive use of air conditioning in Summer, and the use of domestic electrical appliances that are not energy efficient (ElGohary & Khashaba 2018). Moreover, the hot climate in the UAE requires a heavy demand on the space of the conditioning systems. The HVAC systems accounts for approximately 40% average and the Summer peak of nearly 60% of the whole electric demand of the whole country (Rakhshan & Friess 2017). For that, the proposed regulation and technology of retrofitting the existing old villas must focus on space cooling.

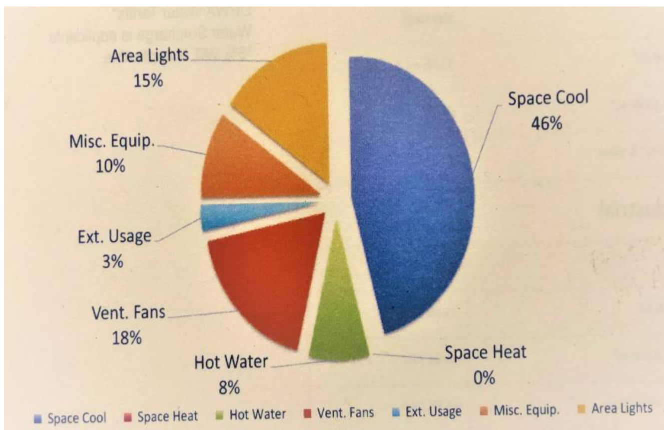

Figure 5: Approximate energy breakdown for a residential building in the UAE (Abi Saab 2018)

2.9.1 Proposed policies for retrofitting Villas in Dubai

This section will show the six main categories of green retrofit policies. It will describe similar policies that are already available in Dubai for each category as well as the recommended policies that may be useful in the future, if implemented in the city. Table (4), summarizes the available policies and recommended ones for retrofitting small-scale low-rise residential building (villas) in Dubai. It will also demonstrate the recommended policies during different stages; the stages are: pilot, promotion and at the end the implementation stage. Figure (6) illustrate basic framework to reach the dull implementation of green retrofit regulation and policies for villas in Dubai.

Table 4: Summary of the existing and recommended policies for retrofitting existing small-scale residential buildings (villas) in Dubai (Author 2019)

Category	Available policies in Dubai	Recommended Policies	NO.
Direction-Based policies (DP)	There are many DP polices in the city like DSM strategy 2030 that implements many programs such as building regulation and building retrofit	Formulate strategy that is related directly to the retrofit the existing small-scale residential building in Dubai (Villas)	DP1
		Develop an action plan related to the sustainable retrofitting for the small private villas	DP2
Regulations-based policies (RP)	Emirates GBC published a technical guideline for retrofitting existing buildings which provides a variety of economically viable retrofitting methods to achieve sustainable buildings	Develop a mandatory regulation for the existing old private villas that can enhance the building performance by applying improvements and retrofit technologies in the building based on the retrofit type	RP1
Evaluation-based polices (EP)	Currently Regulatory & supervisory Bureau (RSB) in Dubai working on energy accreditation scheme for ESCO who perform retrofitting. They we're also working on an energy and water rating scheme for existing public and commercial buildings in Dubai according to Elie Matar (Head of Electricity in RSB, Dubai)	Develop a new rating system only for the existing small-scale residential buildings (villas) to ease the implementation of the green retrofit strategy based on the total energy saving and the used of retrofit measuers	EP1
Financial support polices (FP)	Etihad ESCO provides free energy auditing for the owners of the villas as well as having a good business model to help clients to overcome the financing obstacles.	Initiate a subsidy scheme for the owners of the old villas to encourage them to retrofit their villas	FP1
		Providing loans for the owners with low interest rate or with no rate in collaboration with some banks for retrofitting existing villas if the subsidy is not enough	FP2
		Reduce the tax for the green retrofit companies and products in the city	FP3
		Providing funds from the government for the universities and research centers to encourage them to innovate new building technology for the villas with lowest possible cost	FP4
Organization and professional training (OP)	Emirates GBC's provide a Building Retrofit Training (BRT) Program in partnership with Masdar and Dubai Supreme Council of Energy (DSCE).	Adding new course in the Emirates GBC's Building Retrofit Training (BRT) Program for the villas only providing this course for the villa's	OP1

	The program is planned to teach the basics of green retrofit as well as teaching the advanced methods designed for professionals	owners for free	
Knowledge & information (KI)	Dewa has launched a unique programme in 2019 which is “My Sustainable Living”. Through this programme you can check your villa electricity and water consumption if you were in Dubai. Also, it allowed you to compare and monitor your consumption in comparison with other villas in your area to encourage people to save more energy. Also, it contains a customized dashboard, and personalized tips to save as much as possible as well as configure your savings plan.	Adding core subjects in the universities for retrofitting existing buildings	KI1
		Promoting for the green retrofit programs to raise the public awareness	KI2
		Encourage students in the universities to innovate new retrofit technologies	KI3
		Providing a platform that have all the date related to green retrofit based on the building type like creating an app	KI4

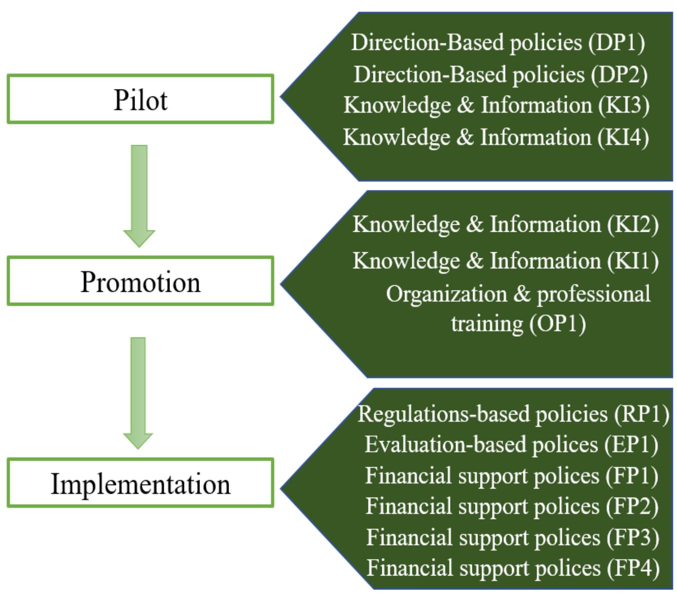

Figure 6: A framework to provide green retrofit regulations for villas in Dubai

2.9.2 Proposed retrofit measures for Villas in Dubai

Based on the previous literature review, three main categories will help to recommend the appropriate strategies and retrofit options in the existing old villas which they are: building service, building envelopes and Installation renewable energy. Table (5) summarized the most common measures for villas that have been used in the previous studies. The main retrofit options that can be implemented in existing old Dubai villas are listed.

Moreover, based on previous studies, we can find that there are many different types of green retrofit when compared with the amount of energy savings in each one. Since we will deal with the small-scale villa, the type of retrofit will be divided into three main types instead of four types, as it was shown in the literature to simplify the framework. The main three types are: light, moderate and deep retrofit. Table (6) describes each type of retrofit and the amount of energy it can save. Also, it illustrates the recommended retrofit options. After the simulation and the analysis for each option, the recommended retrofit measure will be analyzed based on the energy-saving and cooling load since that the biggest percentage that consume energy in the villa is the cooling. This can be helpful to select the options that can be regulated to implement in the existing old villas in Dubai.

Table 5: Technical descriptions of the energy-demand retrofit options: technique (related to energy) (Author, 2019)

No.	Item	Retrofit measures
1	Wall	Adding insulation to the external wall with reflected surface
2	Roof	Cool roof coating or adding insulation layer to the reef
3	Windows & glazing	Replacing the windows with high-performance double-glazing system and window frames with thermal break
4	Lighting	Replace the lighting with low energy LED lights
5	Shading	Adding external shading to the existing windows where it needed
6	Air tightness	sealing the gaps around doors and windows
7	AC	Change the cooling set point temperature
6	AC	Providing a controller with software, controller will help to switch the composer off when it is not needed to maximize the savings
8	AC	Replacing the whole system with better coefficient of performance (COP)
9	PV	Solar water heating

Table 6: Brief and expected savings from each type of retrofitting with the recommended options (Author, 2019)

# of option	Type of retrofit	Brief & Expected savings	Recommended retrofit options
1	Light	Type of retrofit that implements from one to three minor improvements like replacing windows	RO3, RO4, RO5
		It could reduce the final energy consumption up to 30 %	
2	Moderate	Type of retrofit that involves implementing three to five improvements	RO1, RO2, RO3, RO4, RO5,
		It can reduce the final energy consumption from 30% up to 60%	
3	Deep	It includes a high grade of refurbishment upgrade which leads to major improvements that used more than two ones and can reduce the delivered and final energy consumption	RO1, RO2, RO3, RO4, RO5, RO6, RO7, RO8, RO9
		It can result to have more than 60% energy reduction up to 90%	

Chapter three: Methodology

3. Methodology

3.1 introduction

This chapter will highlight the used methodologies about the green retrofit policies that were identified in the previous chapter which is the literature review chapter. Moreover, it will also highlight the importance of the used methodologies in the research as well as address the effects of the implementation of each one to illustrate a layout of how this study will be conducted.

Different methodologies were identified and used in sustainable retrofit regulation and policies. The study in this chapter will highlight both of the cons and pros features for each method that will be explained in detail. By highlighting both the cons and pros of the deferent methodologies, the choice of the most suitable methodology that can carry out the objectives of this study will be selected with the validation and justification of the adopted method in this study.

Many different methods were used regarding the same topic, therefore the methodology that is proposed for this study is a mixed-mode methodology which consists of using the literature review as research method, interviews and computer simulations. Other methods were used in the mixed-mode methodology such as field experiments instead of computer simulation to get real-life results of the proposed and used strategies for sustainable retrofitting.

3.2 Research approach and types of Methodology

The study that involves retrofitting, in general, can be difficult and complex since it has non-controlled variables and that is due to the fact that is the building is already existed. Therefore, it is important to use different specialties is essential in order to be able to use different measures in the existing building. Also, this complexity, evaluating different retrofit strategies can be difficult because of the unlike systems and subsystems that are influenced by distinct factors whether it was environmental factors, social or even technical (Soaresa,b et al. 2017). For that, the selection of the appropriate method can be very critical since it needed to address all the research objectives clearly.

Regarding this topic, many different methodologies have been used in this term as was mentioned before. Many of them compared between multiple codes, policies and regulations that will be useful to conduct and develop new policies for the green retrofitting small-scale residential buildings (villas) in Dubai. While the other researches review the sustainable retrofit measures and the used strategies, which can be applied in the existing building to achieve the building energy efficiency by using the computer simulation. In the simulation, computer software is used to evaluate the effectiveness of the conductive strategies and how much reduction in used energy can be achieved by applying them.

Developing new regulations and policies for the existing small-scale residential buildings (villas) in Dubai is challenging. In order to explore the possibility of developing a new one in Dubai and assessing these strategies, whether they are effective or not, multiple research methodologies need to be used. The following are the types of research methodologies that have been used by previous scholars.

3.2.1 literature review methodology

A literature review methodology is considered as a qualitative research approach that is used for inquiry and collecting data. Many types of research have been used the literature review as a research method when it is related to sustainable retrofit part. This method enables the researcher to collect data from previous research instead of starting from the beginning. By using this approach, the researchers were able to identify a more appropriate regulatory framework to achieve sustainable retrofitting. Moreover, it can help to achieve much more significant understanding of what the green retrofit is with a better idea about how it can be achieved in the existing buildings. It also explores the current trends in this topic, which gives an idea about all the characteristics, factors, barriers and challenges that can be faced while applying any of the green retrofit strategies in the future. By using this method, the researcher would be able only to conduct a new policy in a particular region by identifying all the policies and regulations that have been applied in different countries but also exploring the problems of using specific strategies in Dubai at an intuitive level.

Jagarajan et al. (2017) used this type of method and they were able to identify the factors of the green retrofit that would implement the green retrofit strategies successful, which will be taking into consideration while developing new regulations and policies for the existing residential building in Dubai. In addition, Meacham (2016) addressed the issues and problems with the regulatory system of the existing buildings by mentioning many concerns but focusing on the main one. In his opinion, the main concern was safety and health. All these previous studies helped to develop policies and regulatory frameworks, will lead to a cooperative and efficient building policies and regulations for the small-scale residential buildings in Dubai as well as increasing the building flexibility and reducing costs at the same time.

3.2.2 Computer simulation methodology

This research methodology is considered as quantitative research. Using this type of method can be very useful to find the required results by applying various conditions and variables. Although there is a doubt in the reliability of software generated results, the ease of getting these results immediately with many variables is an advantage. To evaluate and asses the developed strategies for the sustainable retrofit of the existing residential small-scale buildings in Dubai that are needed to be applied in the existing buildings, the computer simulation is a must as a research method.

This methodology can be the best method to use in order to determine whether the chosen strategies are valid or not and that is what Cetiner and Edis (2014) have used in order to assess the environmental performance for a residential building four floors. They selected a case study as a base case. Then, they applied the selected green retrofit strategies while taking into consideration the location of the case and the climate to minimize the percentage of the uncertainty in the results. In the computer simulation, the results display that the overall energy consumption can be reduced from 6186 MWh to 2865 MWh approximately if all the retrofitting strategies were applied in the building.

Wang and Holmberg (2015) used this kind of methodology to calculate the energy consumption in the selected existing building in order to find out their research question. In their research, they chose a typical house in their country as a case study which represents the most used existing housing unit in that region. Using the computer simulation method, helped them to calculate the overall energy consumption in the chosen case study before and after applying the green retrofit options. Salem et al. (2018) also selected the computer simulation to be the research method by using (TES, EDSL) software to analyze the thermal in a typical existing housing unit. Also, by using this method, they were able to calculate the energy reduction after adding the retrofit measures that improved the fabric of the existing housing. The results in the research show that energy demand can be reduced to reach up to 90.24% reduction yearly after applying all the suggested green retrofit measures on the housing envelope.

3.2.3 Mixed-mode Methodology

The mixed-mode methodology is the type of research method where the qualitative and quantitative methods are combined. Combining different methods can resulted in having more reasonable results as well as increasing the certain possibilities. Most of the studies and research that are related to green building retrofit policies and regulations use more than one research methodology. Developing new regulations and policies in this filed can be very challenging. To explore whether they will be effective or not, more than one method needs to be used; it would be challenging to evaluate the effectiveness of these regulations and policies by using only one research approach.

Krarti (2015) used this method; he studied many pieces of literature that published regarding the same topic. He compares the old and new building codes in Kuwait to prove how much the latest form of the energy codes can be very useful to reduce the total energy demand for commercial and residential buildings. Furthermore, he used a computer software to analyze the building energy using the construction features of the chosen existing buildings besides many other inputs like the occupancy pattern. All of that to only evaluate the potential of retrofitting the existing residential buildings in Kuwait. The results of his study show that by implementing the retrofit strategies that he proposed, like changing the roof insulation, the annual energy consumption reduced to reach 293 kWh/m2. Krarti and Dubey (2018) also used the same methodology. In their research, they used a detailed search to improve the technique and to use the strategies to evaluate the suggested retrofitting options for the existing building to achieve energy efficiency combined with a comprehensive energy building analysis.

Moreover, Zhou et al. (2016) used more than one method in their research to observe the factors that affect energy efficiency in the existing buildings. Firstly, they used the literature review methodology to specify the sustainable retrofit broadly. Then, they have chosen a case study to use it in the computer simulation via eQuest software as well as conducting a questioner survey. The survey helped them to know if the operations can meet the occupant's requirements. The result of this research shows that the total energy consumption can be reduced to 57%. This proved the effectiveness of the green retrofitting options that could be possible to provide a policy process as well as providing a regulated framework for the existing buildings.

3.3 Pros and Cons of different research methodologies

In this section, the advantages and disadvantages of each research methodologies will be identified to help select the most appropriate research method to achieve the aims and objectives of this study.

3.3.1 Pros and Cons of literature review methodology

In this method, several studies and articles were reviewed and studied in order to gather more data about a specific subject. It is a useful way that can help to have both general and specific data about the topic from all over the world. Using this method can help to have an idea about the best practices regarding sustainable retrofitting, which will give the researcher an idea about what is already have been done and accomplished. Also, it can be useful to collect more data about what is needed to be knowing or missing in that particular topic to avoid repeating what is already has been approved.

In some topics like the policies and regulations of sustainable retrofitting in the existing old buildings, it is good to use the literature review as the main research methodology since it can save a lot of time and effort to reach a regulatory and policy proposal. Furthermore, it does not require any money to use this method which will help the researcher to save more money to be used in other methods. However, there are some limitations and disadvantages to using this method. For instance, the researcher may search for unnecessary and non-worthy information, which will help the researcher's aims. Additionally, the collected information may not have enough evidence from them to rely on in the research.

3.3.2 Pros and Cons of computer simulation methodology

This kind of research method can help the researcher to build the model in any location and any climate to investigate a specific criterion in order to prove or deny a particular issue. Many various and different computer software depending on the issue that is studied in that research. This software can help the researcher to as countless simulations as it needed with many scenarios using diverse inputs without implementing them in real life. This saves both, time and cost. Another advantage of this method is that the research has the ability to control any variable in the software making it easy for them to find accurate results that he needs to investigate. For that, this type of methodology is considered a very flexible and easy method to use.

On the other hand, there are some disadvantages and limitations to using computer simulation, like any other type of research method. For instance, the results from the software may not be that accurate if there were any wrong inputs while doing the simulation or by putting an incorrect assumption in the software. Moreover, some of the software is not that accurate when compared to real-life measures. Hence, the selection of the right software that is directly related to the issue needed to investigate.

3.3.3 Pros and Cons of Mixed-mode Methodology

Combining different research methods is considered as a reliable methodology in general because the researchers can create and examine a grounded theory. By using this method, the researcher can use the strength in one of the used methods in his research to overcome the weakness in the other used method to achieve the complementarity concept. Studies related to the policies and regulations for the retrofitting existing buildings are becoming exceedingly popular when it comes to evaluating the retrofit options and strategies to the building has many factors and variables. These kinds of methods are considered as a good platform for the huge amount of data encompassing many various areas. This research method is enormously flexible since several combinations of methods can be used to achieve one particular thing, which makes the results more acceptable.

Despite all the mixed-mode methodology advantages, it also has some disadvantages. For example, some of the research needs a high level of confidentiality, where more than one method can be complicated to perform and use. Having an error in a particular fraction of data in one of the used methods may require much more work to be done. Also, it may need to collect more data and maybe more field and test work, which makes this method a tiring exercise if the used resources were not well allocated.

3.4 Research method and justification

Many previous researches have used different research methodologies to investigate the current policies and regulations that are related to the sustainable retrofit of the existing old buildings. The focus of this research is to explore the possibility of providing a set of mandatory policies and strategies in terms of energy aspects for retrofitting existing small-scale residential buildings (Villas) in Dubai that will need more than one research methodology. The most suitable method that can be used related to this topic is the Mixed-mode Method, as it was proven in the previous section. Most of the associated scholars have been used as a Mixed-mode Method using combined research method which they are literature review and computer simulation. In this research, another type of approach is needed to achieve the aims and objectives of the study which is another qualitative research method (Interview).

For this study, the Mixed-mode Methodology will be used to explore the possibilities to establish mandatory policies and regulations for retrofitting the existing old villas in Dubai using three main approaches. The first research method is the literature review methodology, which is considered as one of the more practical ways to have a clear understanding of the green retrofitting as well as collecting data. Also, it will be used to investigate the different initiatives, policies, strategies, challenges and barriers from all over the world to develop what it can be useful to implement in the UAE, focusing on the energy variables. The second method that will be used is the interviews. This approach is mainly for collecting detailed data about the sustainable retrofit policies, initiatives and strategies in Dubai. Through this approach, more data about the retrofit strategies and measures that can be easy to implement in the Dubai existing old villas by interviewing the stakeholders, whether they were from the government or from private companies or from the owners' perspectives. Also, the specific challenges that are related to the Dubai community will be investigated in the interviews. Different views and feedback from many government staff, stakeholders and owners will help to modify and develop the suggested framework and measures to suit old villas in the city to achieve the best practical strategies that can be implemented in Dubai.

The last approach that will be used is a computer simulation, which will be done by selecting a case study to implement all the proposed and modified strategies. Using this approach is essential because it is dynamic abilities to work, providing the finding based on a controllable variable and because it is the ability to allowing the repetition of the same simulation with changing one factor only. Also, it can save a lot of time and money to provide the findings at any time of the year which will be very useful to decide the best strategies and measures that can be used in Dubai old villas.

Integrated Environmental Solutions Virtual Environment (IESVE) software was selected as a simulation tool because it is flexible in providing all the needed data and feedback from the case study. The software will help to create many models by inserting real data from the case study and applying the proposed retrofitting measures in the same case to measure it is effective in reducing the existing building energy consumption. Thus, how much it can reduce electricity bills to achieve sustainable retrofitting. Therefore, the software will evaluate the selected building performance before and after applying the selected retrofit options to investigate the validation of the collected data and proposed strategies.

Examining the data conducted from all the research approaches listed above will be based on the previously mentioned studies related to sustainable retrofitting for the existing buildings and their analytical methods of studying similar topics of research.

3.5 Methodological framework

The following figure describes the framework of used methodologies in this study starting from data collection which collected mainly from the literature review to the recommended future policies and strategies for green retrofitting of the existing villas in Dubai.

