Methodologies of Achieving Energy-Plus Building through Deep Investigation in The Building Energy Performance: Case Study of Existing Multipurpose Building in Dubai, UAE

منهجيات تحقيق مبنى إيجابي الطاقة من خلال دراسة معمقة لأداء طاقة المبنى: حالة دراسية لمبنى متعدد الأغراض في دبي، الإمارات العربية المتحدة

by

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Dissertation submitted in fulfilment

of the requirements for the degree of

MSc SUSTAINABLE DESIGN OF THE BUILT ENVIRONMENT

at

The British University in Dubai

November 2021

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Abstract

The inevitable relation between population and energy demand is deriving the humanity for thinking about safe sources to cover their energy needs especially after the global warming raised during the last decades resulted from the reliance on depleting the fossil fuel. Numerous number of initiatives along with promising solutions have been observed for reduction energy consumption and find alternative clean energy. Energy-Plus Building as one of the latest trends in the sustainable transformation and based on shifting the building from energy consumer to producer with extra energy yield during specific period was investigated with exploring the potentials and obstacles of applying the same in UAE.

A multipurpose building in UAE was the chosen case study where the best methodology applied through IES-VE software simulation, starting from enhancing building envelops materials mainly on the roof to reach the desired U-Value. Moving forward for exploring the best PV orientation, inclination and type which is south, 25° and monocrystalline respectively, the required PV panels that can cover the beak day demand proposed on the roof and parking area. The excessive produced energy and utility bills savings contributes in reducing the payback period for the transformation process to less than five years.

نبذة مختصرة

العلاقة الوثيقة بين التعداد السكاني والطلب على الطاقة تدفع الانسانية للتفكير أكثر بمصادر آمنة لتغطية احتياجاتهم خاصة بعد مشكلة الاحتباس الحراري التي ظهرت وأثرت خلال العقود الماضية على مناخ الأرض وسببها الاعتماد على الوقود الأحفوري كمصدر للطاقة. العديد من المبادرات والحلول الواعدة تظهر باستمرار لمواكبة الدعوات بتخفيف استخدام الطاقة وايجاد حلول اقل ضررا على البيئة. فكرة المباني ايجابية الطاقة تعتبر واحدة من أكثر الأفكار المستدامة حداثة والتي تعتمد على تحول المبنى من مستهلك إلى منتج للطاقة وذلك عند حساب المحصلة النهائية لفترة زمية معينة حيث تم في هذا البحث استكشاف الإمكانيات والعقبات وراء تطبيق مثل هذا النموذج في دولة الإمارات العربية المتحدة.

بالاستعانة بمبنى متعدد الأغراض كحالة دراسية، تم دراسة وتطبيق الوسيلة البحثية المختارة والمعتمدة على المحاكاة في جهاز الحاسوب بدءاً من تحسين الغلاف الخارجي للمبنى وخاصة المواد المستخدمة لعزل السقف من أجل تحقيق نسبة العزل الأمثل ووصولا إلى تدعيم المبنى بأفضل وسيلة من الخلايا الشمسية على مستوى التوجيه والميلان والنوعية حيث تم اعتماد الجهة الجنوبية وميلان خمس وعشرين درجة لذلك. تم بعد ذلك حساب الكمية اللازمة من الخلايا الشمسية من خلال التأكد أن ما سيتم توفيره سيتكفل بتغطية احتياجات المبنى في أكثر يوم استهلاك على مدار العام وذلك باستغلال منطقة السطح والمواقف، بينما تمت دراسة الجدوى لعملية التحول وأظهرت النتائج أن فترة استعادة المصروفات لا تتعدى الخمس سنوات.

Dedication

I dedicate my dissertation to my blessed family, my parents Adnan and Maryam, my beloved and supportive wife Rawan, my kids Yahya and Yousef, my brothers and sister Abdulqader, Mutasem, Hadil and Mohammed, finally my friends who wish me the success and prosperity.

Acknowledgement

Foremost, I want to be thankful for the Almighty God for giving me the capability to complete this dissertation.

I would like to start with expressing my sincere gratitude to my supervisor Dr. Wael Sheta for the continuous support of my dissertation study and research, for his patience, motivation, enthusiasm, and immense knowledge. Besides my supervisor, I would like to thank the rest of BUID committee mainly Prof. Bassam Abu Hijleh and Prof. Hanan Taleb for their encouragement and for making this journey of master's study more professional and desirable.

Special thanks for my beloved family who believed in me especially my patient wife Rawan who was the supportive person by giving me the strength and time to handle this work properly.

Last but not the least; I would like to thank my colleges and friends Rami, Anas and Laith along with all the staff of the British University in Dubai for their help and support. You have all helped me to focus on what has been a hugely worthwhile and enriching process.

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Abbreviations

AED	Arab Emirates Dirhams
BOH	Back of House
DHGC	Dubai Hills Golf Club
EB	Energy Balance
EPB	Energy Plus Buildings
EU	European Union
FIT	Feed in Tariff
FOH	Front of House
GHGE	Greenhouse Gas Emissions
HVAC	Heating Ventilation and Air Conditioning
IES-VE	Integrated Environmental Solutions – Virtual Environment
MEP	Mechanical, Electrical and Plumping
NZEB	Nearly/ Net Zero Energy Building
PBP	Payback Period
PCM	Phase Change Materials
PV	Photo Voltaic
RE	Renewable Energy
RH	Relative Humidity
TLC	Total Levelized Cost
USA	United State of America
U-Value	Thermal Transmission

Chapter One

Introduction

1. Introduction

Previous two decades witnessed many studies to understand and reduce the building effects on the climate crises represented by the carbon emissions and greenhouse effect. From this point of view, studies took several sides and solutions in consideration, starting from building orientation, external materials, double skin, louvers and many others relying on various methodologies that can measure the energy improvement to reach the required comfort level within the minimum cumulative energy between the used and the produced one.

However, the previous approaches considered to be more comprehensive and relying on general approaches connected either to envelope materials and design or to geometry shape and orientation followed by exploring the results of the achieved improvements. On the other hand, energy balance criteria was not considered deeply despite it is the key for understanding and achieving the maximum energy saving system during the building initiation and operation process.

Reference to Dubai, producing extra energy is not recommended since up to now the compensation system is not activated. Accordingly, part of the study will figure conceptually the possibilities and potentials of going through energy plus criteria in Dubai taking in consideration the climate and resources available. In parallel, there will be deep study of the current used strategies related to the same topic and what is the people reaction to similar challenges in addition to study current examples and future proposals all around the world.

1.1 Overview

Global warming resulted from the climate change considered to be the top world’s priory that required to be solved in the current century, the increasing gasses trapped in the atmosphere are directly increasing the overall temperature which is leading to more natural disasters threatening the humans life (Zhang, Wang & Wang 2017).

The past decade observed several initiatives for reducing building energy consumption either by setting strict regulations for the new building efficiency or improving the existing building performance where an obvious weightage of energy consumption is being spent. Considering Dubai where the case study of commercial building will be studied, the research will investigate in the current and future sustainable visions and check how the same is complying with the case study materials and systems. The same will be conducted in order to set several strategies and scenarios that will insure improving the building efficiency and reduce the energy consumption so that it can reach to a level of net plus energy.

Since more than fifteen years United Arab Emirates showed through Emirates Green Building Council (EmiratesGBC) serious need for going towards the global green building initiatives, the same was pushed with high level of building energy consumption that reach up to eighty percentage of total country electricity consumption. This vital step is requiring all parties involvement especially in the construction sector where full commitment will insure the success (Fayyad & John 2017).

According to (Fayyad & John 2020) and reference to Dubai Supreme Council of Energy, one fourth of the existing buildings in Dubai is considered as feeble and have high possibilities for considerable energy saving once being retrofitted, the improvement could save up to one third of the total energy consumption. By adopting the same concept, special studies and codes emerged in UAE in the last decade for controlling the process of construction to insure the proper energy efficiency for new buildings such as Estidama Pearl Rating System in Abu Dhabi and Al Sa’fat rating system in Dubai.

Furthermore, additional initiatives emerged showing the feasibility of retrofit through financial approaches, the same encourages the stakeholders who are the key persons and focal point in the process (Di et al. 2017), especially with warranties of achieving up to fifty-percentages reduction in the energy consumption mainly for the low efficient buildings, Noting that this achievement is not considering yet the introduction of renewable energy to the site. Keeping in mind that payback period is not exceeding ten years to insure the consideration of being a successful investment. Governmental involvement is playing vital role in succeeding the retrofit process through the retrofit construction or the operational stage with offering incentives that could reduce or participate in the initial cost through either the green loans or supportive utility pills.

Dubai recently initiated specialized association called Etihad Energy Services focusing on utilizing the energy performance criteria for over thirty thousand buildings, the same is expected to achieve by end of this decade about 1.7 TWh energy preserving (Krarti & Dubey 2018), keeping in mind that retrofit plans is including the enhancement of envelope thermal insulation which has approved its responsibility for saving up to thirty percentages of energy consumption.

The continues growth in the population resulted in the yearly expanded business in Dubai which is affecting directly on the energy consumption as clear in Fig. (1), however more reliance is being noticed on the renewable energy specially the one produced at Mohammed Bin Rashid Al Maktoum Solar Park.