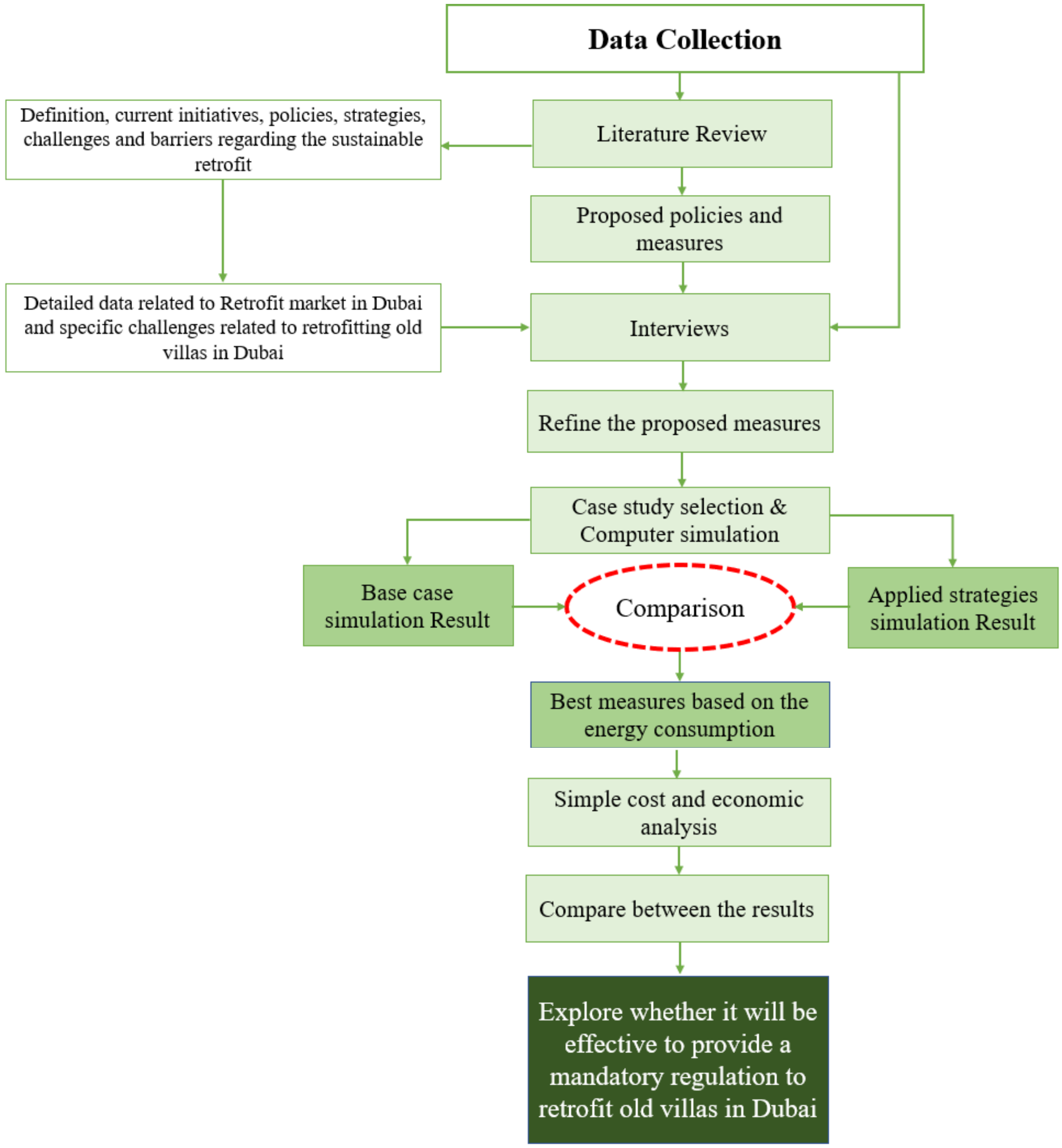

Figure 7: Research approach methodological framework (Author, 2019)

Chapter four: Interviews & Case study

4. Interviews & Case study

4.1 Introduction

This chapter is divided mainly into two main sections. The first one is the interviews where we asked different people from different sectors related to or specializing in retrofit or building energy in Dubai. Also, interviewing some locals in order to modify the suggested framework from the literature review and selected the most appropriate retrofit measures from the energy perspective to retrofit an old villa in the city. The second section is about choosing a case study and model it in a computer simulation using the IES software to measure the effect of applying these measures in a villa and narrow down the measures that can be added as a regulation for villas in Dubai.

4.2 Interviews

4.2.1 Introduction

This section presents the answers obtained from ten different interviews conducted in Dubai in the first three months of 2020. The interviews will mainly target the staff from government and non-government who have direct interaction with the retrofit and building energy for existing buildings as well as local owners. It begins with the introduction of this method procedure, interview protocol and the list of initial and final questions. Then it is followed with the list of interviewees and the main themes and points are provided from answering the interviewer's questions.

4.2.2 Interview protocol

Each interview will contrast from 30 to 60 mins. All the interviews will be audio-recorded and will be used later on to identify the main themes and common viewpoints. Different types of interviews can be used based on the questions that the interviewer is intended to ask, which will identify the type of interview. The purpose of the interviews is to gather more data about the retrofit for villas in Dubai. Also, to find the challenges related to our society that may prevent applying a green retrofit regulation for old villas in the city. Moreover, to find out how we can increase the interest of the owners to do a retrofit, which can lead to refine the proposed framework and refine the proposed retrofit measures. For that, it not possible to have closed-ended questions where the interviewee can select from the provided options. So, between the qualitative and quantitative interviews, the qualitative interview is chosen to be the type that will be used in this section.

Qualitative interviews classified into three main types which they are: Informal conversational interview, interview guide approach and standardized open-ended interview. Each one of them has unique characteristics, strengths and weaknesses. The feature of the informal conversational interview is that there are no prepared questions and it emerges from the immediate context of the conversation (Johnson & Christensen). In contrast, the interview guide approach characterized by specifying all the topics and issues in advance where the interviewer can decide the sequence of questions during the interview. The last kind of qualitative interview, which is the standardized open-ended interview, is characterized by determining both the wording and sequence of questions in advance where all the interviewees are asked the same questions in the same series (Johnson & Christensen).

Interviews are used to get direct feedback from the participants; for that the best type in this research that can help to achieve this research goal is the standardized open-ended interview. Using this type of interview will help to compare the answers of all the interviewees since they will answer the same questions. Thus, it will increase the comparability of response and will reduce the interviewer effects and bias (Johnson & Christensen).

4.2.3 List of interviewees

There were ten interviews conducted. The Interviewees have been divided into four main groups. The first group is representing the government staff and the second one is representing the semi-government staff. The third category is representing the private companies' staff and the last one is the owners specially locals since they owned most of the old existing villas in the city. The details of the interviewees are listed in table (7) below. All the interview details are in Appendix A.

Table 7: List of interviewees (Author 2020)

Group	No. of participant	Interviewee	Position	Date	Site	City
Government staff	P#01	Ryan Ben Sabilala Ryan.sabilala@dewa.gov.ae	Engr-Sustainability	16/02/2020	Dubai Electricity and Water Authority (DEWA)	Dubai
	P#02	Noora AL Hammadi Noora.alhammadi2@dew.gov.ae	Engr-Sustainability	16/02/2020	Dubai Electricity and Water Authority (DEWA)	Dubai
	P#03	Fida AL Hammadi FMHAMMADI@dm.gov.ae	Head of Planning Studies Section - Building Permit Department	02/03/2020	Dubai Municipality (DM)	Dubai
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	P#07	Fadi AlFaris Fadi.Alfaris@quantumesco.com	PhD, CMVP, CEM, PMP, LEED AP, USGBC Faculty, Business Director in the compony	09/03/2020	Quantum Eurostar Energy Solutions LLC	Dubai
Owners	P#08	Rashed Bin Yaroof Alsuwaidi Rashedbinyaroof@hotmail.com	Resident	08/03/2020	Al Twar	Dubai
	P#09	Seham Alfalahi Seham.al-	Resident	08/03/2020	Al Warqa	Dubai

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	P#10	Amina Abdulla Amina.a@economy.ae	Resident	11/03/ 2020	Umm Suqeim	Dubai

It was necessary to do interviewees with different people from different sectors to discover all the challenges from different perspectives to accomplish the main purpose of this section. All the interviewees are in form face-to-face conversations except the last group except the participant # (7) from the private companies and the last group (owners) were in form of telephone interviews.

4.2.4 Pilot interview and questions

The selected interview type was the standardized open-ended question, which needs to determine the exact wording and list of questions in advance. Also, the sequence of the questions should be at the same order. The initial prepared questions to start the conversation with all groups were listed in the table (8).

Table 8: List of the initial questions (Author 2020)

No.	Initial questions
1	Why does UAE need to develop regulations and provide policies to retrofit small scale residential buildings (Villas)?
2	What are the current situations and issues of energy saving in the existing retrofit community in the UAE?
3	What are the issues of retrofitting the small-scale residential buildings (villas) compared to other types of buildings in UAE?
4	What are the common retrofit strategies that are used in current projects in the UAE?
5	How was the performance of the previous related projects to retrofit villas in UAE?
6	How do residents and owners can participate in the retrofit?
7	What kind of the economic issues of retrofit in UAE?

The pilot interview was conducted informally by the researcher with one of the interviewees. From this interview, the initial questions were discussed with Eng. Fida Al Hammadi, before conducting any real interview and compared with the research objective. She found that the questions were too broad and needed to be more focused and direct to the interviewee. Also, all the questions were the same for all the groups. The feedback was not to generalize the questions for all groups which will not be effective because of the owners. They may know nothing about the retrofit and its benefits. Since there is a difference between the interviewee's backgrounds, an adjustment needed to modify the level of the questions for the different interviewee categories. All the questions modified and adjusted to be understandable, especially for the last group. It was essential to use other questions with an easy language since they may not have any idea about the term retrofit, and it will be hard for them to understand. Thus, the set of prepared questions for the owner's group was different than the questions of the governmental and private companies' staff. Although the questions have differed, all of them are prepared to achieve the same goal of the interviews. The final questions are listed in the table (9).

Table 9: List of the final questions (Author 2020)

Group	No.	Final questions
Government + Semi government + Private companies	1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?
	2	How was the performance of the previous related projects to retrofit villas in UAE?
	3	Why it is hard to implement the retrofit strategy in small villa?
	4	What are the ways that you think we can catch the interest of the owners and local clients?
	5	What are the best strategies that can be implemented in the villas?
	6	In your opinion, which one of these strategies we can add it as a regulation to retrofit the existing old villas and why?
Local owners	1	Did you hear before about the term (Retrofit)?
	2	After we talk about what is a retrofit, will you apply the retrofit strategies in your villa to reduce your energy consumption and to reduce your electricity bill?
	3	Do you prefer to force the owners to apply these strategies on the old villas or make it optional and why?
	4	If there is a new regulation from the government to retrofit the old houses and villas, will you do it without any funds from the government?
	5	Do you think it is hard for you as an owner to implement the retrofit strategies in your home if it was mandatory and why?
	6	If there are government subsidies or conventional loan, would you retrofit your home without imposing strict regulation in particular?
	7	As a villa owner, what are the things that you need from the government, or you believe it will help you to be able to retrofit your villa easily and conveniently without having any strict regulations in particular?

4.3 Case study

4.3.1 Introduction

This section, in general, will cover the overview of the site and case study selection in the city of Dubai as well as the reason behind selecting this typical case study as a base case. It will then explain the procedure of the simulations by calculating the energy consumption in the case study chosen before and after applying the proposed green retrofit strategies and measures. Computer simulation will help to select the most appropriate ones that will be easy for the government to regulate some rules to implement these strategies.

4.3.2 Site and case study selection

Many of the old residential areas in Dubai have been changed to commercial areas and investment buildings due to the local resident of these areas moving to newer regions such as Al Rashidiya and Abu Hail. One of the few areas with a majority of residential houses is Al Mamzar and Nadd Al Hamar. Figure (8) shows the Nadd Al Hamar area, which is considered as a small, residential and industrial community in the city. The residential part of this area has many old neighborhoods with many existing villas. As per the statics from the GIS section in Dubai municipality, 1236 villas were permitted and built-in these neighborhoods before 2011, which represented the current requirement of the green building energy code and regulation in. In fact, 717 villas built between 1980 and 2003, where even no kind of green building codes was applied when they were made (Dubai Municipality).

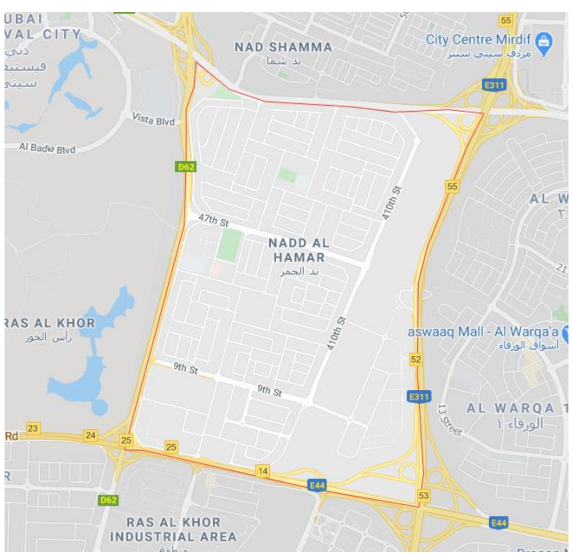


Figure 8: Nadd Al Hamar location (Google Maps 2019)

According to figure (9), that shows the number of villas that were built in Nadd Al Hamar in different periods before applying the green codes and while contracting these villas. From the table, we can notice that the most significant number of villas that were built in Nadd Al Hamar were in the period from 2000 till 2004, with a total of 453 villas based on the data from the GIS section in Dubai municipality. It can be seen that the number of villas fell slightly in the next period (2005-2009) to be 427 villas while there are 301 villas in the period 1995 till 1999 where no any type of green buildings. Therefore, the case study that was selected as a base case was chosen in that period with nearly the same construction material and the same used systems (Dubai Municipality).

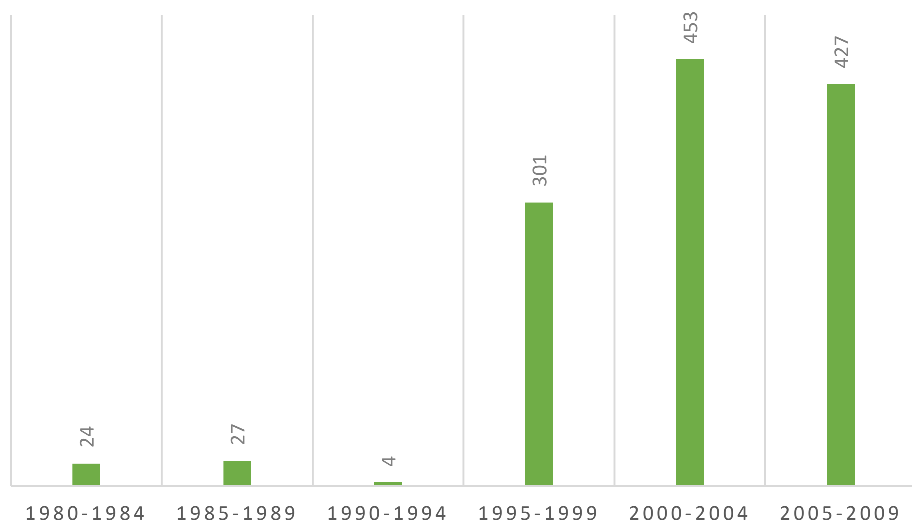


Figure 9: Number of existing villas in Nadd Alhamar in different periods (Dubai Municipality)

4.3.3 Climate of the city

The climate in the United Arab Emirates (UAE) is a hot desert climate. Hence, it has a hot

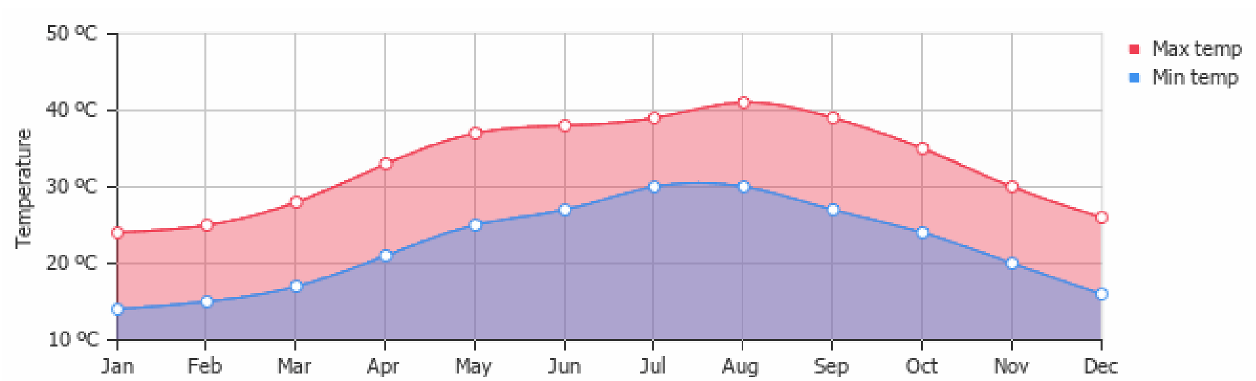
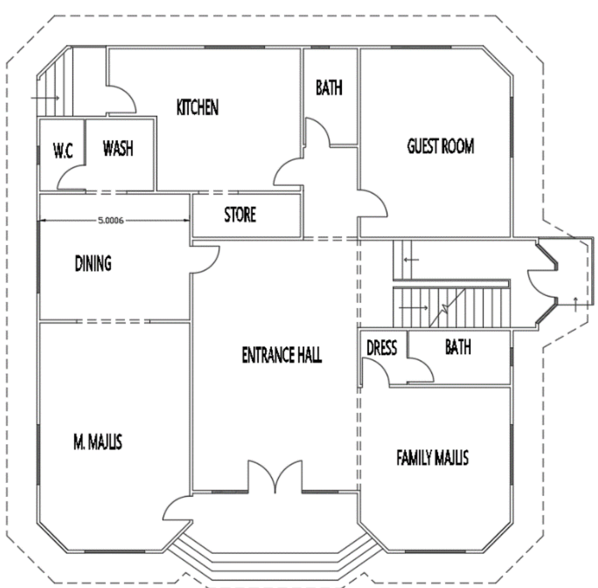


Figure 10: Minimum and maximum monthly temperature in Dubai (Average monthly temperature in Dubai, United Arab Emirates (celsius) 2019)

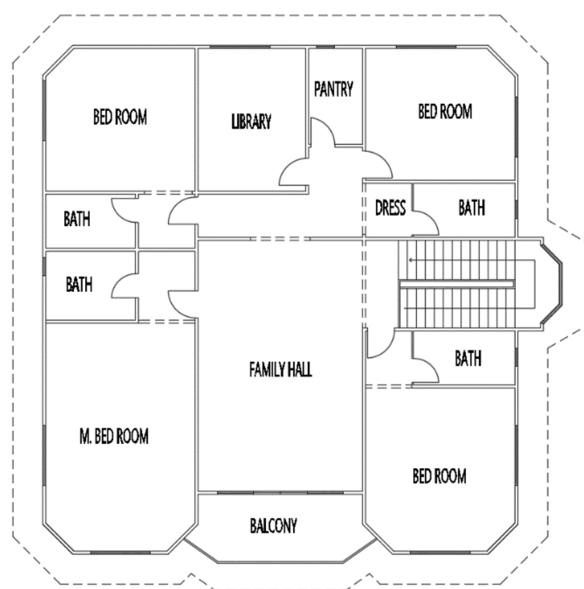
summer and very little rainfall, although this changes slightly in the past couple of years due to climate change. It also has a warm winter. This means most of the time, people need air conditioning most of the time (Climate and average weather in United Arab Emirates 2019). In Dubai, specifically, the minimum and maximum average monthly temperatures are shown below in figure (10). The figure shows that the first three months in the year January, February, March and the last two November and December have a nice average temperature. The warmest month in the year is August, while the coolest one is January. However, on average, the temperatures in the city are always high (Average monthly temperature in Dubai, United Arab Emirates (celsius) 2019).

4.3.4 Background of Case Study

The villa was built in 1998 in Nadd Alhamar neighborhood with no any consideration of the energy efficiency since it built in the period pre-2003. Most of the existing villas in that area are built with the same construction materials, using the same HVAC systems used in the selected case study. The villa consists of two floors (G+1) where the ground floor has multiple functions like kitchen, guest bedroom, majlis and dining areas while the bedrooms are on the first floor. Figure (11) shows the typical plan of the case study. The drawings of the villa were collated through Dubai Municipality. Table (10) represents the basic information of this villa in order to take it as a base case. This case study seeks to examine the validity of implementing the retrofit measures.



Ground Floor Plan



First Floor Plan

Figure 11: Case study floors plans

Table 10: Selected case study parameter

Parameter	Existing villa
Year of built	1998
No. of floor	2 (G+1)
Total area	554 m^2
Floor height	3.7m
HVAC	Split air conditioner
Set point temp.	22°C
Number of people	10 adults
Model thermal zone	Ground floor: All family activities that are mostly occupied at the daytime + kitchen and a guest room First floor: Main Bedrooms that are mostly occupied at the nighttime 4 occupants are working in the weekdays from 8: 00 a.m. until 4 p.m.

4.3.5 Base case model & construction material

The base case model of the selected villa from the previous section was drawn in the software. Figure (12) shows the model of the base case through the IES VE software.

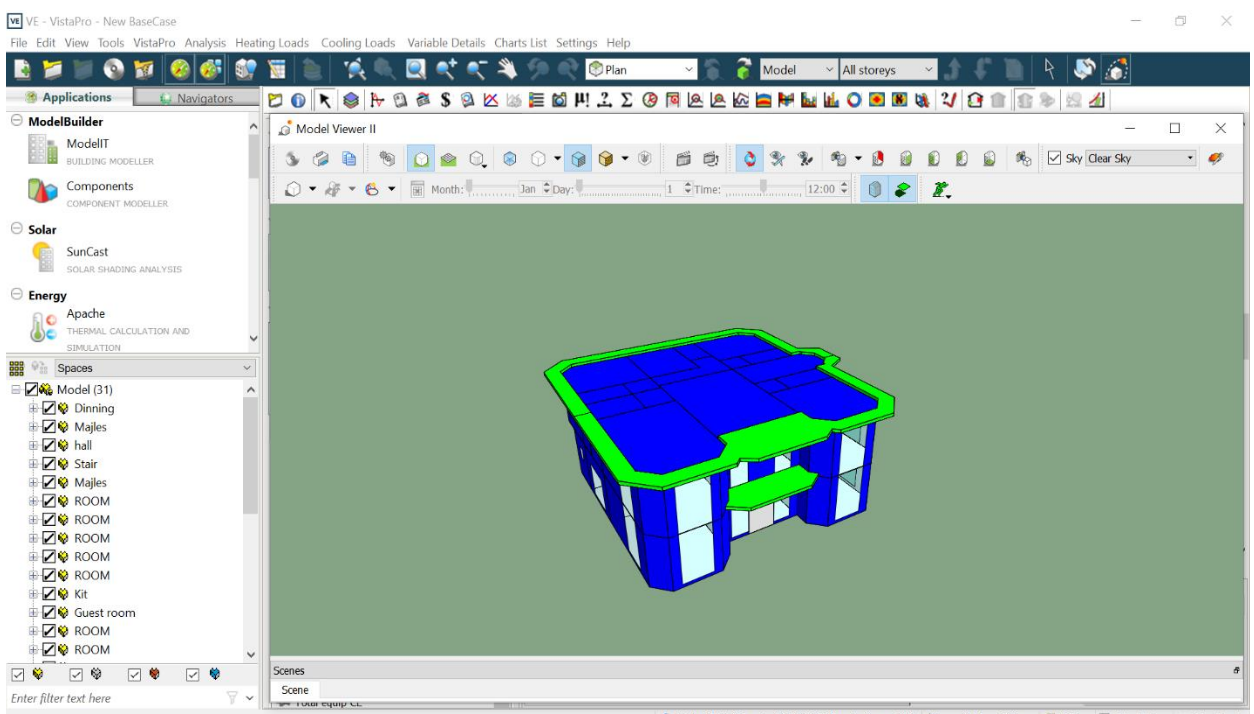


Figure 12: Case study model in the IES (Author 2020)

After the model has been drawn, all the construction materials were added in the software to comply with existing villa conditions and drawings that attached in the appendix B. Table (13) below indicates the assigned construction materials in the IES VE for the roof, external window glazing, external walls and floors that were used to validate the model. Also, the total U-Values of the actual villa model in reference to the drawings submitted for construction were indicated in the table. Moreover, the recommended U-Values of each element were indicated as per as Dubai green building regulations for the villa in the same table to know how much applying the retrofit strategies can enhance the U-Value.

Figure 13: Base case construction materials and U-Value

Element	Total U-Value (W/m^2 K)	Recommended U-Value (W/m^2 K)	Construction Layers (outside to inside)
External wall	1.9	0.57	24 mm plaster from the outside
			Primer and minimum 4 coats of pure epoxy system from joints
			150 mm concrete
			24 mm plaster from the inside
External window glazing	5.59 SHGC 0.86	0.43/0.75 SHGC 0.58	Single pane clear SHGC 0.86
Roof	1.50	0.3	30x30x2.5 cm thick cement tiles
			50 mm Screed sand & cement mortar
			2mm Damp proof course (D.P.C) rhoflex
			1mm 2 hot bituminous coats
			70 mm foam concrete layed in slope 1:50
			5.9 mm Heat proof course roof mat
			150 mm RCC slab
			10 mm ceiling plaster & finishing
			30 mm flooring tiles

4.3.6 Software Validation

The validation process in any simulation is crucial to calibrate the simulation model in the software. It is essential to do this process while setting up the model to compare it with the real energy consumption and bills in order to ensure accurate simulation results at the end. The verification of the simulation model is done by the means of the actual energy consumption and weather data statistics. The validation process can be achieved by the calibration the model of the case study to represent the real case accurately. Adding all the inputs at the beginning with the construction material and ending with internal gains and number of people to take the initial model and compare it to the reality. This process can be done several times until we ensure that the overall energy consumption is matching or near to the real system. When the marginal error is within 5% of the actual readings, the model is considered calibrated and it is ready to ally different strategies on it. However, when the percentage of error is more than 5%, it means that the modify is not calibrated and needed to be adjusted until it reaches 5% or less. The section below will represent the energy consumption validation between real energy bills from DEWA and the overall energy consumption for the base case model of the villa. The 12-month DEWA bills will be in appendix C.

4.3.6.1 Base case energy consumption results & validation

The main aspects of validating the IES VE software base case with the real case in this research is the energy consumption in the villa and the model. Therefore, energy bills for 12 months were collected from DEWA to compare between the base case and the actual consumptions. All the internal gains, lighting, number of people were plugged into the software. Moreover, many profiles have been done to match occupancy behavior in the house. The occupancy behavior helped to make many profiles for occupant availability in the home as well as both of the lighting and cooling profile. After that, ApacheSim application was mainly used for showing both of the cooling and electricity consumption levels in order to compare it with the real energy bills from DEWA and actual climate conditions. Since the dates in the DEWA bills were irregular and the dates were not in the first of each month, the average of the two months was taken to be more closed to the reality. Hence, the cost of two months average was taken as the actual cost for each month. Table (11) represent both of the actual energy bills in MWh and the actual energy cost in AED for the villa for each month.

Table 11: Energy consumption bills and cost of the case study for 12 months

Month	Actual energy bills (MWh)	Actual energy cost (AED)
Jan	4.48	522.17
Feb	4.3	436.17
Mar	5.18	416.33
Apr	6.68	515.45
May	9.26	716.63
Jun	12	1031.63
Jul	12.76	1391.25
Aug	12.7	1491.00
Sep	12.42	1483.13
Oct	9.96	1446.38
Nov	6.98	1123.50
Dec	5.26	732.38
Summed total	102.16	11305.98

After inserting all the gathered information of the case study as mentioned above, a simulation for the base case model was conducted through IES VE software in reference to the construction materials of the villa and the UAE climatic conditions identified in the software. Both of the total energy consumption and cooling load were simulated. Table (12) below represents the base case model simulation for both the cooling load and energy consumption. Also, it shows the comparison between the actual energy bills and the base case energy consumption from the result obtained after the simulation. The discrepancy between real data and simulated data varieties from 0.5% to 5.0% with an average of 2.8% as shown in the figure (14).

Table 12: Actual energy consumption validation in IES VE

Month	Actual energy bills (MWh)	cooling plant sens. load (MWh)	BASE CASE energy consumption (MWh)	Difference Percentage (%)
Jan	4.48	5.08	4.7	-4.2%
Feb	4.3	6.81	4.5	-4.6%
Mar	5.18	9.53	5.3	-3.2%
Apr	6.68	14.29	7.0	-2.3%
May	9.26	20.36	9.3	-0.6%
Jun	12	23.93	11.8	1.5%
Jul	12.76	26.50	12.5	2.1%
Aug	12.7	26.97	12.6	0.5%
Sep	12.42	23.81	11.8	5.0%
Oct	9.96	18.80	9.8	1.3%
Nov	6.98	12.44	7.3	-4.1%
Dec	5.26	7.12	5.5	-5.0%
Summed total	102.16	195.64	102.2	0.0%

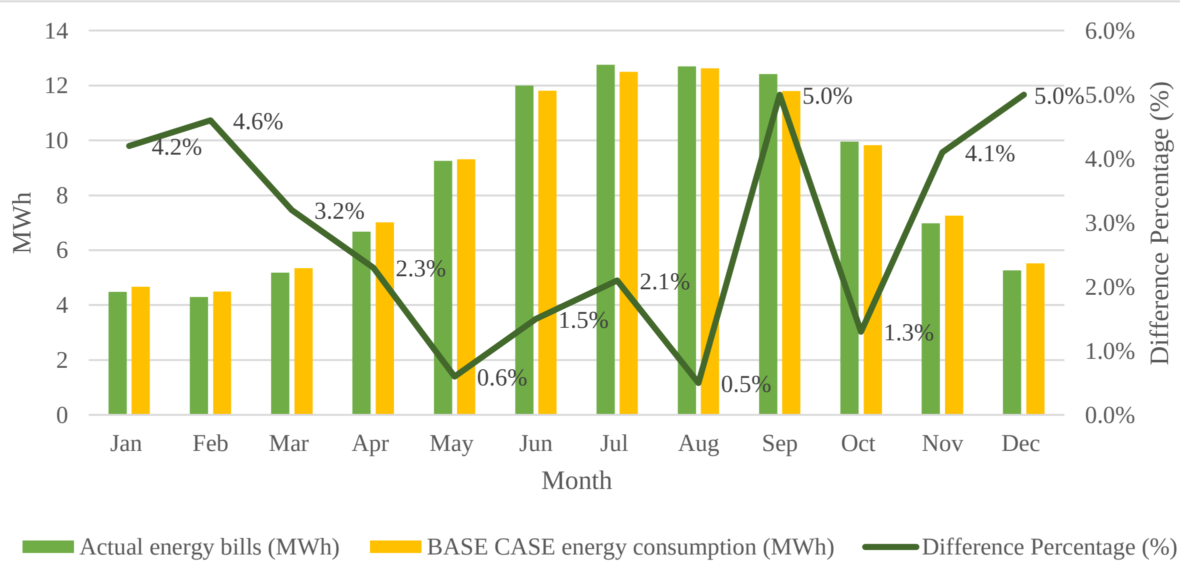


Figure 14: validation and discrepancy percentage

4.3.7 Retrofit measures for simulation

Through the literate review, the cases in the UAE and the interviews, the most common retrofit measures for a small villa in Dubai were collected. They will be simulated to evaluate the performance of each one. The simulation will help assess the energy consumption of the villa after applying the retrofit measures. Hence, analyze the results with the cost to select the most appropriate measure that can be added as regulation at an affordable price. Table (13) represents the retrofit measures that will be applied in the case study. The following section will explain in brief the simulation scenarios that represents the different retrofit measures and the results of the IES VE.

Table 13: Retrofit measures for IES VE simulation

No. of measure	Retrofit approach	Element	Retrofit measures
M#1	Envelope	Wall	Adding insulation to the external wall with reflected surface
M#2		Roof	Adding insulation layer to the roof
M#3		Windows & glazing	Replacing the windows with relatively high-performance double-glazing system and window frames with thermal break
M#4		Shading	Adding external shading to the existing windows where it needed
M#5	System	Lighting	Replace the lighting with low energy LED lights
M#6		AC	Change the cooling set point temperature
M#6	Envelope & system	All	All the previous measures

Chapter Five: Results and Discussion

5. Results and Discussion

In this chapter, the results from both interviews and software simulations will be obtained and displayed in the first section. While in the second section, all the results will be analyzed and discussed by doing a simple economic study for the simulation results. In the last part of the chapter, all the obtained results and discussions will be analyzed to approach the goal of this dissertation.

5.1 Results

5.1.1 Main themes from the interviews

After conducting all the interviews with different people from different backgrounds and experiences and analyzing them, findings were organized and the main points have emerged from these interviews. The main themes of the interview data are presented in the subsections below.

5.1.1.1 Availability of policies and regulation to retrofit old existing villas

Both government and semi-government staff confirmed that there is no any kind of regulation to force the owners to retrofit their old existing villas. The interviewee from the private companies indicated that they also did not come across any kind of regulations and policies, however, they may use ASHRAE standard for villas to optimize the energy performance. In case of deep retrofit, all the companies compelled to use Energy Efficient systems and products based on the Emirates Authority for Standardization and Metrology (ESMA) or Dhabi Quality and Conformity Council (QCC) regulations. The interviewee from the semi-government staff pointed out of the existing for many initiatives to retrofit the building. Although there are no any regulations regarding that, but there are efforts to retrofit old buildings. Also, they said that until now small villas are not in clear strategies in retrofitting the villas. Still, at some point they will start to consider the residential building but not the small scale as villas unless the owner wanted to his own house, Etihad ESCO will help him to do so.

5.1.1.2 Previous experience and results of retrofitting existing old villa

Interviews have shown that the retrofitting has been very successful till now. The government staff interviewee indicates that this term is not just about to pertain to energy conservation and efficiency; it also includes any other works that will benefit the operation of the buildings. Most of the retrofitted projects increased operational efficiency and optimized equipment parameters hence less energy consumption. Both Dewa and Etihad ESCO interviewee said that there is a retrofitting program targeting 1,656 homes from the Mohammed bin Rashid Housing Establishment which they have started to work on two years ago and It was financed entirely by Dewa. Light retrofit measures have been used in these villas mainly. For example, they installed smart LED lighting and provided a solar panel in each house to generate energy as well as they work on the water-saving. The total saving and results of this project are confidential. Also, private companies' interviewees emphasize that the retrofit projects have been very successful till now. In their last six years' experience, they have seen and worked in projects with savings ranging from 15% to 40%, and most importantly, sustaining these savings over the years as well as many other projects even for villas if suitable and appropriate measures implemented well.

5.1.1.3 Challenges of providing a regulation to retrofit small old villas

All the interviews from the government, semi-government and private companies do not consider retrofitting a villa that difficult. However, the biggest challenge is the economic aspect. Companies that do retrofits usually do not consider the small villas under the scope of their interest due to low-income cost. One of the government interviewees belief that if there is an opportunity for the owners to invest in this without losing anything, the retrofit program will be very beneficial. Two of the workers in this field who were interviewed indicated that the challenge in a retrofit small single villa is the long payback period, which may be around seven to ten years. Also, when they will do the cost-benefit analysis of deep retrofit costs. For example, the payback period is very long. It most often doesn't motivate the owner to invest, which is mainly because of the low usage in comparison to commercial or retail or another type of buildings. However, if a single owner has multiple villas and decides to retrofit them together, then the retrofit costs are relatively lower because of increased quantities, which is called the (Economies of scale). One of the semi-government interviewee's beliefs that lack of financing models for retrofitting is an issue since the biggest challenge in this field is the economic part. He indicated that there is a financing model but not that clear for the clients and used only in a small range, which is the solar market that provided by Etihad ESCO and the available models are not that clear for the clients, maybe.

Another main challenge in applying regulations to retrofit old villas is cultural issues and lack of awareness, especially with local owners. The difficult thing in retrofit is how to reach those owners and convince them to retrofit their old villas. One of the government interviewees said that owners who are well educated would not be hard to convince then since they will be aware of the benefits of the retrofit program. They will easily adapt the strategies to create savings out of energy water as well as healthy spaces. Another government interviewee said that it is unfortunate that this culture does not exist in our local community with the local owners. It is difficult to convince them to retrofit, especially since the owners of these villas are from the old generation and not aware much of the building energy. Therefore, the cultural issue is enormous in this matter, and it is the most significant challenge in this topic. Regarding this challenge, one of the semi-government interviewees referred to the term that is called "Split intensive ". This term can relate to, for example, a developer does not care about the amount of energy consumed by tenants in the homes they rent because the electricity bill is paid by the tenant himself and not from the company. So, if the developer will put money to retrofit the building, he will not get any benefit from the savings, unlike the tenants. For that, most of them do not care about retrofitting, but maybe they will do if the government forced it.

5.1.1.4 How to convince owners and catch their interest to do retrofitting

While a majority of the participants mentioned that the main challenge is the financing and economic issue from the previous theme. All of the interviewees agreed on providing an alternative financing solution to these projects will be helped effectively on the eagerness of the owners and clients to implement the retrofit strategies in their building. In the end, it will benefit all different parties. Finding convince financing alternatives can defeat this issue and makes the retrofit very successful which is the future.

One of the government interviewees believes that in order to overcome this issue, we need to think outside the box and find alternatives and initiatives that can facilitate the process economically. In the beginning, everything may be challenging and the level of accepting that from the locals would be very low. For example, if there is an opportunity for the owners to invest in retrofitting without losing anything, this will be very beneficial. This market will grow through the years and eventually, clients may produce electricity from their house and that is the government approach in the future. Other interviewees emphasized to start working on the awareness level for the clients to manage the energy consumption in a smart and economical approach. Also, he suggested linking more between the investment to the benefits and the returns to make the project feasible. Another government interviewee suggested having a guaranteed savings contract agreement between the owner and the ESCO. For example, if this villa will save energy with a specific target and the company did not achieve it, so they will get their money back or provide for owners a comfortable financing plan. Also, on top of the guaranteed savings agreement, an incentive program from the government will ensure the participation of more household owners in the retrofit program, like the installation of PV with percentage subsidized by the government. Another governmental interviewed participant suggested providing some kind of insurance between both the company and the owners of the villas. This agreement is considered as a win-win deal for both parties. For example, ensure the owners that this will benefit them in terms of cost. For instance, if the company did not reach the agreeable target by the end of the year, the owner can pay the company only the percentage of the savings. This suggestion is similar to the guaranteed savings contract that was suggested by another participant. One of the recommendations is to make a good offer to the owner to catch their interest like providing five years of warranty and free maintenance for the newly installed systems, for example.

Another interviewee commented on the financing issue by saying if this issue were solved effectively, maybe the owners will be more interested in the retrofit because you know that most of the owners may not have the money to do that. Another one said: nowadays, owners are not aware of this issue and may not be interested in invest in such things unless it was free or it will benefit them financially. Talking about this issue, an interviewee from a private company said that the cost of retrofit has to make sense to the owner with a quicker payback period. For this, energy consultants should be smart to propose simple and cost-effective solutions such as intelligent thermostats, water aerators, fixing fenestration gaps and try to change occupant behavior with good awareness sessions. From the same perspective, another interviewee from the private company group believes that increasing the awareness level and linking the benefit of the energy efficiency project to the cost savings can be a solution. Also, conducting a life cycle cost assessment studies to show the values of the retrofitting project can be some of the solutions to overcome this challenge.

5.1.1.5 Best strategies that can be implemented in the old villas

In this theme, there are two different opinions from the interviewees about the good retrofit measures that should be implemented in villas. Many various strategies can be applied in a building to reduce energy consumptions. For the villas, two of the participants indicated that changing the HVAC system is one of the suitable improvements for villas but should not be considered as a good strategy to start with. First, we need to make sure that the envelope is efficient. That is because if you change the HVAC but the envelope is not that efficient, the insulation is bad, the doors and windows are bad, there is so much infiltration. In this case, the HVAC will work hard in order to make up for the shortage and eventually, the conserved energy will not be that much. The most important thing is to know what to start with to achieve maximum energy conservation. They both emphasize on making sure that the envelope is well insulated and meet the requirements of the green building, even if it was the minimum requirement and then starting to change the AC and last stage is adding renewables like PV. In a retrofit, they both believe that we need to taking care of the efficiency at first, then the consumption. This is basically what the Energy Efficiency Triangle is about where there is a bottom layer is the first thing that we need to improve our behavior inside the house where we should consume less energy and turn off the lights in the unoccupied rooms. The occupant's behavior or culture is essential. The second layer is about replacing the equipment like replacing the lighting fixtures with LED lighting. The peak layer of the energy efficiency triangle is about using renewables as a retrofit option in the last stage. What they really need is that to do a good retrofit, the companies should start from the base of the retrofitting, not from the top. The base is the envelope of the building and the last strategy would be renewable, not the first thing to implement. If the base, which is the building envelope is not efficient, anything you will do it later will not be as efficient as it supposed to be; this is similar to what is happening now in the retrofit projects for villas. Nowadays, they are just putting renewables like solar PVs and that is it, which is wrong in their opinion. Moreover, they suggest assessing first all the passive systems. For instance, providing window shades. After that, consider retrofitting the HVAC systems and lighting. Once the consumption goes down, based on these strategies, we can put solar PV in the end. Also, they suggested using AL SA'FAT rating system as a starting point where in the future, all the villas will meet the same requirements.

On the other hand, the rest of the interviewee indicates that for villas, it is better to use the most straightforward way. The easiest way is changing the lights and adding solar in the villas since it has a low cost compared to other retrofit strategies, like adding wall insulation and changing the AC. Also, because these strategies are the most convincing, especially since they take short period of time and are low cost. However, there are many projects for villas related to adding solar and PV panels which there is no need to add it as regulations for retrofit. That is what Etihad ESCO and DEWA have done in the Mohamed bin Rashid housing retrofitting program. They did not consider doing a deep retrofit or changing the AC because, in this case, they need to contract with another company. Also, they will need more time and money since this strategy may need to make big changes in the wall, unlike changing the lights and adding the solar, which they can do it in one or two visits only. For that, these interviewees believe that it is better to consider the light retrofit measures if it will be any kind of regulations to do so from the government. Other participants suggested using a highly efficient air conditioning system and a programmable thermostat with LED lights as well as using control and management systems while another interviewee indicates that some large villas have small chiller and FAHUs which can be optimized to a great extent using smart controls and time-based operations using setback modes.