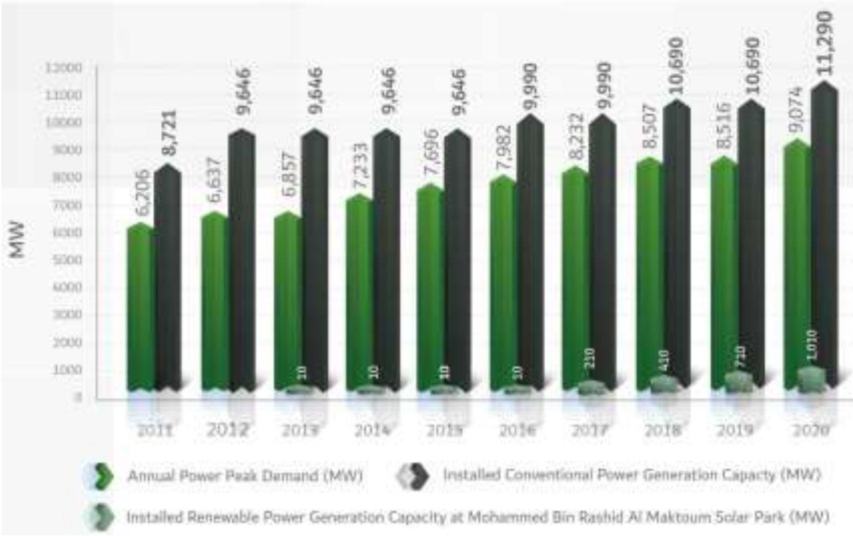
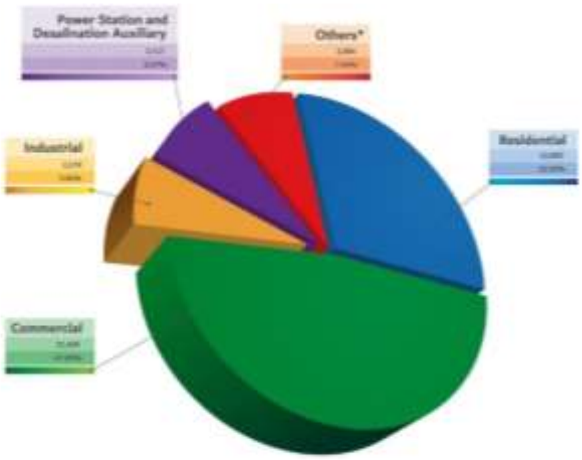


Figure 1 Annual Power Demand and Generation in Dubai (DEWA 2020)

On the other hand, the consumption distribution should be taken in consideration for the future proposed barriers since more than eighty percentages of energy consumption is directed to the residential and commercial sectors as clear in Fig. (2), this issue is derived by the country economy direction through relying on the properties and tourism investment which is requiring high energy demand to fulfill the arid climate and high temperature, accordingly considerable amount of energy is being consumed for the cooling system that reaching up to eighty percentages of the building electricity consumption (Krarti & Dubey 2018).

Figure 2 Electrical Consumption Distribution in Dubai (DEWA 2020)



1.2 Building Energy Performance

Building contribution in energy consumption is reaching up to forty percentages while the global ambition is to reduce the carbon dioxide by eighty percentages by the year two thousand and fifty. Many trends and initiatives have been tested and got promising results such as nearly or net zero energy buildings (NZEB) either for retrofitting the existing buildings or follow the new green guidelines initiated by the relevant authorities (Passer et al. 2016).

Theoretically, NZEB describes buildings with the ability to contribute in part of the building required operational energy from a renewable resource (Yu et al. 2019). NZEB is considered the first step in enhancing building effects on the environment, the same is considered a self-benefit process limited to a concerned building, one of the raised issues against this process is the lake of potentials for some buildings to reach energy efficiency reference to each building criteria. From this point of view, new trend is being raised regarding increasing the building generated energy to be as an energy plus building (EPB) so that it can fulfill other buildings energy requirements.

Day by day, emerging researches is proofing that energy plus buildings (EPB) will be the most desired direction by the providers and end-users (Gustafsson et al. 2019), this will require many features to work with and be improved together in order to reach the optimum energy level for the building. Maximizing solar energy engagement, improving heating and cooling devices with respect to the balanced ventilation of temperature recovery, and finally improving building envelope so that improvement will be considered architecturally and economically wise.

In general, the building is considered as an EPB once the produced energy received from the renewable resources during one year exceeds the energy consumptions required for operating the building (Firlag 2019) and in such a case, the possibility of passing the extra produced electricity to the grid will play fundamental role in succeeding the whole process. Keeping in mind and reference to (Melgar, Bohórquez & Márquez 2018) the high efficiency of the building is mandatory to reach plus energy level and the same should by executed under two base roles represented in reducing the consumed energy and retrofit cost to the lowest possible level.