5.1.1.6 What owners need to be part in applying retrofit policies

This theme was extracted from interviewing the last group of the interviews list, which they are the owners, specifically local owners. All of the interviewees from this group agreed on providing funds or easy payment plans from the government to be part of these projects is the main thing. Also, providing service and maintenance for the system after doing the project is crucial for them. The last participant in this group suggested having strict regulations in the construction market from the government side as well as ensuring that the materials are as per specifications, and with fixed prices. Besides, providing owners with temporary housing options while their villa is being retrofitted if it will need time to be retrofitted. Also, easing the process of retrofitting by providing “government-approved” contractors that are specifically approved to carry out retrofit jobs. Moreover, providing owners who are willing to retrofit their villas with government discounts on construction materials, for example. The interviewee indicates that giving someone from the government to check the retrofitting work is done as per the regulations would be a good step and important to have someone from the government to follow-up on these kinds of things.

5.1.2 Simulation results

In this section, each retrofit measure that was listed in the previous section will be explained briefly; how this strategy can be achieved in reality and how can we adjust it in the software to explore how much it can save both cooling load and energy.

5.1.2.1 Scenario 1: Wall insulation

In this scenario, a layer of wall insulation will be added in the IES VE software. As it was mentioned in the literature review, adding wall insulation can be one of the retrofit measures that will help reduce energy consumption. From the cases in the literature review, it was found that the most common of wall insulation that can be appropriate for existing building is the Expanded Polystyrene (EPS) that is used in the Exterior Insulation Finishing Systems (EIFS). The selected thickness for the insulation was chosen to achieve the recommended U-value for the wall. In this case, a 100 mm thickness was added to the villa wall in the simulation. Figure (15) represents the results obtained from the IES VE software.

	Room cooling plant sens. load (MWh)	Total energy (MWh)
Date	St1-External wall - EPS.aps	St1-External wall - EPS.aps
Jan 01-31	6.4198	4.8939
Feb 01-28	7.5501	4.6224
Mar 01-31	9.5996	5.3575
Apr 01-30	13.0606	6.8124
May 01-31	17.7207	8.8783
Jun 01-30	20.7084	11.2778
Jul 01-31	22.6653	11.8569
Aug 01-31	23.0362	11.9783
Sep 01-30	20.7439	11.2838
Oct 01-31	16.9513	9.5179
Nov 01-30	11.9793	7.1860
Dec 01-31	7.9920	5.6678
Summed total	178.4272	99.3330

Figure 15: Results of retrofit measure #1 wall insulation

5.1.2.2 Scenario 2: Roof insulation

In this scenario, roof insulation will be added to see how much it can help to save the cooling load and energy. In the literature review cases, a cool roof system and polystyrene insulation were used in different cases to retrofit the roof. In this case study, polystyrene insulation for the roof will be added. The selection of the insulation thickness will be based on achieving the recommended U-value for the roof as per the green building codes in Dubai as was mentioned previously. In this case, a 50 mm polystyrene insulation for the roof will be added. Figure (16) shows the results obtained from the IES VE software after adding a roof insulation.

	Room cooling plant sens. load (MWh)	Total energy (MWh)
Date	St2-Roof inulation-XPS.aps	St2-Roof inulation-XPS.aps
Jan 01-31	5.4664	4.7350
Feb 01-28	6.8910	4.5126
Mar 01-31	9.3210	5.3110
Apr 01-30	13.5478	6.8936
May 01-31	18.9770	9.0877
Jun 01-30	22.2963	11.5425
Jul 01-31	24.5010	12.1629
Aug 01-31	24.9550	12.2980
Sep 01-30	22.1911	11.5250
Oct 01-31	17.8695	9.6710
Nov 01-30	12.2424	7.2299
Dec 01-31	7.4762	5.5818
Summed total	185.7346	100.5509

Figure 16: Results of retrofit measure # 2 roof insulation

5.1.2.3 Scenario 3: Window glaze replacement

In this scenario, the type of window glazing will be replaced. There are many types of glazing materials that can be replaced the old one like double glazing and triple glazing. In this case, the most common type of glazing for villas will be used for the simulation, which is a double-glazing window with an air gap. Figure (17) shows the results obtained from the IES VE software after changing the window glazing.

	Room cooling plant sens. load (MWh)	Total energy (MWh)
Date	ST3.aps	ST3.aps
Jan 01-31	4.8140	4.6263
Feb 01-28	6.1287	4.3855
Mar 01-31	8.5124	5.1763
Apr 01-30	12.5433	6.7262
May 01-31	17.6300	8.8632
Jun 01-30	20.8464	11.3008
Jul 01-31	22.9543	11.9051
Aug 01-31	23.3026	12.0227
Sep 01-30	20.7015	11.2767
Oct 01-31	16.5008	9.4428
Nov 01-30	11.1004	7.0395
Dec 01-31	6.6686	5.4472
Summed total	171.7030	98.2123

Figure 17: Results of retrofit measure # 3 window glazing replacement

5.1.2.4 Scenario 4: Shading

External shading devices can contribute to minimizing the heat adsorbed from outside and reemitted to the outside environment. Many types of shading devices can be used in any building based on climate and window orientation. In this case, the external shadings were placed in the outside windows based on the window orientation. The selected type was standard horizontal overhang shading. Figure (18) represents the results obtained from the IES VE software after adding external shading for windows.

	Room cooling plant sens. load (MWh)	Total energy (MWh)
Date	ST4.aps	ST4.aps
Jan 01-31	4.6818	4.6042
Feb 01-28	6.3516	4.4226
Mar 01-31	9.0585	5.2673
Apr 01-30	13.8480	6.9436
May 01-31	19.9526	9.2503
Jun 01-30	23.5475	11.7510
Jul 01-31	26.0914	12.4280
Aug 01-31	26.5017	12.5558
Sep 01-30	23.2887	11.7079
Oct 01-31	18.2708	9.7379
Nov 01-30	11.9837	7.1867
Dec 01-31	6.7266	5.4569
Summed total	190.3028	101.3123

Figure 18: Results of retrofit measure # 4 adding external shading

5.1.2.5 Scenario 5: Lighting replacement

Most of the old bulbs were considered low efficient bulbs because of their high watts and low lamp lifetime. In this case, the lights that are used are fluorescent lamps that had a wattage that can reach to 25 watts. The retrofit option is to reduce these old lamps with much more efficient bulbs to reduce the heat generated by the old ones. Hence, the energy that is used for space cooling will be saved. In the simulation, a new led bulb will be used with a 2 watt. Figure (19) represents the results obtained from the IES VE software after replacing the old bulbs with new efficient LED bulbs.

	Room cooling plant sens. load (MWh)	Total energy (MWh)
Date	St5-LED lighting.aps	St5-LED lighting.aps
Jan 01-31	4.7786	4.2521
Feb 01-28	6.5263	4.1191
Mar 01-31	9.2127	4.9247
Apr 01-30	13.9666	6.6070
May 01-31	20.0355	8.8958
Jun 01-30	23.6158	11.4060
Jul 01-31	26.1671	12.0723
Aug 01-31	26.6372	12.2101
Sep 01-30	23.4878	11.3846
Oct 01-31	18.4685	9.4025
Nov 01-30	12.1214	6.8533
Dec 01-31	6.8074	5.1021
Summed total	191.8251	97.2296

Figure 19: Results of retrofit measure # 5 lighting replacement

5.1.2.6 Scenario 6: Air Conditioning (AC) Setpoint

The setpoint is basically the accepted temperature that the building will meet. Every adjustment in the setpoint of the air-conditioning that makes it closer to the outside building temperature can make a difference in energy consumption. It was found that every 1°C adjustment can cut the energy required for both cooling and heating by 5–10% (Indoor comfort and temperature setpoints). In this case study, the AC is spilt unit that has a thermostat that is set manually by the user. Replacing the old thermostat with a new advanced thermostat that can change the setpoint automatically for each room based on its temperature. In this simulation we will check the effect of changing the setpoint by making the cooling setpoint 26 °C. Figure (20) shows the results obtained from the IES VE software after changing the AC set-point.

	Room cooling plant sens. load (MWh)	Total energy (MWh)
Date	St6-AC setpoint.aps	St6-AC setpoint.aps
Jan 01-31	2.7911	4.2891
Feb 01-28	4.3640	4.0914
Mar 01-31	6.6597	4.8675
Apr 01-30	11.3074	6.5202
May 01-31	17.2836	8.8055
Jun 01-30	20.9684	11.3212
Jul 01-31	23.4571	11.9889
Aug 01-31	23.9216	12.1258
Sep 01-30	20.8423	11.3002
Oct 01-31	15.7225	9.3131
Nov 01-30	9.4923	6.7715
Dec 01-31	4.4474	5.0770
Summed total	161.2574	96.4714

Figure 20: Results of retrofit measure # 5 changing AC setpoint

5.1.2.7 Scenario 7: All retrofit measures

In the last scenario, the retrofit options are: adding both of the wall and roof insulation, window glazing replacement, adding eternal shading devices, changing old lighting and changing the AC setpoint will be applied. This simulation will help to determine the total electricity saving from all these options. Figure (21) shows the results obtained from the IES VE software after applying all six retrofit measures.

	Room cooling plant sens. load (MWh)	Total energy (MWh)
Date	St7-All strategies.aps	St7-All strategies.aps
Jan 01-31	5.5363	4.3654
Feb 01-28	5.6878	3.9676
Mar 01-31	6.7943	4.5086
Apr 01-30	8.7566	5.7261
May 01-31	11.4500	7.4519
Jun 01-30	13.7869	9.7553
Jul 01-31	14.7532	10.1570
Aug 01-31	14.9285	10.2457
Sep 01-30	13.7725	9.7529
Oct 01-31	11.6862	8.2591
Nov 01-30	8.8010	6.2873
Dec 01-31	6.6307	5.0596
Summed total	122.5841	85.5366

Figure 21: Results of retrofit measure # 7 all retrofit measures

5.2 Discussion

In this section, all the retrofit measures scenarios result from M # 1 to M # 6 will be analyzed to investigate the impact of each measure in reducing the cooling load as well as energy consumption. The results of the simulations will be discussed in terms of the overall electricity consumption savings along with the total reduction achieved in the cooling load. Then it will be followed by evaluating the simulation that applies all the retrofit measures together to figure which of the strategies will have more significant energy savings compared with the base case results. After that, the chapter will be followed by a simple economic analysis for each strategy to decide which one of these strategies can be added as a regulation along with the interviewee's opinions.

5.2.1 Cooling and energy savings

In this section, the results of the case study simulations will be compared with the total electricity saving and cooling load achieved for each retrofit strategy in the below sub sections. Then all the simulation results will be discussed to investigate the impact of each strategy independently and all of them together.

5.2.1.1 M#1: Wall insulation

In this simulation, adding wall insulation to the base case was conducted. As it is shown in table (14), saving percentage for the total cooling load in this strategy is 8.8%, while the total electricity saving is 2.81%. The electricity savings from the wall insulation was expected to be higher than 2.81% only, which may be affected due to high internal gains in this particular villa.

Table 14: Cooling and electricity savings from retrofit measure #1

Month	Base case cooling load (MWh)	Base case total energy (MWh)	M#1 cooling load (MWh)	M#1 total energy (MWh)
Jan	5.08	4.67	6.42	4.89
Feb	6.81	4.50	7.55	4.62
Mar	9.53	5.35	9.60	5.36
Apr	14.29	7.02	13.06	6.81
May	20.36	9.32	17.72	8.88
Jun	23.93	11.82	20.71	11.28
Jul	26.50	12.50	22.67	11.86
Aug	26.97	12.63	23.04	11.98
Sep	23.81	11.79	20.74	11.28
Oct	18.80	9.83	16.95	9.52
Nov	12.44	7.26	11.98	7.19
Dec	7.12	5.52	7.99	5.67
Summed total	195.64	102.20	178.43	99.33
Savings Percentage %	-	-	**8.80%**	**2.81%**

5.2.1.2 M#2: Roof insulation

In this simulation, a layer of XPS roof insulation was added to the roof construction layer. After this addition, the U-Value of the roof was 0.29 W/m2, which is as per the DM regulation. The result of both cooling load and energy consumption was collected in the table (15). The table displays the contrast between the base case and this retrofit measure in cooling capacity and energy consumption. The results show that the total cooling load reduction can reach up to 5.06% and the total electricity saving can be 1.62%.

Table 15: Cooling and electricity savings from retrofit measure #2

Month	Base case cooling load (MWh)	Base case total energy (MWh)	M#2 cooling load (MWh)	M#2 total energy (MWh)
Jan	5.08	4.67	5.47	4.74
Feb	6.81	4.50	6.89	4.51
Mar	9.53	5.35	9.32	5.31
Apr	14.29	7.02	13.55	6.89
May	20.36	9.32	18.98	9.09
Jun	23.93	11.82	22.30	11.54
Jul	26.50	12.50	24.50	12.16
Aug	26.97	12.63	24.96	12.30
Sep	23.81	11.79	22.19	11.53
Oct	18.80	9.83	17.87	9.67
Nov	12.44	7.26	12.24	7.23
Dec	7.12	5.52	7.48	5.58
Summed total	195.64	102.20	185.73	100.55
Savings Percentage %	-	-	**5.06%**	**1.62%**

5.2.1.3 M#3: Window glazing replacement

In this simulation, the type of window glazing was replaced with a double-glazed window. Table (16) represents the results obtained from the software after replacing the windows in the base case. From the results, we can see that the double-glazed window can affect the cooling load and achieve a 12.23% reduction in the cooling, whereas the total savings in electricity was 3.90%.

Table 16: Cooling and electricity savings from retrofit measure #3

Month	Base case cooling load (MWh)	Base case total energy (MWh)	M#3 cooling load (MWh)	M#3 total energy (MWh)
Jan	5.08	4.67	4.81	4.63
Feb	6.81	4.50	6.13	4.39
Mar	9.53	5.35	8.51	5.18
Apr	14.29	7.02	12.54	6.73
May	20.36	9.32	17.63	8.86
Jun	23.93	11.82	20.85	11.30
Jul	26.50	12.50	22.95	11.91
Aug	26.97	12.63	23.30	12.02
Sep	23.81	11.79	20.70	11.28
Oct	18.80	9.83	16.50	9.44
Nov	12.44	7.26	11.10	7.04
Dec	7.12	5.52	6.67	5.45
Summed total	195.64	102.20	171.70	98.21
Savings Percentage %	-	-	**12.23%**	**3.90%**

5.2.1.4 M#4: External shading

Adding an external shading is considered as one of the passive retrofit strategies which was addressed in the literature review. This retrofit measure applied in the simulation after modeling a shading device above the windows in the base case. The results represented in table (17) shows that this strategy can help achieve 2.73% and 0.87% cooling and electricity savings respectively.

Table 17: Cooling and electricity savings from retrofit measure #4

Month	Base case cooling load (MWh)	Base case total energy (MWh)	M#4 cooling load (MWh)	M#4 total energy (MWh)
Jan	5.08	4.67	4.68	4.60
Feb	6.81	4.50	6.35	4.42
Mar	9.53	5.35	9.06	5.27
Apr	14.29	7.02	13.85	6.94
May	20.36	9.32	19.95	9.25
Jun	23.93	11.82	23.55	11.75
Jul	26.50	12.50	26.09	12.43
Aug	26.97	12.63	26.50	12.56
Sep	23.81	11.79	23.29	11.71
Oct	18.80	9.83	18.27	9.74
Nov	12.44	7.26	11.98	7.19
Dec	7.12	5.52	6.73	5.46
Summed total	195.64	102.20	190.30	101.31
Savings Percentage %	-	-	**2.73%**	**0.87%**

5.2.1.5 M#5: Lighting replacement

In this simulation, the old fluorescent lighting fixtures were replaced by energy-efficient LED lighting in the software. The results obtained from the simulation were represented in table (18) below. The results show that this retrofit strategy can achieve 1.95% cooling savings and 4.86% energy savings. This measure is the only retrofit measure that has an electricity-saving more than cooling load saving since it is related more to the internal gains in the case study.

Table 18: Cooling and electricity savings from retrofit measure #5

Month	Base case cooling load (MWh)	Base case total energy (MWh)	M#5 cooling load (MWh)	M#5 total energy (MWh)
Jan	5.08	4.67	4.78	4.25
Feb	6.81	4.50	6.53	4.12
Mar	9.53	5.35	9.21	4.92
Apr	14.29	7.02	13.97	6.61
May	20.36	9.32	20.04	8.90
Jun	23.93	11.82	23.62	11.41
Jul	26.50	12.50	26.17	12.07
Aug	26.97	12.63	26.64	12.21
Sep	23.81	11.79	23.49	11.38
Oct	18.80	9.83	18.47	9.40
Nov	12.44	7.26	12.12	6.85
Dec	7.12	5.52	6.81	5.10
Summed total	195.64	102.20	191.83	97.23
Savings Percentage %	-	-	**1.95%**	**4.86%**

5.2.1.6 M#6: Air Conditioning AC setpoint

HVAC systems can play a significant role in total energy consumption. There are many retrofit measures that are related to the HVAC system. The most common one, in a small-scale residential building, as the case study is adding a programmable energy-efficient thermostat to set the air condition setpoint automatically. In the simulation, the cooling setpoint was changed from 22 **°C** to 26 °C in the IES VE software. The results obtained from this simulation were represented in table (19) below. From the results, we can notice that the AC setpoint retrofit strategy helped to achieve 17.57% and 5.61% savings in the cooling and electricity, respectively.

Table 19: Cooling and electricity savings from retrofit measure #6

Month	Base case cooling load (MWh)	Base case total energy (MWh)	M#6 cooling load (MWh)	M#6 total energy (MWh)
Jan	5.08	4.67	2.79	4.29
Feb	6.81	4.50	4.36	4.09
Mar	9.53	5.35	6.66	4.87
Apr	14.29	7.02	11.31	6.52
May	20.36	9.32	17.28	8.81
Jun	23.93	11.82	20.97	11.32
Jul	26.50	12.50	23.46	11.99
Aug	26.97	12.63	23.92	12.13
Sep	23.81	11.79	20.84	11.30
Oct	18.80	9.83	15.72	9.31
Nov	12.44	7.26	9.49	6.77
Dec	7.12	5.52	4.45	5.08
Summed total	195.64	102.20	161.26	96.47
Savings Percentage %	-	-	**17.57%**	**5.61%**

5.2.1.7 M#7: All retrofit measures

In the last simulation, all the previous retrofit measures were simulated together to see how much it can affect the cooling and energy savings. It has been found after the simulation that the total cooling savings was 37.34%, whereas the total energy savings was 16.31% as it is shown in table (20). The total electricity savings from the retrofit measures that were applied in this case study were much lower than expected. The lower results may be due to the high internal gains in this particular villa. However, the same measures may contribute to reducing energy consumption more than these results depending on the occupant's behavior in the villa. I believe that increasing the level of awareness of the occupants about all the common retrofit measures may contribute to achieving more cooling and energy savings.

Table 20: Cooling and electricity savings from all six retrofit measures

Month	Base case cooling load (MWh)	Base case total energy (MWh)	M#7 cooling load (MWh)	M#7 total energy (MWh)
Jan	5.08	4.67	5.54	4.37
Feb	6.81	4.50	5.69	3.97
Mar	9.53	5.35	6.79	4.51
Apr	14.29	7.02	8.76	5.73
May	20.36	9.32	11.45	7.45
Jun	23.93	11.82	13.79	9.76
Jul	26.50	12.50	14.75	10.16
Aug	26.97	12.63	14.93	10.25
Sep	23.81	11.79	13.77	9.75
Oct	18.80	9.83	11.69	8.26
Nov	12.44	7.26	8.80	6.29
Dec	7.12	5.52	6.63	5.06
Summed total	195.64	102.20	122.58	85.54
Savings Percentage %	-	-	**37.34%**	**16.31%**

5.2.2 Electricity and cooling savings

After the implementation of the retrofit measures, the cooling load savings have been measured in the IES software. From figure (22), we can notice that the cooling reduction varies from 1.95% to 17.57% in measure #6. Changing AC set point, which is the retrofit measure #6, has the highest cooling load savings since the AC contributes more in the total cooling load in any villa. The second highest cooling load saving was achieved in retrofit measure #3, which is the window glaze replacement since it is useful to reduce the heat transition from outside to inside of the villa. The third and fourth highest cooling saving was in retrofit measures # 1 and #2 that are related to wall and roof insulation, whereas the lowest cooling saving was achieved in retrofit measure #5 by lighting replacement.

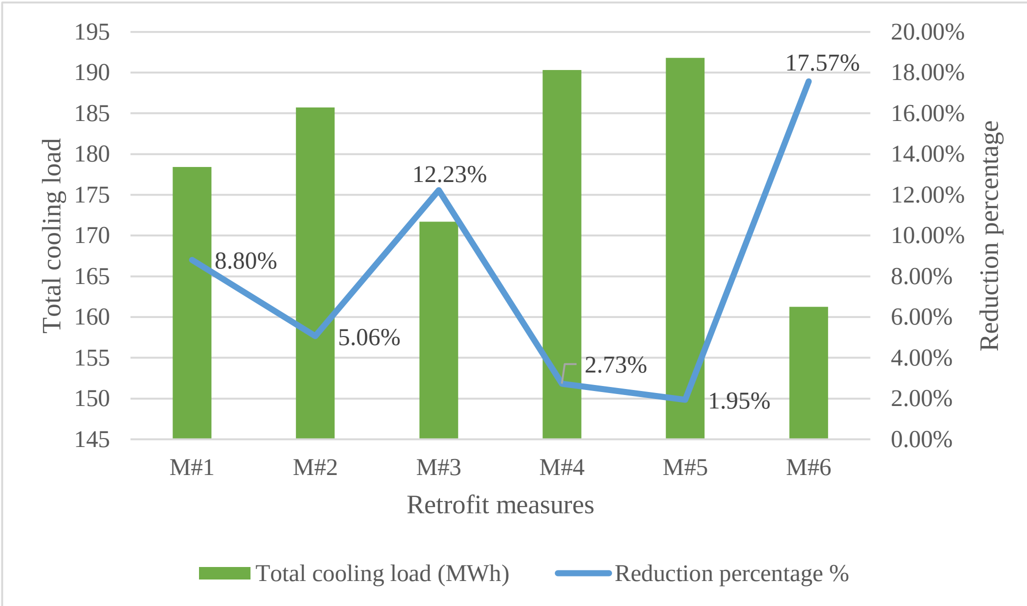


Figure 22: Cooling load savings comparison between all strategies

Along with the cooling load saving, the most important is the energy savings that were also calculated in the software simulations. Figure (23) illustrates the difference in the total energy savings in all the proposed retrofit measures from measure#1 to measure #6. As illustrated in the figure, the total energy savings range from 0.87% to 5.61%. From the figure, we notice that the highest energy savings achieved by retrofit measure #6, which is the AC setpoint. The second higher energy savings was achieved in measure #5, which is lighting replacement by 4.86% total savings. Then it followed by 3.90% and 2.81% savings in energy-related to measure # 3, which is window glaze replacement and measure #1, which is wall insulation, respectively. The lowest energy savings was achieved in retrofit measure #4, which is the external shadings while the second-lowest savings in energy was produced by measure #2, which is the roof insulation.

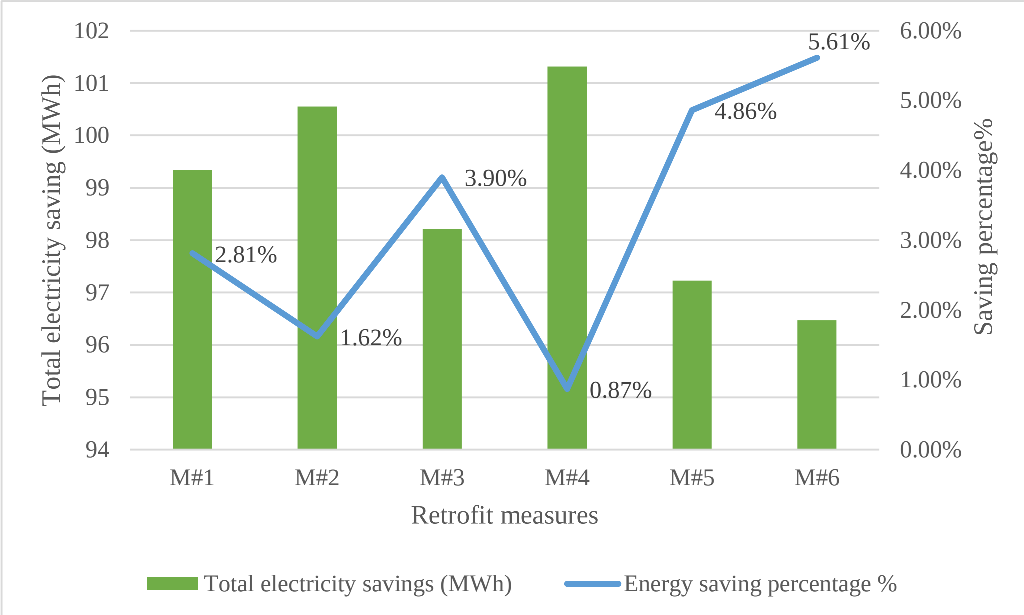


Figure 23: Electricity savings comparison between all strategies

The comparison between the total cooling load saving and the total energy savings for each retrofit measure is shown in the figure (24) below. It presents the difference in the savings percentage, which clearly shows a direct relationship between these two variables in all measures except in measure #5, which is the lighting replacement. The biggest savings in both cooling load and energy was achieved in the simulation related to retrofit measure #6, which is the AC setpoint. That means that the AC setpoint retrofit measure may be one of the excellent strategies to adopt as regulation. The measure that has low savings in both cooling and energy was measure #4, which is the external shadings; however, it is not the lowest savings in the cooling load. Therefore, this measure can be replaced by adding internal shades in the villa instead of providing external shading devices.

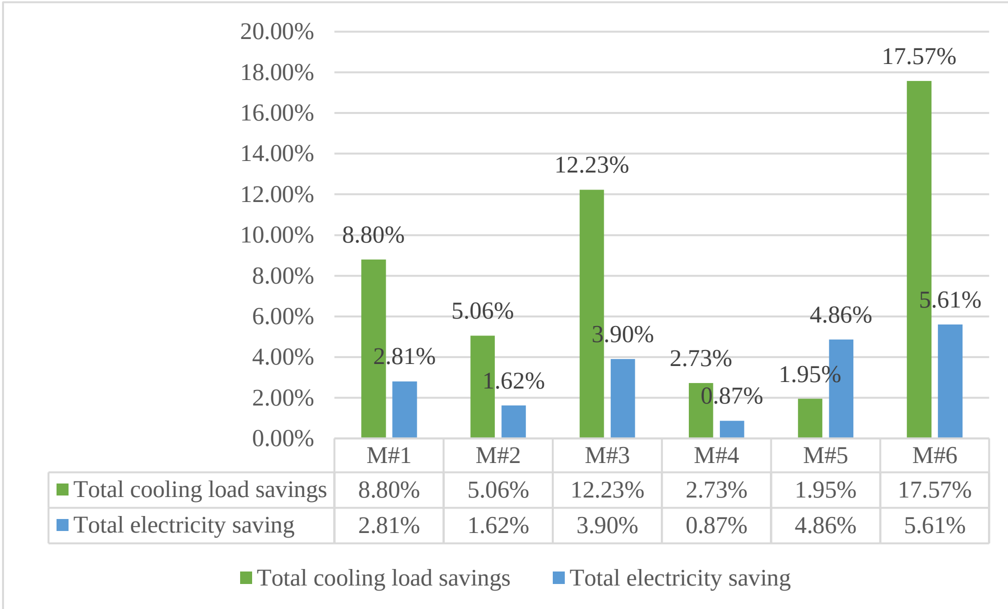


Figure 24: Total cooling load and electricity savings comparison between all strategies

5.2.3 Economic analysis

In this section, a basic economic analysis will be made for each retrofit measure to give a rough idea about the economic feasibility of applying the selected retrofit measures. The annual energy savings for each retrofit measure that were identified in the previous sections will be used to measure the simple Payback period for each measure, by multiplying the total energy savings by the unit energy cost used in Dubai. The cost of applying each retrofit measure will be estimated on the basis of prevailing market rates and through local quotations in the UAE.

The increase in the initial building cost will be calculated by subtracting the cost of materials used in the case study model from the cost of the materials used in each retrofit measure proposed through deferent simulations. Then, the annual energy cost savings will be calculated by multiplying the total savings in energy by the unit of the energy cost from DEWA. All of these calculations will be used to calculate the time of the Payback period. The time of the simple Payback period will be calculated in years using a simple equation: The cost after applying a retrofit measure / Total annual energy savings. The calculations will be done twice to show the difference between locals and non-local users of the villa and the difference in the cost rate.

The following subsections will determine the simple payback period for each retrofit measure, excluding two retrofit measures. The first one is measure #4, which is adding external shadings since it has the lowest energy savings and it may be expensive, which will lead to a long Payback period.

The second one is changing AC set point, since there is no need to change the existing thermostat in the villa.

5.2.3.1 Time of the Payback period for the retrofit measures

In order to calculate the annual electricity cost savings, the unit of energy cost is needed. In Dubai, for residential buildings, the energy cost is depending on the user consumption to promote for the efficient use of electricity and encourage people to consume efficiently. For example, if the consumption was 2000 kWh and less, the energy cost will be 0.23 AED/kWh. However, the cost is also depending on whether the user of the villa is local or not. There is a different rate of electricity for the resident in the UAE. The energy cost rate for locals is lesser than the non-locals in the private villas. Figure (25) below shows the energy cost for each consumption category for the UAE locals' while figure (26) displays the energy cost for each consumption category for the non-locals.

Consumption (kWh)/ month		Slab tariff (fils/kWh)
G	0-2000	7.5
Y	2001-4000	9.0
O	4001-6000	10.5
R	6001 & Above	12.5

Figure 25: Cost of every KWh in residential and commercial buildings for locals

Consumption (kWh)/ month		Slab tariff (fils/kWh)
G	0-2000	23
Y	2001-4000	28
O	4001-6000	32
R	6001 & Above	38

Figure 26: Cost of every KWh in residential and commercial buildings (Dubai Electricity & Water Authority | Slab Tariff 2020)

The annual energy consumption for each retrofit strategy will be calculated based on the energy cost for the energy consumption in each month. Table (21) shows the calculation of the annual total energy consumption cost for the base case and table (22) will show the calculations if the same house was rented or sold to a non-local family.

Table 21: Annual energy consumption cost for the base case (local family)

Month	Base case (kwh)	Tariff (AED)				Total (AED)
		(2000x0.23) G	(2000x0.28) Y	(2000x0.32) O	(2000x0.38) R	
Jan	4670	150	180	70.35	0	400.35
Feb	4499.4	150	180	52.44	0	382.44
Mar	5346.6	150	180	141.39	0	471.39
Apr	7016.5	150	180	210	127.06	667.06
May	9319	150	180	210	414.88	954.88
Jun	11815.5	150	180	210	726.94	1266.93
Jul	12495.5	150	180	210	811.94	1351.93
Aug	12633.3	150	180	210	829.16	1369.16
Sep	11794.2	150	180	210	724.28	1264.28
Oct	9825.7	150	180	210	478.21	1018.21
Nov	7262.9	150	180	210	157.86	697.86
Dec	5523.1	150	180	159.93	0	489.93
Annual energy consumption cost for Base case (local)						10334.43

Table 22: Annual energy consumption cost for the base case (non-local family)

Month	Base case (kwh)	Tariff (AED)				Total (AED)
		(2000x0.23) G	(2000x0.28) Y	(2000x0.32) O	(2000x0.38) R	
Jan	4670	460	560	214.4	0	1234.4
Feb	4499.4	460	560	159.81	0	1179.81
Mar	5346.6	460	560	430.91	0	1450.91
Apr	7016.5	460	560	640	386.27	2046.27
May	9319	460	560	640	1261.22	2921.22
Jun	11815.5	460	560	640	2209.89	3869.89
Jul	12495.5	460	560	640	2468.29	4128.29
Aug	12633.3	460	560	640	2520.65	4180.65
Sep	11794.2	460	560	640	2201.80	3861.80
Oct	9825.7	460	560	640	1453.77	3113.77
Nov	7262.9	460	560	640	479.90	2139.90
Dec	5523.1	460	560	487.39	0	1507.39
Annual energy consumption cost for Base case (expat)						31634.3

5.2.3.1.1 Payback period of M#1: Wall insulation

By adding a wall insulation in the facade, a 2.81% energy savings were achieved. The following are the calculations that have been done to calculate the time for the Payback period for this measure:

The area of the walls was calculated from the AutoCAD drawings (excluding glazing area) was = 276 m^2

Based on the bill of quantities of a similar villa from the styro company that is included in appendix D, it shows that each square meter will cost 160 AED. The total price for wall insulation including vat for both supply and apply is 160 AED x 276 m^2 = 44160 AED

The annual energy cost of the base case (local family) is: 10334.43 AED

The annual savings after adding wall insulation = 10334.43 x 2.81% = 290.39 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{44160}{290.39} = 152.3 \; years$

The annual energy cost of the base case (non-local family) is: 31634.3 AED

The annual savings after adding wall insulation = 31634.3 x 2.81% = 888.92 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{44160}{888.92} = 49.7 \; years$

5.2.3.1.2 Payback period of M#2: Roof insulation

By adding a roof insulation in the existing roof, a 1.62% energy savings were achieved. The following are the calculations that have been done to calculate the time for the Payback period for this measure:

The area of the roof was calculated from the AutoCAD drawings which was = 212 m^2

Approximate increase of the initial cost for roof insulation:

supply and apply of 5mm heat XPS roof insulation board: 15.5 AED × 212= 3286AED

1-layer Geotextile: 3 AED × 212 = 636 AED

Total cost: 3922 AED

Total cost including VAT (5%) = 4118.1AED

The annual energy cost of the base case (local family) is: 10334.43 AED

The annual savings after replacing the windows will = 10334.43 x 1.62% = 165.35 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{4118.1}{165.35} = 24.9 \; years$

The annual energy cost of the base case (non-local family) is: 31634.3 AED

The annual savings after replacing the windows will = 31634.3 x 1.62% = 512.47 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{4118.1}{512.47} = 8.03 \; years$

5.2.3.1.3 Payback period of M#3: Window glazing replacement

By replacing the old windows which was single glazed windows with a double-glazing window, a 3.90% in energy savings were achieved. The following are the calculations that have been done to calculate the time for the Payback period for this measure:

Area of glazing in the four elevations approximately: 110 m^2

Cost of a double glaze window (including the installation + aluminum frame) = 400 AED/m^2

Total cost of glazing = 110 AED × 400 AED = 44000 AED

Total cost including VAT (5%) = 2200 AED

Total cost of replacing the glazing = 46200 AED

The annual energy cost of the base case (local family) is: 10334.43 AED

The annual savings after replacing the windows will = 10334.43 x 3.90% = 403.04 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{46200}{403.04} = 114.6 years$

The annual energy cost of the base case (non-local family) is: 31634.3 AED

The annual savings after replacing the windows will = 31634.3 x 3.90% = 1233.73 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{46200}{1233.73} = 37.4\ years$

5.2.3.1.4 Payback period of M#5: Lighting replacement

By replacing the old bulbs in the villa by a new Efficient LED bulb, a 4.86% energy savings were achieved. The following are the calculations that have been done to calculate the time for the Payback period for this measure:

Total cost of lighting replacement as per the lighting quotation in appendix D is: 21009.75 AED

The annual energy cost of the base case (local family) is: 10334.43 AED

The annual savings after replacing the windows will = 10334.43 x 4.86% = 502.25 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{21009.75}{502.25} = 41.8\ years$

The annual energy cost of the base case (non-local family) is: 31634.3 AED

The annual savings after replacing the windows will = 31634.3 x 4.86% = 1537.42 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{21009.75}{1537.42} = 13.66\ years$

5.2.3.1.6 Payback period of M#7: All retrofit measures

By all the previous retrofit measures in the villa excluding the external shading devices, a 18.8% energy savings were achieved. The following are the calculations that have been done to calculate the time for the Payback period for this measure:

- Cost of M#1 = 44160 AED

- Cost of M#2 = 4118.1 AED
- Cost of M#3 = 46200 AED
- Cost of M#5 = 21009.75 AED

Total cost of the previous retrofit measures = 115,487.85 AED

The annual energy cost of the base case (local family) is: 10334.43 AED

Annual savings after applying previous retrofit measures = 10334.43 x 18.8% = 1942.87 AED

Time for payback = $\frac{\text{Total cost after applying a retrofit measure}}{\text{Total annual energy savings}} = \frac{115{,}487.85}{1942.87} = 59.44\ years$

The annual energy cost of the base case (non-local family) is: 31634.3 AED

Annual savings after applying previous retrofit measures = 31634.3 x 18.8% = 5947.25 AED

Time for payback = $\frac{\text{Increase in the initial building cost}}{\text{Total annual energy savings}} = \frac{115{,}487.85}{5947.25} = 19.42\ years$

5.3 Analysis of Results and discussion

Many retrofit measures can be implemented to chive the optimum energy savings in the villa. Among different and most common measures for villas considered in the previous sections, changing the AC set point was the measure that saves the most significant amount of energy while adding an external shade was the least. However, the economic part should be analyzed along with each measure to decide whether these measures can affordable or not. In the previous section 5.2.3.1 Time of the Payback period, a simple payback period for each measure has been calculated with a cost approximation for both local family as well as the non-local family. Table (23) represents the approximate simple payback period for each measure in years for both local and non-local family.

Table 23: Simple payback period for the retrofit measures

Type of family	**Payback period for each measure (years)**				
	M#1(Wall insulation)	M#2 (Roof insulation)	M#3 (Window glazing replacement)	M#5 (Lighting replacement)	M#7 (All retrofit measures)
Local	152.3	24.9	114.6	41.8	59.44
Non-local	49.7	8.03	37.4	13.66	19.42

From the table, we can notice that the payback period in all retrofit measures was extremely high for the local family since the cost rate is already subsidized by the government for them. For that, it will be useless if there were laws that force the locales to retrofit their old villas unless the government contributes to creating other incentives that encourage them to do that. However, in the non-locals family, the payback period for each measure was much lesser than the time for the locals' families. This due to the different cost rates for electricity. Although the payback period was less, the time of the payback period still high which means it will be difficult to mandate retrofit old villas using any of the previous measures.

The long payback period is one of the significant issues that make it difficult for owners to invest in their old houses. However, applying some of the selected retrofit measures combined can be effective with less payback period. Table (24) below shows the savings as well as the time of the payback period for many combined retrofit measure options.

Table 24: savings and payback period for different retrofit options

# of options	Retrofit Measures	Savings (AED)	Time of payback period (year)
O1	M#1 + M#6	2663.6	16.57
O2	M#3 + M#6	1774.68	15.32
O3	M#5 + M#6	3312.11	6.34
O4	M#2 + M#6	2287.16	1.80
O5	M#2 + M#3 + M#5 + M#6	5058.32	14.1
O6	M#3 + M#5 + M#6	4545.85	14.78
O7	M#2 + M#5 + M#6	3824.58	6.57

As it is shown in table 24, we tried to explore the possibility of combining more than one retrofit measure to achieve the maximum savings with less time of payback. The time was calculated in regard to the actual price of DEWA bills. There were many options that combine between two measures at least to achieve maximum saving along with the less time to payback. In this case, the best option was option 4 which combined changing the AC set point as well as adding roof insulation. The saving in the option can reach up to 2287.16 AED and the time of payback is 1.8 years. Both option 3 and option require approximately less than 7 years to pay back which means it may be considered to be part of the options that can be mandatory for villas. On the other hand, option 1 (changing AC set point and adding wall insulation) needs a lot of time to pay back due to the high price of applying insulation in the villa. Hence, applying retrofit measures in a mandatory way would not be effective without providing good incentives and special funds for the owners.

From the simulation results and the time of the payback period, two measures can contribute to saving energy with less time for the payback period. These measures are: Adding roof insulation and changing the AC setpoint combined together. Therefore, these measures can be added as regulation from the government since it can be affordable for the owners as well as can helped to save energy. Although the percentage of savings and the time of the payback period can be various from villa to another and from product material to another, these two measures can be set as a regulation for the selected old villa. Also, if we combining replacing old bulbs it will help to achieve more savings with less time for payback than the other measurers.

Figure (28) below shows a simple recommended framework that the government and semi-government can cooperate to start work. They can start by surveying the existing old villas based on different aspects. These aspects could be the age of the villa (villas that were built before 2003) as well as the quality of construction and the used construction materials. Then begin to label the villas based on the villa construction condition. Forcing implementing retrofit strategies in the villas that need a deep retrofit would not be possible and it should not but it can be voluntary and up to the owner. This due to a long time for payback period which will not be convincing for owners to do and apply. However, it is recommended to have government support financially for the environment as well as the good health and well-being of this type of villa. On the other hand, it would be more convenient to mandate implementing retrofit measures in the villas that need moderate and light retrofit since applying these measures can have less time for the payback period.

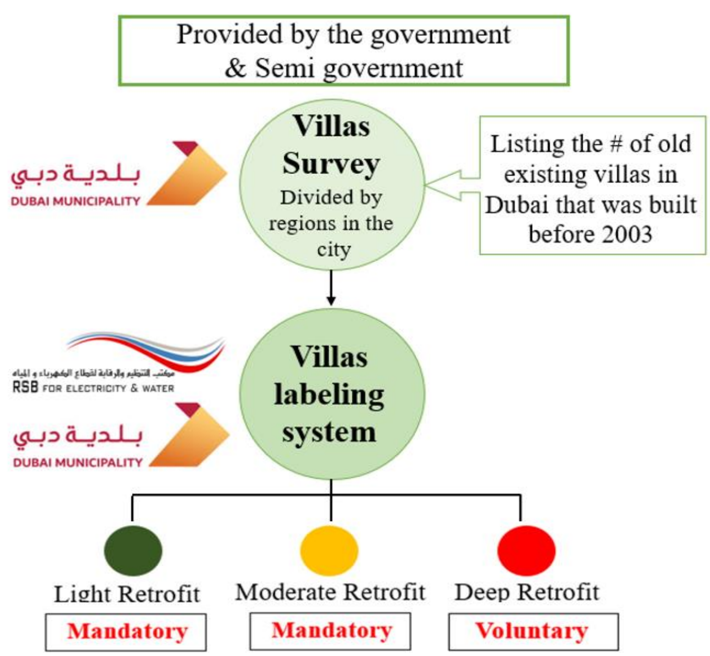


Figure 27: Process of applying retrofit regulations

Chapter Six: Conclusion & Recommendations

6. Conclusion & recommendations

This chapter will discuss all the findings and outcomes from the research objectives, which is mainly about exploring the possibility of providing a retrofit regulation for existing old villas in Dubai. Also, it will summarize the main findings and results and consist of the research contribution in the field. Then it will be followed by the research limitation and difficulties. After that, it will end up with recommendations and future work.