EPB is describing buildings that have cumulative positive energy once subtracting the produced energy from the consumed one, thus, new phrase called Energy Balance (EB) came up expertizing surplus energy introduced by variant renewable resources and exceeds the building operational needs (Kim et al. 2019). Chastas et al. (2018) advising that for achieving positive EB, a high consideration should be given to the envelope insulation and internal air-tightness, this off course accompanied with utilizing the maximum RE available in the site.

1.3 Passive and Active Design

Enhancing the building energy efficiency is relying on two main directions that fulfill each other to reach the optimum results. Starting from the passive direction which concentrates on building major components represented in the envelope including external walls and roof, considering the passive retrofit direction is more essential reference to its position as the barrier between the building environment and external climate which show why it is recommended by the most of the green building regulations and sustainability guidelines (Jafari & Poshtiri 2017). On the other hand, some limitations can be presented once relying on the passive solutions since it is affected directly by external climate conditions and timely wise during day or year such as natural lighting and ventilation (Chen, Yang & Wang 2017).

(Krarti & Dubey 2018) assuming that proper materials used for building envelope could save up to one fifth of the cooling energy required in the hot climates while in public buildings ten percentage of the lighting electricity could be saved once using lighting sensors, in addition to that special dimming system can reduce the consumption up to one fourth.

Active design as the complementary in the building renovation is directed principally in perfecting the building systems such as but not limited to internal temperature and light in addition to air quality and circulation, noting that any active process done inside the building must unfortunately be derived through energy consumption which is desired to be reduced (Sun, Gou & Lau 2018). Accordingly, passive design improvement is more and highly recommended to reduce the dependence on the active solution and finally reduce the energy consumption.

1.4 Renewable Energy and UAE Consumption Profiles

The concept of going towards the renewable energy (RE) was to find clean resources that reduce the effect on environment since burning the fossil fuel has proved its serious and direct impact in creating the greenhouse effect. Furthermore, RE is helping in transferring the countries to a static energy security position without being under external control or undesirable interventions. Furthermore, it could empower the national economy by transforming the situation from importing energy to be a self-sufficiency or even exceed that by exporting clean energy to neighbors (Malik et al. 2019)

Encouraging results are being raised during the last decade reference to (IRENA 2020) when the comparison set between the current and upcoming future level of renewable energy efficiency from one direction and relying on fossil fuel with its inefficient and highly cost process of capturing and storing the carbon dioxide from another direction. Around two hundred and sixty gigawatts were produced relying on renewable energy which is covering around eighty percentage of the total electricity used around the world reaching double amount produced in 2019 (IRENA 2021).

Starting approximately from the middle of last century UAE as part of the gulf countries witnessed rabid construction revolution derived by the petroleum discovery, the same was accompanied with decreasing the price of provided energy to encourage the growth of economy under high level of living standards, this unfortunately led to categorize the country as one of the highest energy consumption in world per capita (Krarti & Dubey 2018).

The alarming categorization encouraged UAE starting from last decade to go deeply for renewable solutions (Said, Alshehhi & Mehmood 2018b). Figure (3) illustrates UAE potential reliance on the RE by reaching up to two third of the total energy production in year two thousand eighteen showing considerable increase from the previous year by nineteen percentages and the same was replacing the charcoal usage.

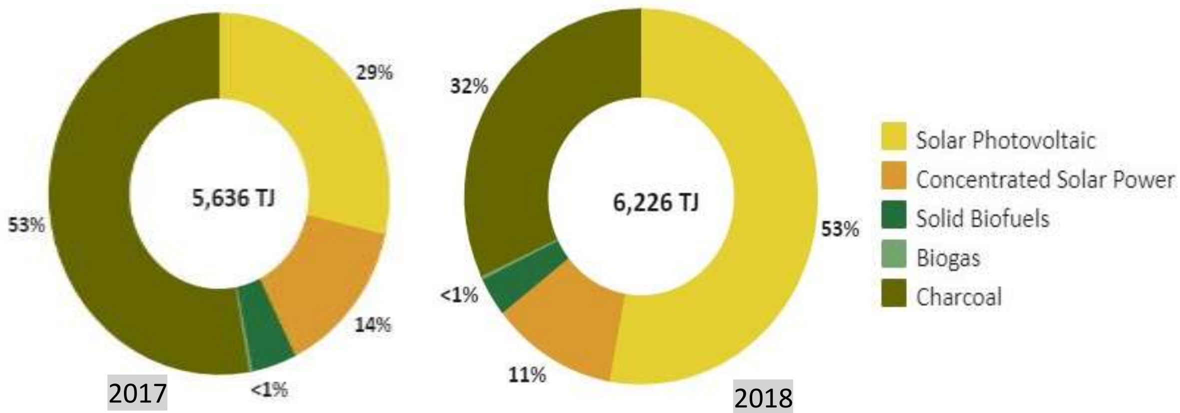


Figure 3 Energy Generation Resources in UAE (IRENA 2021)