The main research objectives that were introduced at the beginning of this study and identified are:

- **To understand the term of sustainable retrofit by gathering information about its types, factors, benefits, success and challenges**. All the data were gathered and explained in chapter 2, section 2 and 3.
- **To collect data about the policies and regulations of sustainable retrofit worldwide.** This information and data were illustrated in chapter 2. Many policies and regulations related to the topic were identified in the chapter.
- **To gathering information about sustainable retrofit regulation in Dubai for villas and the challenges that may be faced them.** This information was collected mainly from interviewing experts and owners in the city, which were represented in the first section of chapter 4.
- **To collect data about both actual size and age of the old existing residential buildings in Dubai to select a case study.** The data were shown in the second section of chapter 4.
- **To provide recommended policies and retrofit measures for Villas from the energy aspect.** The recommended policies and measures were identified at the end of chapter 2. Moreover, the recommended measures were refined after interviewing experts in chapter 4.
- **To select the most appropriate retrofit options and evaluate them based on the energy savings as well as the time of payback period to choose the most appropriate and effective ones that could be forced as regulation in all old existing villas.** All the chosen retrofit measures were simulated to evaluate their effectiveness in saving energy in the second part of chapter 4. Besides, the time of the payback period was identified for each measure in chapter 5, section 4.
- **To analyze all the gathered data in order to explore whether providing these policies and regulations can be useful in retrofitting villas**, which were identified in the last section of chapter 5.

6.1 Summary of the research

This research was conducted to investigate and explore the possibility of providing a green retrofit regulation for this kind of building by applying the most common retrofit measures for houses. The study was conducted using a mixed-mode methodology where it is combined between the literature review a research method as well as using the interviews and computer simulation. The first part of the study was the literature review, where many data were collected in order to understand the term of sustainable retrofit as well as finding the most common retrofit policies and strategies worldwide. At the end of this part, many recommended policies and strategies were recommended for the existing old villas in Dubai. Many measures were gathered that can be applied in deferent elements in the villa like walls, roof and windows.

The second part of the study was conducted by interviewing many interviewees. The interviewees were grouped into four main groups which they are: governmental staff, semi-government staff, private compony staff and owners. It was essential to hear from different people in the field to find out the main challenges in developing regulations for this sector from various points of view. Most of the interviewees' opinion who worked in the field these days believes that it may be possible to provide a retrofit regulation if we can overcome the economic issues. Many suggestions were collected from the interviews regarding the financial issue. For example: providing incentives programs for such projects from the government to ensure having more participants in the retrofit program. Also, when implementing any retrofit strategy, it should be subsidized by the government. Moreover, providing an agreement with the banks to offer a low rate in these kinds of projects with various business models for owners to select the most comfortable one for them.

The third part of the study was conducted by using the last research method, which is a computer simulation. An old existing villa in Dubai, UAE, was selected to investigate the amount of the saved energy that can be achieved if a specific retrofit measure was implemented. Also, by providing simple and approximate calculations for the time of the payback period for each measure. Each retrofit measure was covered by a simulation to help select the measures that can achieve the highest saving of energy along with the shortest time of the payback period. Seven simulations were tested. Each simulation represents one retrofit measure to check the savings in cooling load and total energy. Also, a simple economic study was conducted for each measure to compare it with the overall energy reduction. The most measure that can save energy with the shortest time for the payback period was selected to be recommended a regulation for retrofitting existing old villas in the city. The results of the simulations show that changing the AC set point can save the highest percentage of cooling load and energy to reach 17.57 % and 5.61%, respectively. In addition, it does not require any additional cost to change the set point. Therefore, this retrofit strategy can be recommended to be a retrofit regulation for old villas. However, there are different electricity rate for locals and non-locals' families. Forcing any of these retrofit measures will require a lot of money comparing to the savings and the time of pay back period. It is not recommended to mandate any of these regulations to local families since the rate of electricity is already reduced from the government. For that, mandating some of these measures to nonlocal families could be more feasible economically.

6.2Research limitations

The main purpose of the research is to explore the possibility of providing a green retrofit regulation for the existing housing stock in Dubai. Although the main aim is achieved, it must be acknowledged that this study has some limitations that need to be aware of.

Although the selected case study was a typical villa that represents many other similar villas in the chosen neighborhood with the same age and construction materials, however, we cannot generalize the case study to the rest of the existing villas in the city. Besides, each villa depends also on the user's behavior, their quantity and the used appliances. So, energy savings may vary from villa to another, which may affect the total amount of energy savings and the payback period of the investment. Moreover, the research did not investigate different types of materials in each retrofit measure since it is not that main goal in the study. But some types may contribute more to achieve higher energy savings. In addition, all the interviewees from owners' categories were local owners. They may narrow down the challenges that may be faced and not taking into account other problems that may face non-local owners if such regulations could apply.

6.3 Recommendations and future work

The findings and outcomes of this study showed that providing a regulation can be a good step if we can overcome two main issues, cultural and economic. Some potential recommendations can be studied for future research.

Firstly, this study was mainly to explore the possibility of providing regulations to retrofit the old existing villas in Dubai, so many studies may conduct to include all villas in different cities in the UAE and compare various initiates that were established regarding the same topic. The comparison may end up providing a whole structure and framework for all cities to retrofit the biggest possible number of old villas in the country. Also, since the economic issue was one of the biggest challenges in this field, many future pieces of research can be conducted to explore ways to overcome this issue as well as providing more than one business model to apply the retrofit strategies and measures. Moreover, many retrofit measures were not included in this study because of the lack of information and detailed drawings for the selected case study, so other retrofit measures that related to the HVAC system should be simulated and studied in detail.

Secondly, monitoring the villa pre- and post-retrofit can clearly identify the villa's performance in reality instead of using virtual software. Monitoring the villa in reality can also be useful to compare between the software simulation results and the real results in order to evaluate the simulation tools as a method in defining the energy savings as well as providing a deep understanding of the achieved energy in reality.

Lastly, we noticed from the findings that there is some of a retrofit measure that can be effective even if it is in a small percentage, like adding an external shading device. Note that these strategies are not audited in the process of permitting any villa. In view of avoiding retrofitting the buildings that are currently permitted in the next 10 or 20 years, we have to take into consideration the location of the windows in the villa as well as providing external shading devices where it is needed. All of these are apparent directions for continuing future work in the field to find out optimal solutions of sustainable retrofitting in the low scale small residential buildings to improve both of the energy efficiency of the building and quality life of the occupants.

Sustainable retrofitting of existing villas is still not well recognized and not paid that much of attention from different sectors because it is small scale in comparison to the amount of the money needed to retrofit them as well as the long payback period. Finding alternative solutions to overcome the economic issue and finding encouraging incentives to the owners may help to achieve an optimum balance between retrofit measure and cost-effectiveness. Also, it is essential to consider other benefits of the retrofit on a larger scale from different aspects like social, economic and environmental to meet the required energy savings and to provide a high-quality living environment for people.

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Appendices

Appendix A

Questions and answers of the interviewees:

1- Ryan interview:

Group	No.	Interviewee Name & Email	Position	Date	Site	City
Government staff	1	Ryan Ben Sabilala Ryan.sabilala@dewa.gov.ae	Engr-Sustainability	16/02/2020	Dubai Electricity and Water Authority (DEWA)	Dubai

#	Question	Answer
1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?	So far there is none, Etihad ESCO is doing retrofit programs now but I don't think that they have some policies between them and Dubai Municipality.
2	How was the performance of the previous related projects to retrofit villas in UAE?	When you say retrofit, it doesn't just pertain to energy conservation and efficiency. It can include other works which will benefit the operation of the buildings. Usually, the result of retrofit activities is increased operational efficiency and optimized equipment parameters hence less energy consumption. There are retrofits which focuses on the healthy work spaces.
3	Why it is hard to implement the retrofit strategy in small villa?	Owner's buy in is very important including government policies. Owners who are well educated and aware by the benefits of retrofit program will easily adapt the strategies to create savings out of energy water as well as healthy spaces.
4	What are the ways that you think we can catch the interest of the owners and local clients?	There should be a guaranteed savings contract agreement between the owner and the ESCO. For example, if this villa will save energy with a specific target and it was not achieved by the company, so they will get their money back or provide for owners comfortable financing plan. On top of the guaranteed savings agreement, an incentive program from the government will ensure participation of more household owner in retrofit program, example, installation of PV with percentage subsidized by the government.
5	What are the best strategies	I think the first thing to do provide awareness, because as I

	that can be implemented in the villas?	said is how the owners will accept that. As a strategy, in my opinion changing the HVAC for example is not a good strategy to start with. First, we need to make sure that the envelope is efficient. Because at the end, if you change the HVAC but your envelope is not that efficient. The insulation is bad, the doors and windows are bad, there is so much infiltration. Then the HVAC will work hard in order to make up for the shortage. So, at the end, you did not do something for energy. Better to check first your envelope and insulation is good enough and meeting the requirement of the green building, even if it was the minimum requirement. Then we can use strategies to change the HVAC system. So, the role is always efficiency first approach. So, we take in consideration first the efficiency, then the consumption. The last thing to consider here is to add renewable energy in the building. Now what have been done is the reverse. Everyone is trying to put renewable and put a lot of solar PVs and that is it which is wrong. I believe you should take at first all the passive systems for example window shades in consideration and after that one you consider retrofitting the HVAC systems and lighting and once the consumption goes down based on these strategies, you can put solar PV because when you do this you minimize the area of the coverage of the solar PV in the roof. So, the lesser area for the solar PV, the lesser the cost that you will buy for these solar PVs.
6	In your opinion, which one of these strategies we can add it as a regulation to retrofit the existing old villas and why?	In order to implement the retrofit program, is better to start with AL SA'FAT rating system. I guess it is the best starting point to do the retrofit. From there you can set the guideline and do another version from it to set the requirement for the existing buildings and retrofit. For example, AL SA'FAT set the requirement. So, if the existing villa does not meet these requirements, there is an opportunity to go for retrofit. In other words, AL SA'FAT requires that glass window has to have this kind of U-value, then your villas does not meet this requirement. So that is an opportunity for you to do a retrofit. After that when AL SA'FAT will be a mandatory, then everyone will do retrofit.

2- Noora interview:

Group	No.	Interviewee Name & Email	Position	Date	Site	City
Government staff	2	Noora AL Hammadi Noora.alhammadi2@dew.gov.ae	Engr- Sustainability	16/02/2020	Dubai Electricity and Water Authority (DEWA)	Dubai

#	Question	Answer
1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?	No policies as far as I know until now.
2	How was the performance of the previous related projects to retrofit villas in UAE?	Etihad ESCO with DEWA support had a retrofitting program targeting more than 2,092 facilities and buildings in Dubai. The result of this program was huge. For example, I think it achieved above 100 million kilowatt-hours of electricity and more than 130 million gallons of water. These achievements save a huge amount of carbon emissions yearly. Other kind of retrofitting program was targeting 1,656 homes for the Mohammed bin Rashid Housing Establishment. However, our section in DEWA which is (sustainability engineering section) scope of work only target DEWAs building only.
3	Why it is hard to implement the retrofit strategy in small villa?	We can't say that its hard, but if we look to the retrofitting provider company usually the small villas are not under their scope or their interest due to low income cost. It is mainly because of the cost.
4	What are the ways that you think we can catch the interest of the owners and local clients?	The definition of retrofit is not really known here specially between the owners. In term for office buildings the term retrofit is still strange, how about for villas. So, we need to increase the knowledge about this terminology. And to provide some kind of insurance between both the company and the villas owners. it's like a win-win deal. For example, ensure the owners that this will benefit you in terms of cost and if the company did reach the target by the end of the year, the owner should pay for the company by percentage of saving or any other reward.
5	What are the best strategies	I think we should start from the base of the retrofitting not from

	that can be implemented in the villas?	the top. The base is the envelop of the building. Last strategy would be renewable not the first thing to implement. If the base and the base here is the envelope was not that good. Anything you will do it later will not be efficient as it supposes to be.
6	In your opinion, which one of these strategies we can add it as a regulation to retrofit the existing old villas and why?	If you have a rule like AL SA'FAT, the people will be forced to implement the retrofit strategy to meet this guideline requirement.

3- Fida interview:

Group	No.	Interviewee Name & Email	Position	Date	Site	City
Government staff	3	Fida AL Hammadi FMHAMMADI@dm.gov.ae	Head of Planning Studies Section - Building Permit Department	02/03/2020	Dubai Municipality (DM)	Dubai

#	Question	Answer
1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?	There are no regulations regarding that, but the Green building council already have launched a guideline for retrofitting the existing buildings. Also, they approved a labeling system for the existing buildings from H.H Sheik Ahmed Bin Saeed. They started to do that because the retrofit is costly, especially for the nonresidential buildings. However, they can do residential buildings or villas if the owner asked for that through Etihad ESCO.
2	How was the performance of the previous related projects to retrofit villas in UAE?	For the results, the project that I am aware of is the retrofitting of Mohammed Bin Rashid housing, which done by Etihad ESCO and I am not sure about their results and whether it was affecting or not.
3	Why it is hard to implement the retrofit strategy in small villa?	It is not that hard. On the other hand, I think it will be successful if we think outside the box and find alternatives and initiatives that can facilitate the process. For example, if I (As a governmental authority) , do a study of the local villa to try to retrofit this villa, then surely in the interest of the energy consumption I will install solar panels at first and change many things, so the energy may decrease to a certain extent and the owner can reach a point where he can produce electricity from his house. These are the directions of H.H Sheikh Hamdan at the summit when he said that the energy production plants are central stations outside the emirate and I look forward to the energy production stations inside the emirate to be decentralized which means they can be on the homes and buildings. If there is an opportunity for the owners to invest in this without losing anything, this will be very beneficial. So, the difficult thing in retrofit is how to reach that owner and convince him to retrofit his villa. All of this may lead the owners to a point where they can even sell the energy produced in their own houses.

		I will tell you about the municipality's experience when they were trying to add a new regulation for new buildings, which is adding solar heaters in the villas. Initially, we received many problems, complaints and objections. After we force this law and despite everything, the price of solar heaters has decreased significantly during these years. Through one law, it found an entire market for these heaters and became great competitions between companies. As for the retrofit, there are no regulations, and therefore there is no big market interested in this. Thus, the prices are rather high, and I think this should start gradually. This means that we should force everyone by law, but we should begin by selecting specific categories that can benefit a lot from retrofitting. I do not think that forcing people by laws and regulations, especially with local owners. Unfortunately, this culture does not exist with the local owners, and it is difficult to convince them to retrofit, especially since the owners of these villas are from the old generation and not aware much of the building energy. Therefore, the cultural issue is huge in this matter, and I think it is the most significant challenge in this topic.
4	What are the ways that you think we can catch the interest of the owners and local clients?	If we find convincing financing alternatives, this issue can be very successful and this is the future. Nowadays, owners are not aware of this issue and may not be interested in invest in such things, unless it was free or it will benefit them financially.
5	What are the best strategies that can be implemented in the villas?	Having good incentives and easy funds for the owners can make this issue feasible, regardless of the used retrofit strategy in the villa. But the easiest way is changing the lights and adding solar in the villas. Therefore, it is important to have a financing alternative, for example, if there is a competition between investors, or it is possible to agree with the banks by setting less interest in these projects. The existence of convincing incentives and financing is fundamental.
6	In your opinion, which one of these strategies we can add it as a regulation to retrofit the existing old villas and why?	I believe that the most convenient and easy way for retrofit villas is changing the lights and adding solar and that is what Etihad ESCO and DEWA have done in Mohamed bin Rashid housing. It will cost less and they can do it in a short time. But how much can it reduce energy consumption precisely; I don’t know that.

4- Ankit interview:

Group	No.	Interviewee Name & Email	Position	Date	Site	City
Semi-Government staff	4	Ankit Sharma ankit.sharma@etihadesco.com	Energy Consultant – CEM, CMVP, CBCP, LEED & GA	05/03/2020	Etihad Energy Services Company (Etihad ESCO)	Dubai

#	Question	Answer
1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?	No regulation but we have done many projects.
2	How was the performance of the previous related projects to retrofit villas in UAE?	For villas, we have don Mohammed bin Rashid villas two years ago. Then we did 5000 villas, which is done by DEWA but we were on site project management team. It was finance fully by Dewa since it was their project, but we did it. It was in Dubai and for locals, so as that we did retrofitting. As a measurement we did lighting for example we install smart lighting and LED and we worked in water savings and we provide them with solar panels which generate energy. So that basically what we have did in villas but the results are confidential and have not been published yet.
3	Why it is hard to implement the retrofit strategy in small villa?	Actually, it is not hard but the commercial factor is the major one. If we consider the locals because the payback will be very high around 7 to 10 years. So that is not visible and commercially not viable. Also, we cannot disturb to much. Like if we go for a normal retrofit in commercial building of industry, it will take around 9 to 12 months but for home you can take 3 to 6 months. If it was not a deep retrofit, we can do it easily, we have done it. Considering lighting and solar, we can do it in one week. If we will change the HVAC, it depends. If we for example will change the windows and the split AC with another one that is more efficient, we can do it in a week but of you want to for chiller for example, you have to piping and ducting then it will take time. Month maybe.
4	What are the ways that you	Major consumption for the villas is AC. If we put new AC or

	think we can catch the interest of the owners and local clients?	smart AC, then there is regular maintenance are needed. So, if there are some plans and offers for the owners like if we provide for the owner 5 years of warranty and a free maintenance from our side. Then the owners may try to make benefits from these offers and will accept to change in their houses.
5	What are the best strategies that can be implemented in the villas?	When we think about the strategies for villas. We did Lighting, water service and solar panels. We only consider that, because what we can do considering the cost and time. For example, the light retrofit like changing the lights and some water savings like two kw we can say it is around 25 to 30 thousand and it is a one-time cost. If we go for AC, we need to give it to somebody else and we may need to do big changes in the wall. For example, we may need to break the wall and we may destroy the type of paint and texture of that wall which will be a bit costly as well as it will be not visible because it may take a lot of time. Also, envelope retrofit is not easy thing to do. It is considering a deep retrofit and the payback period is higher. It may be from 7 to 10 years and the above retrofit measures we can do it in a short period of time like one or two visits.
6	In your opinion, which one of these strategies we can add it as a regulation to retrofit the existing old villas and why?	It is better to consider the measures of the light retrofit like changing the lights and adding solar. Also, I think there are a star rating should be applied in the equipment to insure using the high efficiency appliances. Maybe these can add as a regulation. For example, it should be more than 4 stars and that is how we can insure using a good equipment's.

5- Majd interview:

Group	No.	Interviewee Name & Email	Position	Date	Site	City
Semi-Government staff	5	Majd Fayyad Majd.fayyad@emiratesgbc.org	CEM, LEEP AP (O&M), TRUE Advisor Technical Manager	2/24/2020	Emirates Green Building Council	Dubai

#	Question	Answer
1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?	There are no policies and regulations to retrofit old villas until now in the UAE. And not just for villas, for all buildings in general. All that we have in the UAE regarding this matter are some initiatives and retrofit programs under the Dubai supreme council of energy and implemented by Etihad ESCO. But still, it is not a mandated program and does not consider as a regulation. These initiatives are not only on Dubai, there are different programs also that will be launched soon regarding the retrofit in Abu Dhabi. Also, there is another one in Ras Al-Khaimah. Also, SEWA trying to do something regarding that in Sharjah by identifying the big consumers. From our side in the green building council, we only have the technical guidelines and training program to enable the engineers to do a good retrofit. Also, nowadays, we are working on a study targeting the deep retrofit, which will be published by the end of this year, hopefully. In general, there are efforts from the government and the private sector as well to advance the retrofitting market but no policies and regulations.
2	How was the performance of the previous related projects to retrofit villas in UAE?	Maybe ESCO is doing something for villas, but I am not sure about that and not aware of any retrofitting projects for villas.
3	Why it is hard to implement the retrofit strategy in small villa?	It is not hard. Like any retrofit project, many easy retrofit measures can be applied in the building. These measures are called low-cost measures, which are very easy to implement. Also, it may depend on the challenges, but in the villa's cases, there are no significant challenges. Maybe if we will change the AC, it may be a little complicated. But I think the biggest challenge in retrofitting is that it does not mandate it and all that we have done are just initiatives. Also, the lack of awareness of the clients and the owners about the importance of retrofitting. The third thing is, there is something which is called "Split

		intensive “. This term can refer to, for example, a developer does not care about the amount of energy consumed by tenants in the homes they rent because the electricity bill is paid by the tenant himself and not from the company. So, if the developer will put money to retrofit the building, he will not get any benefit from the savings, unlike the tenants. For that, most of them do not care about retrofitting, but maybe they will do if the government forced it. Also, lack of financing models for retrofitting and the available models are not that clear for the clients, maybe.
4	What are the ways that you think we can catch the interest of the owners and local clients?	If we solve the financing issue, maybe the owners will be more interested in the retrofit because you know that most of the owners may not have the money to do that. Here we can benefit from ESCO and how they are trying to overcome the financing issue. For that, ESCO is having a model for such projects; for example, they have something called energy performance contracting where they can be paid by the energy savings in the building. This can enable the company to install the equipment without being paid form the client. After that, the client can pay on the savings. So basically, the ESCO company will finance the project and they get paid by the savings. Thus, the model is the main approach for companies. Whether it is a big building or a small villa, they will use the same method but I think it is for small range like installing a solar in the building.
5	What are the best strategies that can be implemented in the villas?	First of all, there are many good practices globally and even in the ESCO market. For example, in Dubai, they started the market for five years, so these companies are mature enough. Also, there is a guideline on how to retrofit. Maybe what will be best nowadays is how to improve the retrofit by adding new technologies—also having strategies and measures not only for the sallow retrofit but also for the deep retrofit. How we can implement ESCO models and how we can have financing for these projects.
6	In your opinion, which one of these strategies we can add it as a regulation to retrofit the existing old villas and why?	I personally believe that it should be a regulation from the government even if the percentage of the saving is not that high, which means mandating the sallow retrofit strategies.

6- Naveen interview:

Group	No.	Interviewee Name & Email	Position	Date	Company	City
Private company staff	6	Naveen Gowd naveen@pactivesolutions.com	CEO	09/02/2020	Pactive Sustainable Solutions	Dubai

#	Question	Answer
1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?	So far, we have not come across any such regulation on retrofitting; however, when deep retrofit happens, we are compelled to use Energy Efficient systems / products, this is because of the regulations such as ESMA or QCC etc. Example if you decide to replace AC units, then you will get only efficient AC units in the market.
2	How was the performance of the previous related projects to retrofit villas in UAE?	Retrofitting has been very successful till now. In our last 6 years' experience we have seen projects with savings ranging from 15% to 40%, and most importantly sustaining these savings over years.
3	Why it is hard to implement the retrofit strategy in small villa?	Single villa is a small building and when we do the cost benefit analysis of deep retrofit costs, the payback period is very long and most often doesn't motivate the owner to invest. This is because of the low usage in comparison to commercial or retail or other type of buildings. However, if a single owner has multiple villas and decides to retrofit them together, then the retrofit costs are fairly lower because of increased quantities. (Economies of scale)
4	What are the ways that you think we can catch the interest of the owners and local clients?	If you are talking about Villas, then the cost of retrofit has to make sense to the owner with quicker payback period. For this, energy consultants should be smart to propose simple and cost-effective solutions such as intelligent thermostats, water aerators, fixing fenestration gaps and try to change occupant behavior with good awareness sessions.
5	What are the best strategies that can be implemented in the villas?	Some I have listed above. Water and AC are the 2 areas where you will see large and faster benefits. Of course, lights have to be efficient and in today's era, most villa owners would have already upgraded their lights, if not this is also an option. Also, some large villas have small chiller and FAHUs which can be optimized to a great extent using smart controls and time-based operations using setback modes.
6	In your opinion, which one	Like we all know, AC is the big elephant in the room, hence

	of these strategies we can add it as a regulation to retrofit the existing old villas and why?	making sure efficient ACs are installed will have a significant impact. I am not sure how this can be regulated, because you cannot tell a villa owner to change ACs which are working fine and not old enough to change. Hence the regulation should take into consideration aspects such as age of the villa, the quality of construction and type of occupants. The owners might get motivated if there is some sort of incentivization of retrofitting villas.

7- Fadi Interview:

Group	No.	Interviewee Name & Email	Position	Date	Company	City
Private company staff	7	Fadi AlFaris Fadi.Alfaris@quantumesco.com	PhD, CMVP, CEM, PMP, LEED AP, USGBC Faculty, Business Director in the compony	09/03 /2020	Quantum Eurostar Energy Solutions LLC	Dubai

#	Question	Answer
1	Is there any regulation and policies that can insure retrofitting the existing low-rise small-scale villas and what are they?	As far as I know, no local policies and regulation to force or insure retrofitting for villas. However, some ESCO used ASHRAE standard for the homes and villas to optimize the energy performance.
2	How was the performance of the previous related projects to retrofit villas in UAE?	For Villas, technology and awareness both play a significant role in improving energy performance. For the results, there are many projects show that we can save energy significantly even for villas if we used good and appropriate measures.
3	Why it is hard to implement the retrofit strategy in small villa?	It is not hard; we can start with awareness level to manage the energy consumption in a smart and economic approach. However, if we link the investment to the benefits and the returns, the project will be feasible.
4	What are the ways that you think we can catch the interest of the owners and local clients?	Increase awareness level Link the benefit of the energy efficiency project to the cost saving Conduct a life cycle cost assessment studies to show the values of the retrofitting project
5	What are the best strategies that can be implemented in the villas?	Control and management system if existing villa
6	In your opinion, which one of these strategies we can add it as a regulation to retrofit the existing old villas and why?	I suggest to use highly efficient air conditioning system and programmable thermostat with LED lights

8- Rashed interview:

Group	No.	Interviewee Name	Interviewee Email	Date	City
Local owner	8	Rashed Bin Yaroof Alsuwaidi	rashedbinyaroof@hotmail.com	08/03/2020	Dubai

#	Question	Answer
1	Did you hear before about the term (Retrofit)?	Yes, I’ve heard about it, it is a system regarding inserting new energy consist of clean sources such as the sun, the wind, etc.
2	After we talk about what is a retrofit, will you apply the retrofit strategies in your villa to reduce your energy consumption and to reduce your electricity bill?	Yes, I will and currently I’m embedding some sources such as the solar lights for outdoor purposes plus all indoor lights are LED system.
3	Do you prefer to force the owners to apply these strategies on the old villas or make it optional and why?	I prefer it to be optional for the old and existing houses because it is costly for the people to change the entire electric system, unless they will receive some governmental support in consultation, designing, and as well as the material price required, in that case many of the existing houses owners will implement the new system.
4	If there is a new regulation from the government to retrofit the old houses and villas, will you do it without any funds from the government?	Depends on the cost of the change and the value of the future saving on my monthly electricity Billings, if it will reduce significantly my monthly electricity Billings then I will change, but anyways we need certain incentives from the government, especially in consultation and designing of the new system.
5	Do you think it is hard for you as an owner to implement the retrofit strategies in your home if it was mandatory and why?	For me personally, if it is mandatory, I am capable financially to change my entire electric system and implement the new retrofit strategies, but not everyone will find it as easy.
6	If there are government subsidies or conventional loan, would you retrofit your home without imposing strict regulation in particular?	Of course, because it will create a lot of savings in my energy Billings and will create a better environment.
7	As a villa owner, what are the things that you need from the government, or you believe it will help you to be able to retrofit your villa easily and	Consultation, funds, designing, material, and maintenance.

	conveniently without having any strict regulations in particular?	

9- Seham interview:

Group	No.	Interviewee Name	Interviewee Email	Date	City
Local owner	9	Seham Alfalahi	Seham.al-falahi@hotmail.com	08/03/2020	Dubai

#	Question	Answer
1	Did you hear before about the term (Retrofit)?	No, I’ve never heard about this term before.
2	After we talk about what is a retrofit, will you apply the retrofit strategies in your villa to reduce your energy consumption and to reduce your electricity bill?	Yes, if that will benefit me.
3	Do you prefer to force the owners to apply these strategies on the old villas or make it optional and why?	I think forcing is better to ensure that everyone can get benefited from it, but as an authority, they should afford it for free.
4	If there is a new regulation from the government to retrofit the old houses and villas, will you do it without any funds from the government?	I don’t I will do it without any funds.
5	Do you think it is hard for you as an owner to implement the retrofit strategies in your home if it was mandatory and why?	Only if it were at my cost otherwise, it would be difficult for me. But in general, I guess it will not be that hard.
6	If there are government subsidies or conventional loan, would you retrofit your home without imposing strict regulation in particular?	Maybe, if I was sure that it will reduce my electricity bills.
7	As a villa owner, what are the things that you need from the government, or you believe it will help you to be able to retrofit your villa easily and conveniently without having any strict regulations in particular?	Fund, service providers contact and regulation to do so.

10- Amina interview:

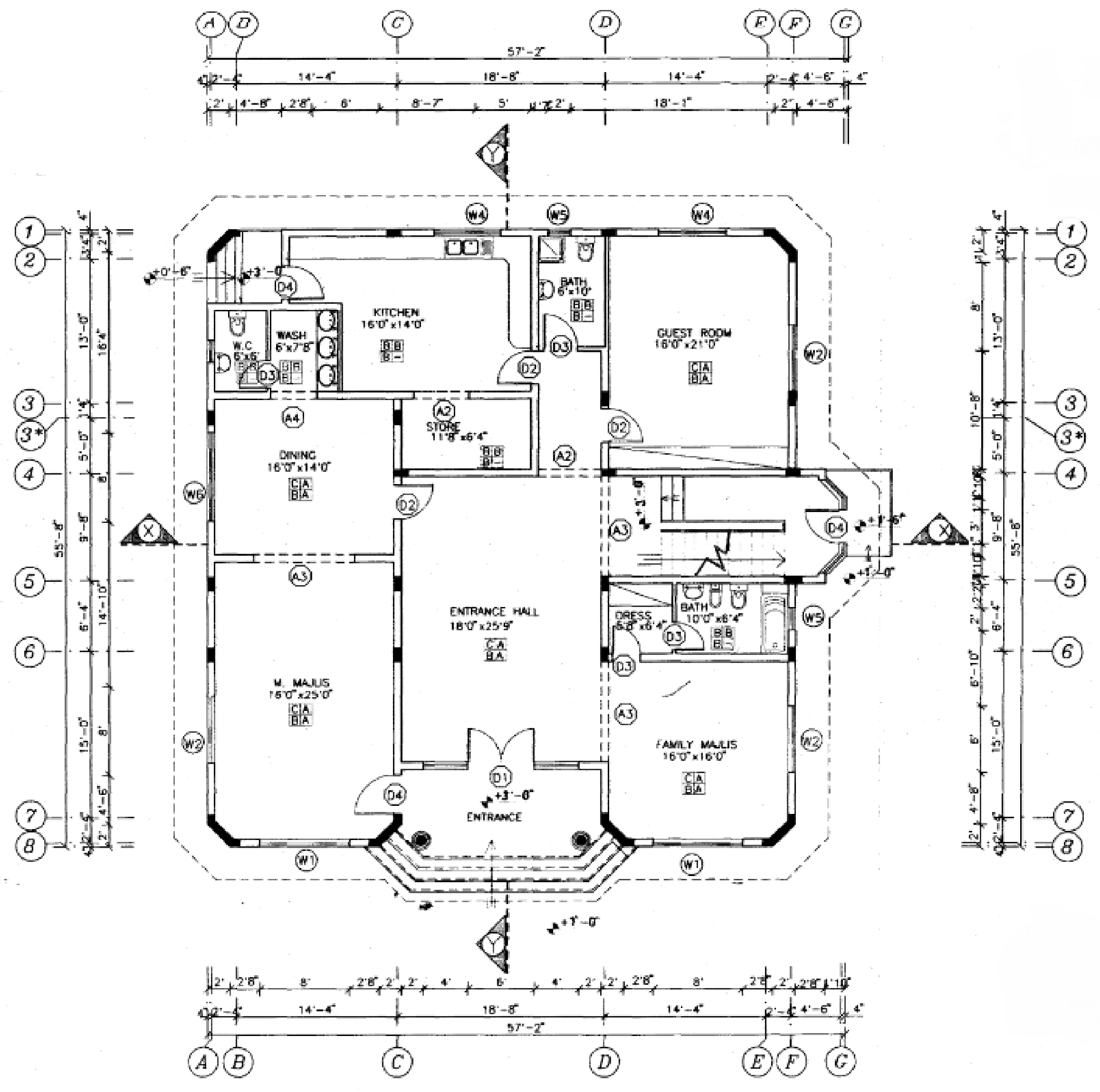
Group	No.	Interviewee Name	Interviewee Email	Date	City
Local owner	10	Amina Abdulla	Amina.a@economy.ae	11/03/2020	Dubai

#	Question	Answer
1	Did you hear before about the term (Retrofit)?	I have heard of the term, but I have never heard of its implementation, specifically in Dubai.
2	After we talk about what is a retrofit, will you apply the retrofit strategies in your villa to reduce your energy consumption and to reduce your electricity bill?	Yes, I would I consider applying the retrofit strategies; however, I would need to understand the impact of the reduction, in comparison to the amount I will be spending to retrofit my house. I will need to consider the high costs associated with changing windows, etc.
3	Do you prefer to force the owners to apply these strategies on the old villas or make it optional and why?	I personally think it should not be mandatory specially because the impact will mostly be for the owners, if their bills are reduced and so on. However, it would be helpful if the government provides more information about the different retrofit strategies and their impacts. This will convince owners, who are able to afford retrofits, to consider it. However, I do not think making it compulsory is going to be efficient, as many owners might not be financially able to implement such strategies.
4	If there is a new regulation from the government to retrofit the old houses and villas, will you do it without any funds from the government?	If it was absolutely compulsory, I will not have a choice, of course. But personally, I would not financially prioritize retrofitting my house. I think this would force a lot of owner to take loans, in order to follow the government's regulation.
5	Do you think it is hard for you as an owner to implement the retrofit strategies in your home if it was mandatory and why?	Yes, it will be hard for me to implement such strategies because even if I don't consider the amount of money it requires, it would probably be hard for me to stay in the house while the retrofitting is being done. This will require me to temporarily live in another place, for example.
6	If there are government subsidies or conventional loan, would you retrofit your home without imposing strict regulation in particular?	Providing a loan would definitely encourage more owners to implement some retrofit strategies. However, as I mentioned before, more studies need to be made public about the impact of these strategies on the reduction in electricity consumption, etc. It is

		also important for the government to provide owners with specific manuals, material specifications, and fixed costs for these materials in the market in order to encourage them to implement specific strategies.
7	As a villa owner, what are the things that you need from the government, or you believe it will help you to be able to retrofit your villa easily and conveniently without having any strict regulations in particular?	Funds or payment plans. Strict regulations in the construction market from the government, to ensure materials are as per specifications, and with fixed prices. Possibility of providing owners with temporary housing options while their villa is being retrofitted. Easing the process of retrofitting by providing “government-approved” contractors that are specifically approved to carry out retrofit jobs. Providing owners who are willing to retrofit their villas with government discounts on construction materials, for example. Providing someone from the government to check the retrofitting work is done as per the regulations. For example, for myself, I am a working woman, it will be hard for me to follow up with the work that is being done on my villa. I also don’t have much background knowledge on types of materials, construction and so on, so it would be important to have someone from the government to follow-up on these kinds of things.

Appendix B

Case study drawings



GROUND FLOOR PLAN
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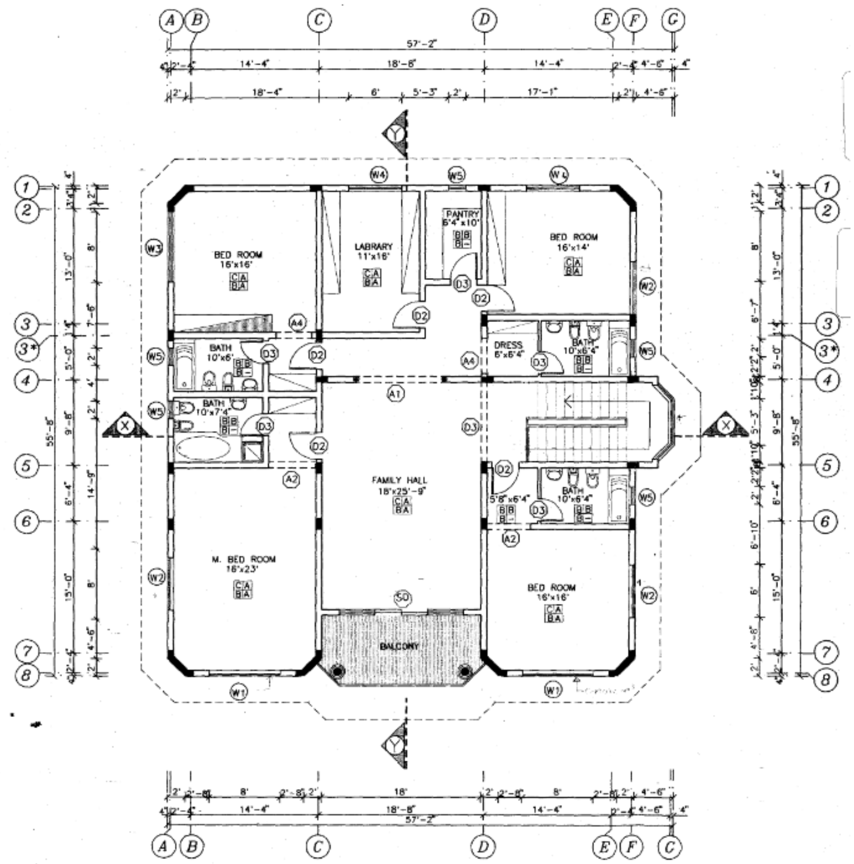
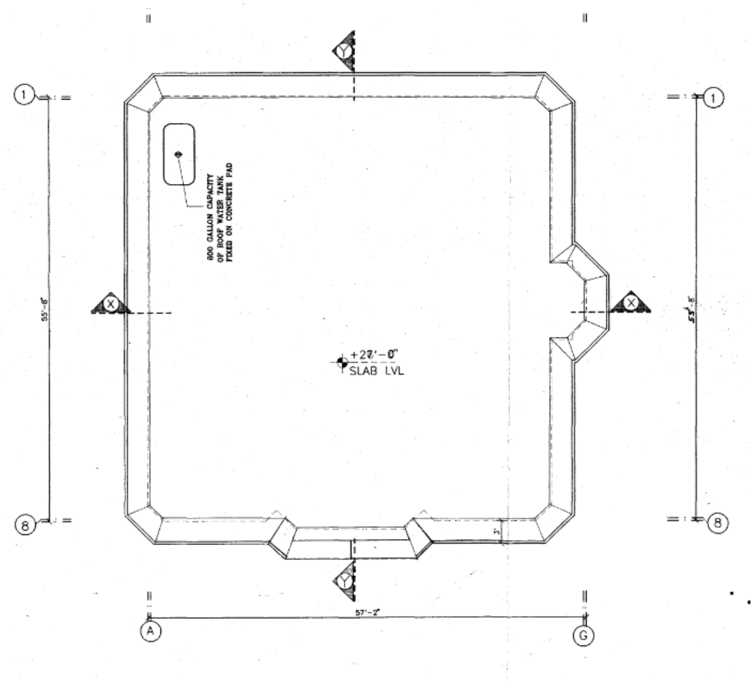


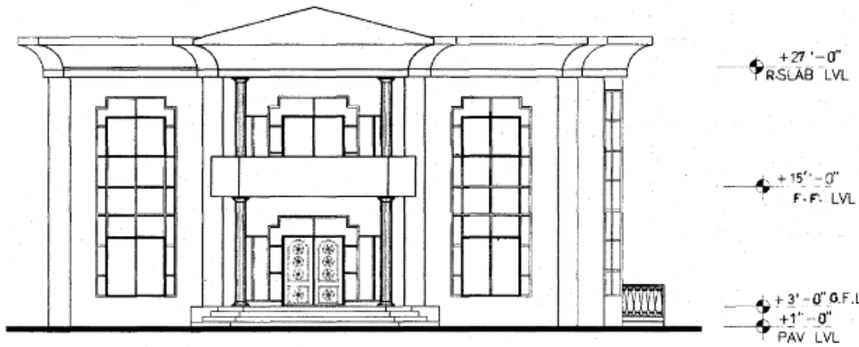
FIRST FLOOR PLAN

scale 1"=8'-0"

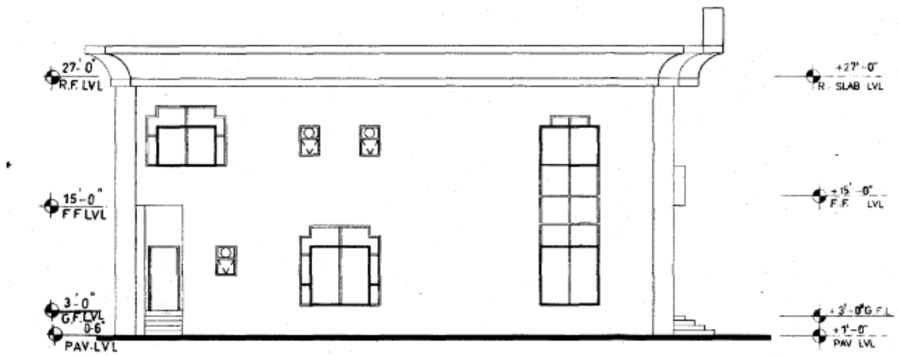


ROOF FLOOR PLAN

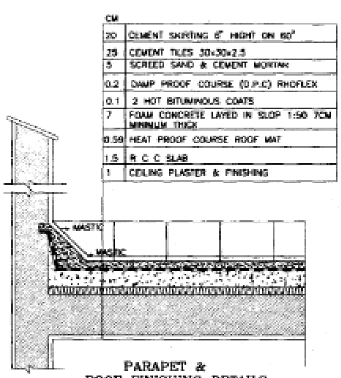
scale 1"=8'-0"



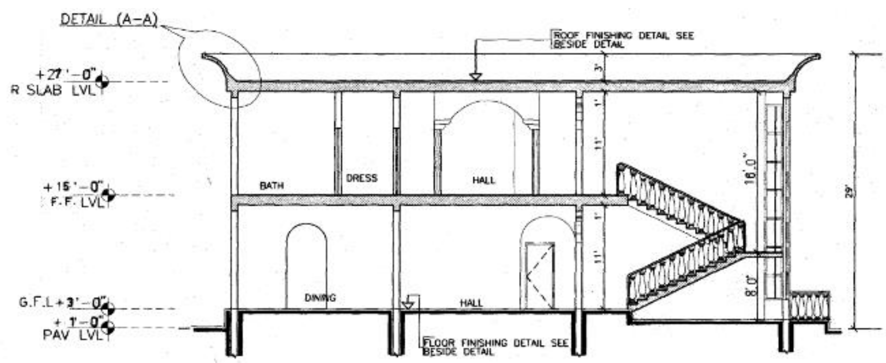
FRONT ELEVATION
SCALE:-1'=8'-0"