1.5 Motivation of the work

UAE is now deeply acquainted about benefits of reducing the energy consumption alongside with its effects on reducing gas emissions. Moreover, many motivations are being released in the seek of transformation to sustainable community, one of the promising visions is reaching to energy plus buildings and communities. In parallel to this crucial step and to insure the success of such a transition, convenient agenda must be established including all sides starting from the targeting level to be reached in addition to the best used approaches and scenarios as well as investigating the constraints and future limitations that could face the procedure as cost wise, political, community acceptance, available resources and others.

Numerous studies had been settled proofing the possibilities of enhancing the building energy efficiency to reach the NZEB and EPB around the world with different limitations and resources related to the climate, geographical location, available materials and resources, governmental subsidies and investments. Obvious lack of information and samples presented when the research related to the status of EPB in UAE and the same will be the base of work motivation. The paper will deeply figure the status of an existing commercial building and overview the used systems, materials and energy performance to find the best environmental and sustainable solutions for transition towards EPB. The paper will explore several methodologies with analysing the potentials and limitations for each methodology to figure the best direction that can utilize building and site available resources to increase the energy efficiency. Moreover, new trends and materials will be tested and applied in several scenarios such as Photo Voltaic (PV) sells with the most and maximum appropriate locations in the targeted site as well as figuring best ways of utilizing and distributing the surplus electricity produced specially that selling the electricity to grid is not activated yet in UAE.

Through the literature review, investigation for the current status and future visions of EPB including the energy balance criteria and its participations in building efficiency, in addition to analysing the passive and active strategies used in buildings either for the new construction or for retrofitting stage. The study will concentrate on a five years old commercial building constructed in UAE using real consumption monthly bills and materials used in the construction in addition to operation systems used as a part of the analysis inputs for the selected research methodology and the same will be considered as the base case. With the figured results, the enhancement direction will be clear and multiple scenarios to be applied including slight and major modifications under controlled cost plan and specific local and international sustainable guidelines.

The final outputs including the best scenarios will lead to appropriate recommendations that can be used in country vision of reaching the clean energy plan by mid of this century as well as contributing in initiating the guidelines that is being issued by the relevant authority and followed by the market stakeholders until reaching to variant categories of end-users.

1.6 Aims and Objectives

The paper is handling main and primary objectives, concentrating on figuring the potentials and limitations of transferring an existing commercial building to achieve best possible energy efficiency and to check the possibility of producing clean energy that exceeds the building consumption so that it can be considered as EPB, the same will be conducted under specific limitations and standards such as cost, available resources and materials as well as surrounding environmental and social aspects. However, the research will adopt below directions and objectives:

- Overviewing the status of the selected building from energy consumptions, materials and systems used in order to validate point before proceeding with the enhancement.
- Exploring the current sustainable and green building regulations available in the UAE, in addition to study the international most trending procedures.
- Check the best direction of introducing passive and active techniques to achieve the optimum results, in addition to figuring the pros and cons of using passive and active strategies.
- Investigating the most recent techniques used for collecting and storing the RE and check its capability once used in UAE.
- Analyzing the results of building energy in the current situation and after enhancement.

1.7 Research Outlines

The dissertation is divided to six main chapters, and below general summary for what each chapter includes.

Chapter one includes overview on the country energy profiles and future prospects in addition to defining the EPB and its applications in addition to research work motivation as well as the research outline.

The second chapter will include deep study of energy balance criteria and its principles in addition to analyzing the EPB parameters and strategies, moving to exploring the potentials of retrofitting existing buildings with studying the passive and active directions that can achieve the required target. Finally, the chapter will present UAE energy profiles including the consumption and supply before discussing the research gab and problem statement.

Moving to the third chapter, which is including the common methodologies used worldwide to investigate the EPB and the same will included at least four methodologies with exploring each one advantages and disadvantages in order to reach to best direction that suits the research topic and prospects.

Chapter four will take the case study in consideration with its base and current information and actual results as recorded through meters and authority bills, the same will be validated by applying the selected methodology and make the proper comparison to verify its credibility. Moreover, the building environmental tools will be presented including the surrounding temperature, day lighting levels, humidity and wind speed. All of the previous aspects will help in recognising the study profiles including the daily, weekly, monthly and yearly durations.

Chapter five concentrates on applying several scenarios that increase the building efficiency through choosing several types of available RE tools and thermal insulation materials specially for the building envelope in addition to figure the best ways of utilizing the surplus energy in the building site.

The final chapter will conclude the results obtained in the previous chapter with the final recommendation and answers for the dissertation questions on who to make the proper transfer to EPB and the potential benefits on the environment and community.

Chapter Two

Literature Review

2. Literature Review

2.1 Overview and Problem Statement

Starting from nineteen seventies, the world was shocked with two oil crises that awakened the governments and decision makers to start thinking in alternatives for energy resources that must be cheaper, safe and durable. In Paris agreement held in middle of last decade, recognized initiatives was observed calling for mitigating the carbon dioxide emissions in order to maintain the global rise temperature beneath two Celsius centigrade (Malik et al. 2019). Following that, numerous guidelines related to widening the reliance on RE and increasing the building efficiency have been established, besides that, change is reaching individual awareness and social conduct (Antonakakis, Chatziantoniou & Filis 2017).

UAE is considered one of the five most energy consumers per capita worldwide (Salameh et al. 2020), this was derived mainly where more than one third of buildings energy consumption used for cooling purposes. This in fact encourages most of the enhancement plans to spend efforts for understanding the criteria and potential solutions to reduce buildings cooling demand either through better insulation procedures or more efficient cooling systems or any other way that can achieve better energy targets.

Considerable studies discussed in a literature way the concept of NZEB and EPB, but limited researchers were relying their concentration on the weighting aspects of balance energy forecasting. In addition to that, commercial building is taking minor attention once compared with the residential buildings (Bandeiras et al. 2020). Finally, there is no clear and straightforward classification for the differences between NZEP and EPB specially that both of them are referring to the same concept for contributing RE in the building energy performance.

Once relying on the utility as the only energy provider, there is a huge amount of energy losses once comparing the required energy to be produced in order to deliver specific amount to end user, the same can be proportional as one to three; means the combustion device must burn three units of energy to provide one unit of net energy to the final consumer (Bandeiras et al. 2020), for sure this percentage will be decreased once depending on the RE but still there will be losses for the storing and transferring procedures.

2.2 NZEB and EPB

Previous researches demonstrated in variable methodologies the definitions, procedures, and applications of increasing building efficiency and introducing the RE within the operational procedures, NZEB showed more demonstration than EPB which was limited generally on literature review.

2.2.1 NZEB Definition

(Reda & Fatima 2019) claims that NZEB reference to the European Union (EU) relies on surrounding climate and operational situation, while defined as high energy performance building that can be operated passively with nearly zero or little energy that can be introduced from RE. While according to (Ala-juusela et al. 2021), United States of America (USA) defines it as an efficient building where the onsite produced energy covers or barely exceeds the consumed amount. Shirinbakhsh & Harvey (2021) explored four main approaches of defining the NZEB including the zero site energy, net zero sources, cost of energy and finally the zero emissions approach. Another definition proposed by (Wells, Rismanchi & Aye 2018) relying on equality criteria between main components such as the energy generation and usage, energy cost and greenhouse gas emissions (GHGE) and finally decreasing building demand of energy.

2.2.2 EPB Definition

Many studies explored the procedures to achieve the EPB, (Rehman et al. 2019) tested the possibilities of transferring the community towered positive status after combining the produced energy from the available wind and solar radiation in addition to district heating scheme in order to minimize the cost of required electricity within the plot boundary. Sougkakis et al. (2020) invistigated in larg basis the transistion towards energy plus status by relying on smart sharing system between grid and enedusers, where the grid will act as smart storage system and provider while enduseres will act as the provider and consumer in the same time. On the other hand, (Giourka et al. 2019) tested in economically wise the payback period (PBP) for the EPB transition presented in the percentages between the investment consumed for providing the energy and the annual difference in the energy cost after and before the transition, where investment will be appropriate if the PBP covered within twenty years. While (Ala-juusela et al. 2021) believes that positive energy buildings can cover the building and adjacent community with clean energy.

2.2.3 Differences and Intersections between NZEB and EPB

From the previous definitions, (Andreas Jaeger 2020) believes that both directions are almost identical in the technologies used but with different contribution level of introduced RE, in addition to that, NZEB do not take in account the extra energy and storage criteria while the same are considered as major tools for EPB. Both options show resilient solutions once dealing with grid energy failure specially in the presence time of RE (Shirinbakhsh & Harvey 2021). Considering the insulation level, local authorities regulation will be sufficient regarding building envelope specifications once dealing with NZEB, while EPB reference to (Sougkakis et al. 2020) have fundamental attention on decreasing the transmittance factor as clear in Tables (1 and 2).