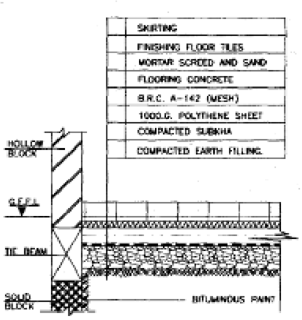
LEFT SIDE ELEVATION
SCALE:-1'=8'-0"



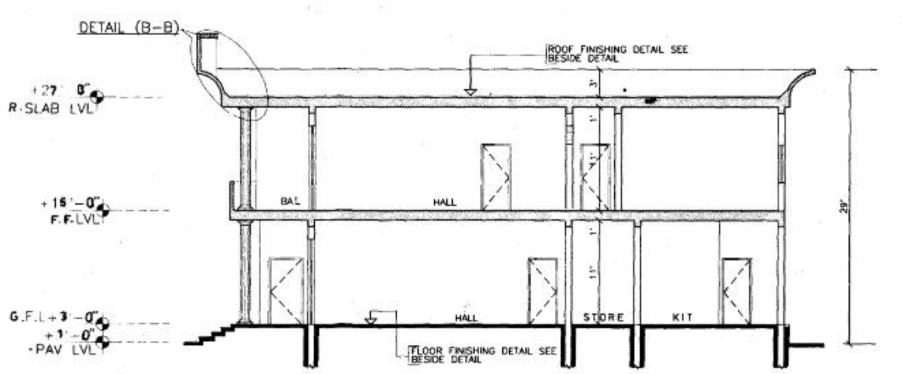
PARAPET &
ROOF FINISHING DETAILS



SECTION X-X



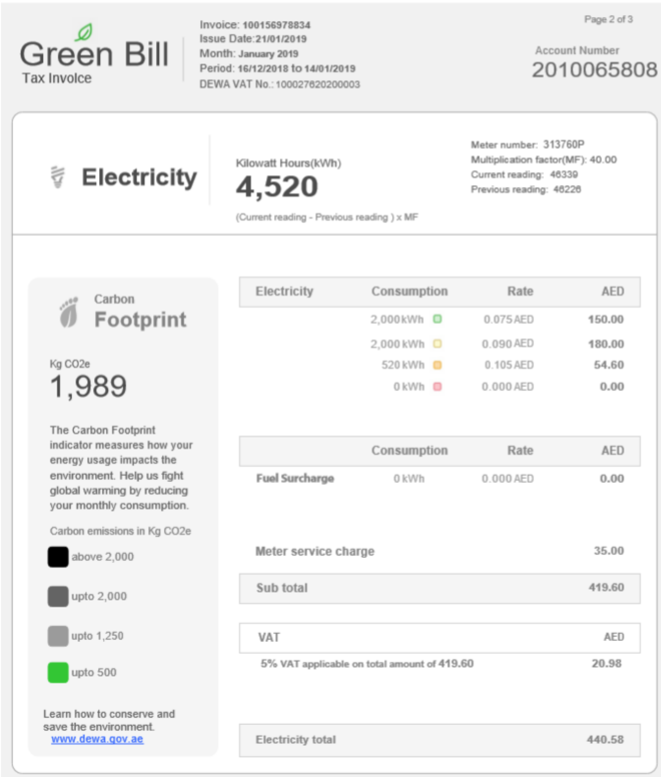
FLOOR FINISHING DETIALS



SECTION Y-Y

Appendix C

DEWA bills:



Green Bill
Tax Invoice

Invoice: 100156978834
Issue Date: 21/01/2019
Month: January 2019
Period: 16/12/2018 to 14/01/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
4,520
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 46339
Previous reading: 46226

Carbon Footprint

Kg CO2e
1,989

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
above 2,000
upto 2,000
upto 1,250
upto 500

Learn how to conserve and save the environment.
www.dewa.gov.ae

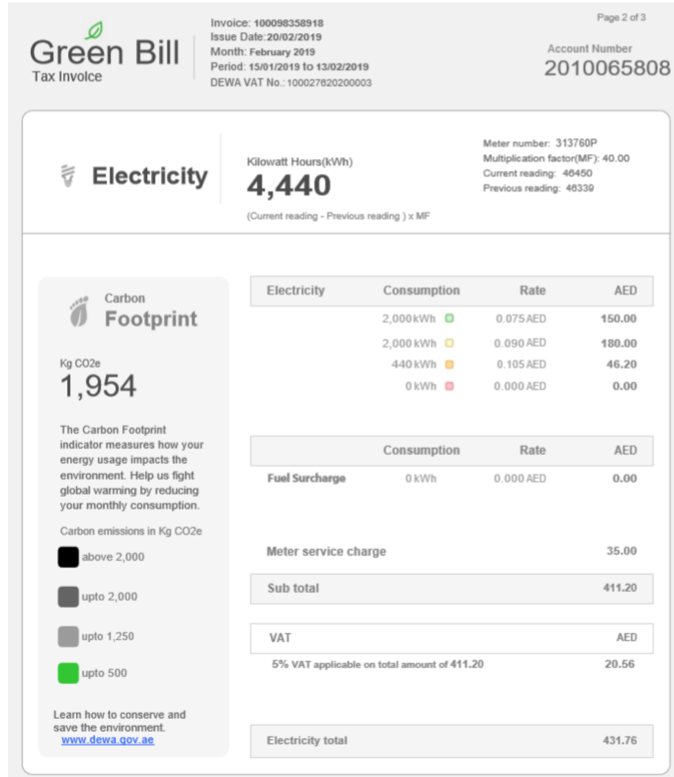
Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	520 kWh	0.105 AED	54.60
	0 kWh	0.000 AED	0.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	419.60

VAT	AED
5% VAT applicable on total amount of 419.60	20.98

Electricity total	440.58



Green Bill
Tax Invoice

Invoice: 100098358918
Issue Date: 20/02/2019
Month: February 2019
Period: 15/01/2019 to 13/02/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
4,440
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 46450
Previous reading: 46339

Carbon Footprint

Kg CO2e
1,954

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Carbon emissions in Kg CO2e
above 2,000
upto 2,000
upto 1,250
upto 500

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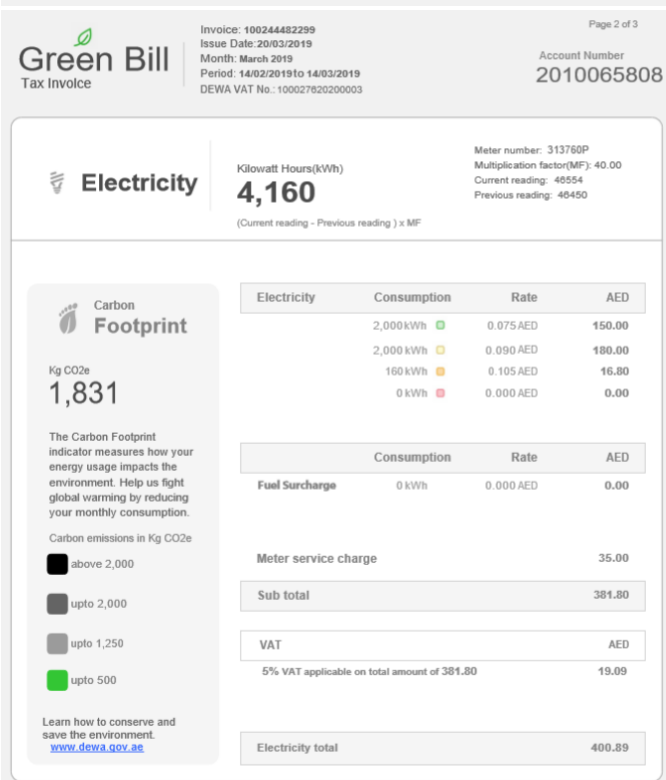
Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	440 kWh	0.105 AED	46.20
	0 kWh	0.000 AED	0.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	411.20

VAT	AED
5% VAT applicable on total amount of 411.20	20.56

Electricity total	431.76



Green Bill
Tax Invoice

Invoice: 100244482299
Issue Date: 20/03/2019
Month: March 2019
Period: 14/02/2019to 14/03/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
4,160
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 46554
Previous reading: 46450

Carbon Footprint

Kg CO2e
1,831

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
above 2,000
upto 2,000
upto 1,250
upto 500

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www.dewa.gov.ae

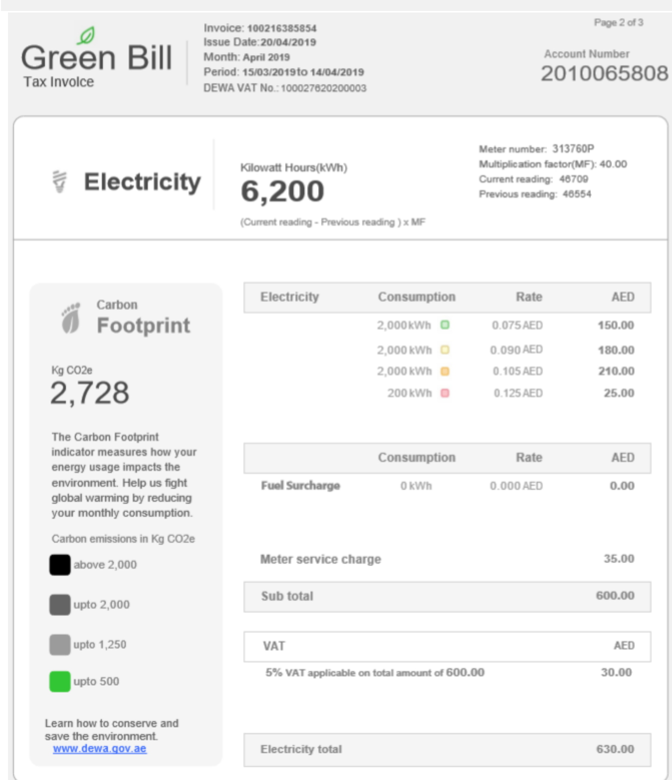
Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	160 kWh	0.105 AED	16.80
	0 kWh	0.000 AED	0.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	381.80

VAT	AED
5% VAT applicable on total amount of 381.80	19.09

Electricity total	400.89



Green Bill
Tax Invoice

Invoice: 100216385854
Issue Date: 20/04/2019
Month: April 2019
Period: 15/03/2019to 14/04/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
6,200
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 46709
Previous reading: 46554

Carbon Footprint

Kg CO2e
2,728

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
above 2,000
upto 2,000
upto 1,250
upto 500

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Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	200 kWh	0.125 AED	25.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	600.00

VAT	AED
5% VAT applicable on total amount of 600.00	30.00

Electricity total	630.00

Green Bill
Tax Invoice

Invoice: 100128110131
Issue Date: 21/05/2019
Month: May 2019
Period: 15/04/2019 to 14/05/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
7,520
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 46897
Previous reading: 46709

Carbon
Footprint

Kg CO2e
3,309

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

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Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	1,520 kWh	0.125 AED	190.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	765.00

VAT	AED
5% VAT applicable on total amount of 765.00	38.25

Electricity total	803.25

Green Bill
Tax Invoice

Invoice: 100128187864
Issue Date: 20/06/2019
Month: June 2019
Period: 15/05/2019 to 15/06/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
11,000
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 47172
Previous reading: 46897

Carbon
Footprint

Kg CO2e
4,840

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

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Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	5,000 kWh	0.125 AED	625.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	1,200.00

VAT	AED
5% VAT applicable on total amount of 1,200.00	60.00

Electricity total	1,260.00

Green Bill
Tax Invoice

Invoice: 100186809362
Issue Date: 24/07/2019
Month: July 2019
Period: 16/06/2019 to 15/07/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
13,000
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 47497
Previous reading: 47172

Carbon
Footprint

Kg CO2e
5,720

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

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Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	7,000 kWh	0.125 AED	875.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	1,450.00

VAT	AED
5% VAT applicable on total amount of 1,450.00	72.50

Electricity total	1,522.50

Green Bill
Tax Invoice

Invoice: 100128340323
Issue Date: 22/08/2019
Month: August 2019
Period: 16/07/2019 to 14/08/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
12,520
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 47810
Previous reading: 47497

Carbon
Footprint

Kg CO2e
5,509

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

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Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	6,520 kWh	0.125 AED	815.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	1,390.00

VAT	AED
5% VAT applicable on total amount of 1,390.00	69.50

Electricity total	1,459.50

Green Bill
Tax Invoice

Invoice: 100274272993
Issue Date: 19/09/2019
Month: September 2019
Period: 15/08/2019 to 14/09/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
12,880
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 48132
Previous reading: 47810

Carbon **Footprint**

Kg CO2e
5,668

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

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Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	6,880 kWh	0.125 AED	860.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	1,435.00

VAT	AED
5% VAT applicable on total amount of 1,435.00	71.75

Electricity total	1,506.75

Green Bill
Tax Invoice

Invoice: 100013880819
Issue Date: 27/10/2019
Month: October 2019
Period: 15/09/2019 to 14/10/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
11,960
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 48431
Previous reading: 48132

Carbon **Footprint**

Kg CO2e
5,263

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

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www.dewa.gov.ae

Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	5,960 kWh	0.125 AED	745.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	1,320.00

VAT	AED
5% VAT applicable on total amount of 1,320.00	66.00

Electricity total	1,386.00

Green Bill
Tax Invoice

Invoice: 100274393782
Issue Date: 20/11/2019
Month: November 2019
Period: 15/10/2019 to 13/11/2019
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
7,960
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 48630
Previous reading: 48431

Carbon **Footprint**

Kg CO2e
3,503

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

Learn how to conserve and save the environment.
www.dewa.gov.ae

Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	1,960 kWh	0.125 AED	245.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	820.00

VAT	AED
5% VAT applicable on total amount of 820.00	41.00

Electricity total	861.00

Green Bill
Tax Invoice

Invoice: 100360294449
Issue Date: 18/12/2018
Month: December 2018
Period: 15/11/2018 to 15/12/2018
DEWA VAT No.: 100027620200003

Page 2 of 3

Account Number
2010065808

Electricity

Kilowatt Hours(kWh)
6,000
(Current reading - Previous reading) x MF

Meter number: 313760P
Multiplication factor(MF): 40.00
Current reading: 46226
Previous reading: 46076

Carbon **Footprint**

Kg CO2e
2,640

The Carbon Footprint indicator measures how your energy usage impacts the environment. Help us fight global warming by reducing your monthly consumption.

Carbon emissions in Kg CO2e
- above 2,000
- upto 2,000
- upto 1,250
- upto 500

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Electricity	Consumption	Rate	AED
	2,000 kWh	0.075 AED	150.00
	2,000 kWh	0.090 AED	180.00
	2,000 kWh	0.105 AED	210.00
	0 kWh	0.000 AED	0.00

	Consumption	Rate	AED
Fuel Surcharge	0 kWh	0.000 AED	0.00

Meter service charge	35.00
Sub total	575.00

VAT	AED
5% VAT applicable on total amount of 575.00	28.75

Electricity total	603.75

Appendix D

Bill of quantity for wall insulation:

Styro ستايرو

Insulations Mat. Ind. (L.L.C.) لصناعة المواد العازلة (ذ.م.م.)

EXPANDED POLYSTYRENE SOLUTIONS

Original **SALES QUOTATION**

Document Number **64130** Document Date **13.05.20**

Document Currency : **AED** Exchange Rate : **1.0000**

Bill of Quantities

#	Description	Quantity	Unit Price	Total Excl. VAT	VAT % (AED)	VAT Amount (AED)	Total Incl. VAT (AED)
001	STYRO EIFS Supply and Apply of EIFS 10 cm Standard Impact for Full System with Textured Paint SIZE = 1200 L x 600 W x 100 T -mm Nos = 639	460.00 Sqm	160.00	73,600.00	5.00 %	3,680.00	77,280.00

- Supply & apply of STYRO GRAYPOR 180 (1200 L x 600 W x 100 T - MM)
- Supply & apply of one coat of Styrofix (Adhesive for EPS boards)
- Supply & apply of 1st coat of Styrobond DP (basecoat)
- Supply & apply of Terramesh - Standard – 160 gsm (Alkali resistant fiber glass reinforcing mesh)
- Supply & apply of 2nd coat of Styrobond DP (basecoat)
- Supply & apply of Final Superfine Finish

Price list:

AL MAHRAN ALUMINIUM & GLASS CONT.

We would like to take this opportunity to introduce ourselves to you.

Al MAHRAN Aluminum is an aluminum and glass company which specializes in manufacturing and installing of – Framed or Frameless, Shop fronts, Windows, Hinged Doors, Pivot Doors, Sliding Folding Doors, Sliding Stacking Doors, Patio Doors, Skylights and Showers. Windows, cupboards, kitchen, staircase, With over 15 years' experience, and being involved in residential and commercial projects all over **U.A.E** and abroad, we offer excellent workmanship and reliable service all the time...

As we only use quality products and with the assistance of computer software to calculate our prices we are most competitive in the market place.

All our work is in accordance with the **U.A.E** standers. We would have the greatest of pleasure in assisting you with any tender/quote or inquiry that you may have and there is no job to big or small that we will not do!

We are situated in **industrial area no # 6** and you are welcome to pay us a visit at any time.

On behalf of AL MAHRAN aluminum we thank you and look forward in satisfying all your aluminum and glass needs

Note: we will provide you to the best and discounted rates from the whole market of U.A.E

We are offering the price of doors, windows,cupboard,kitchen, glass work, through following price list.

Al gorier aluminum

Description	Price
12 cm Aluminum section.	600per meter.
10.50cm Aluminum section.	550 per meter.

Arabian aluminum.

Description	Price
12cm Aluminum section.	550 per meter.
10.5cm Aluminum section.	500 per meter.

National aluminum.

Description	Price
12cm Aluminum section.	450 per meter.
10.5cm Aluminum section.	400 per meter.

Lighting quotation:

GLOBAL LIGHT & POWER LLC

AN LED LIGHTING COMPANY

QUOTATION

Client:	Mr. Khulood Ali Albedwawi
Contact / Number:	04 206 4091
Address:	Dubai, UAE
Project & Location:	Private Villa
Quote Ref:	QOR25438
Date:	17-Jun-20

PREPARED BY

Karim Ali
Global Light & Power LLC
PO Box 72641
Al Quoz Industrial 1, Street 11B, Warehouse 004
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SECTION 1: LED LIGHTING FIXTURES

GLP Image	Series Name	New Model Number	Description	Function	Qty	Unit Discounted Rate	Total Price
	LANA - DL110247	110247-DLY022 + 770081-CC0280 (2pcs)	22W (11W per head) / 180-250VAC 50/60Hz Double head recessed adjustable down light LED chip: Cree COB Color Temperature: 3000K Glass: Clear Fixture Material: Die-cast aluminum Fixture Finish: Powder-coated White Beam angle: 36° per side IP Rating: 20 Supplied with standard phase dimmable driver	**22W RECESSED ADJUSTABLE DOUBLE HEAD DOWN LIGHT**	35	AED 480.00	AED 16,800.00
	LANA - DL110429	110434-DLY011 + 770081-CC0280	11W / 180-250VAC 50/60Hz Round Recessed down light LED chip: Cree COB Color Temperature: 3000K Reflector: Anti-glare optical Fixture Material: Die-cast aluminum Fixture Finish: Powder-coated White Beam angle: 36° IP Rating: 20 Supplied with standard phase dimmable driver	**11W RECESSED DOWN LIGHT**	8	AED 111.00	AED 888.00
	LANA - DL110334	110334-DLY013	13W / 180-250VAC 50/60Hz Recessed Downlight LED chip: Cree COB Color Temperature: 3000K Glass: Clear Reflector: Polycarbonate with aluminum coating Fixture Material: Die-cast aluminum Fixture Finish: Powder-coated White Beam angle: 36° IP Rating: 65 Supplied with non-dimmable driver.	**13W RECESSED DOWN LIGHT**	7	AED 105.00	AED 735.00
	SANA - DL110385	110385-DLY012	12W / 180-250VAC 50/60Hz Surface mounted down light with built-in non-dimmable driver. LED chip: CREE Color Temperature: 3000K Diffuser: Opal polycarbonate Fixture Material: Polycarbonate Fixture Finish: Powder-coated white Beam angle: 120° IP Rating: 54	**12W SURFACE MOUNTED DOWN LIGHT**	6	AED 123.00	AED 738.00
	SANA - DL110401	110401-DLY015	15W / 180-250VAC 50/60Hz Surface mounted light with built-in non-dimmable driver. LED chip: Cree COB Color Temperature: 3000K Reflector: Polycarbonate with aluminum coating Fixture Material: Die-cast aluminum Fixture Finish: Powder-coated white Beam angle: 60° IP Rating: 54	**15W SURFACE MOUNTED DOWN LIGHT**	5	AED 149.25	AED 746.25
	NANNA - WL220202	220202-WLY006	6W / 180-250VAC 50/60Hz Up and Down Wall Sconce LED chip: CREE Color Temperature: 3000K Glass: Clear Fixture Material: Die-cast Aluminum Fixture Finish: Powder-coated Bronze Beam angle: 90° IP Rating: 65	**6W UP&DOWN WALL SCONCE**	7	AED 157.50	AED 1,102.50