Table 1 NZEB Transmittance Factor (Sougkakis et al. 2020)

Building Element	U-Value (W/m^2K)
Walls	0.35
Roof	0.30
Floor	0.65
Windows	1.20

Table 2 EPB Transmittance Factor (Sougkakis et al. 2020)

U-Value (W/m^2K)	
Walls	0.30
Roof	0.25
Floor	0.55
Windows	0.80

2.3 Energy Performance and Balance Criteria

Because of ordinances raised upon the need of reducing the building energy consumption, the buildings are preferred to be tested together as a whole entity including the construction elements and building services, this complexity in the study requirements brief more consistency in the building efficiency parameters. Thermal insulation as an example used to be identified by the heat losses registered within the building envelope including the walls, roof, flooring and glass openings. Substantially, the process is not covering the actual losses reference to the absence of providing energy elements taking place in creating, storing and transferring energy to the desired space. Such an approach of visualising the eventual energy balance will provide a holistically approach of modelling and comparing energy used in the operation phase.

Reference to (Marino et al. 2019), energy balance (EB) is presented in monthly wise by comparing the balance between imported and exported energy from one side and the required load to be produced from another side. From another point of view, weighting factors must be addressed properly in order to understand the energy performance of the building and reaching to clear EB figures (Bandeiras et al. 2020) while according to (Hall & Geissler 2017) the energy balance is relying on three factors represented in time and the proper grid cooperation in addition to the fundamental weighting factors.

One of the visible incentives that could encourage users for transferring to EPB is the net-metering system, the same is monitoring the imported and exported energy so the variable financial report will affect positively on users' behaviour regarding the consumption and saving choices. On the other hand, utilities are benefiting from their side once relying on the metering process by getting rid of providing, installing and monitoring the renewable devices, in addition to reducing the cost of transferring energy which will for sure increase the energy efficiency (Bandeiras et al. 2020).

2.4 Principles of Energy Performance and Balance

Energy balance is analyzed through special computerized programs in order to identify the deference between the input and output energy within the building boundary, also as common exercise the calculated energy demand is usually deviate from the actual consumption and the same is related to many indirect factors such as human behavior.

2.4.1 Balance Scope

Relation between energy demand and supply should have specific consideration, according to (Synnefa et al. 2017), building efficiency should presents energy consumption levels not exceeding twenty kilowatt per square meter yearly, in parallel, RE should produce more than this level to achieve the balance. In advance RE instruments should be applicable to produce around fifty kilowatt hour yearly per square meter. From scientific approach, energy is not lost, it is changing from shape to another reference to the nature of usage and place. Accordingly, the amount of loss is affecting the demand required to keep place in a comfortable situation either through heating or cooling, noting that cumulative energy within the space is not mandatory to be in negative situation specially once passive energy tools support in getting energy from natural resources such as heating achieved from sun light once enter the space through glazing envelope.

The energy balance scope is depending on three main consumption factors taking place within the building. Starting from the operational systems required to provide sufficient and comfortable levels for occupants including lighting, temperature and air quality. The second factor related to the complimentary life style tools such as home appliances in addition to the daily activities, this factor is relying directly on the users' behavior and tools efficiency. The final factor related to the life cycle of systems and materials used for the building since the efficiency and aging is inversed proportionality.

2.4.2 Balance Nature

The balance direction, from scientific point of view, is consistently go adverse the direction of energy, the calculation of the required interior benefited energy within the space since it is relying on two main factors, the first is the envelope quality while the second is the volume of internal space (Manrique Delgado et al. 2018). Noting that the lost energy within the envelope transmission presented by subtracting the total energy supplied to the building from available heat energy within the space, this indeed is leading to more understanding of balancing methods. As a summery, building during the energy and materials consumption is creating emissions that can directly affect the environment, understanding these activities will give more understanding of the total emissions and finally the procedure for limiting the same.

2.4.3 Balance Boundaries

As a common exercise, the balance boundary must be identified by a dimensional limit of the site in order to be more obvious and comparable once settled for study, accordingly, plot limit usually considered the boundaries for the building EB (Bandeiras et al. 2020). Cumulative energy within the plot limit to be considered including all shapes of energy performance for creation, transferring or distribution. Another shape of boundary should be considered related to the cost limits and total levlized cost (TLC) assuming that such a process categorized in the enhancement process which shall include the commercial side along with the environmental prospects. Keeping in mind that initiatives shall include encouraging proofed programs that can attracts investors and decision makers to embrace the idea and even improve it as well as influence others for taking the same action.

The final and most vital shape of boundaries taking about embodied energy for the whole process in case of retrofitting or new building, the idea of reducing the gas emissions must not be limited to the operation stage but also considering all activities involved prior to project completion. For sure it will not be plus or even net zero energy process, but the same can be estimated for how many years of saving carbon dioxide payback to considered as successful environmental investment; same as commercial investment study (Chastas et al. 2018).

2.4.4 Balance Interval

The energy performance is preferred to be controlled within proper time limit; this will make the energy balance system comparison applicable since the energy demand will rely on weather factors that are affected by the seasonal environment variations. The common time interval is set to be in yearly basis, such a consideration is affecting the credibility of energy balance since both energy demand and supply are affected with seasonal factors. Accordingly, reducing the interval duration will increase the efficiency of EB outcomes (Antonov, Heiselberg & Pomianowski 2021). Increasing the number of intervals within the year such seasonally or monthly can lead to more understanding of energy performance no matter of the geographical location of the building. In hot climate like UAE, the energy demand is similarly related with the available renewable solar energy, while in cold climates the relation is conversable.

2.4.5 Balance Regulations

By understanding the previous balancing criteria, energy performance can be tested under specific methods credited by authorized parties who took inconsideration all the surrounding factors and potentials, then information can be involved through agreed process such as formulas, charts or simulation in order to get the desired outcomes that will be followed for enhance the energy performance.

2.5 Energy Plus Buildings

The building can be categorized as EPB once the efficiency performance is conveniently in high level including reasonable usage of energy, accepted commercial procedure and human behavior factor is presented in a comprehensive way, such a way is guaranteeing the positive level of energy balance with pleasured level of thermal comfort and assured cost saving situation (Marino et al. 2019). Moreover, smart solutions are mandatory for transferring the building to be an EPB by using the proper passive and active automation systems including sensors that are calibrating precisely the thermal and visual situation, while the same is connected to controllers that can decide through algorithmic procedures and guidelines to activate building operation systems through actuators.

The continues increasing of fossil fuel cost is one of the encouraging reasons for transferring towards EPB (AbuGrain & Alibaba 2017), so the EPB aim can be phrased in reducing or even eliminating the reliance on non-renewable energy (Bandeiras et al. 2020). Noting that imported energy delivered to the site can be from renewable and non-renewable resources unlike the exported one which come from renewable resources and the same is directly proportional with balance area within the building plot boundary after subtracting building footprint as clear in Fig. (4), from the point view of emissions reduction in EPB and NZEP, it is described as carbon dioxide neutral buildings. Taking the commercial side in consideration is a fundamental step for achieving the EPB, enhancing the building efficiency especially for the envelope must be activated prior to go for using on site renewable resources since the same is affecting directly to amount of required renewable devices and so decreasing the TLC.

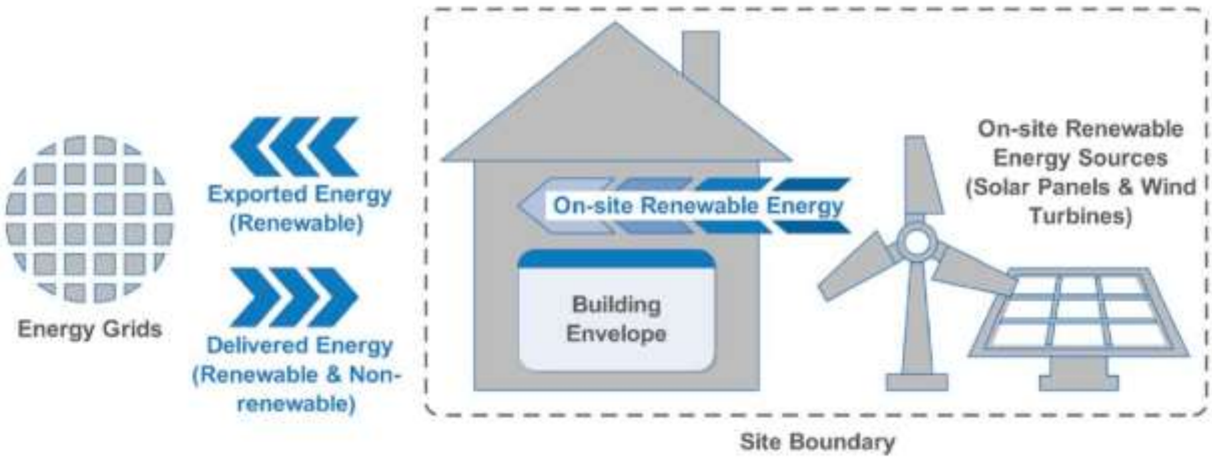


Figure 4 Energy Transaction Across The Building Boundary (Bandeiras et al. 2020)

There are potential benefits for connecting the EPB to the grid specially regarding the type of used energy for the building such as district heating and cooling as well as the natural gas supply controlled by the relevant authority in reasonable cost reference to supported governmental programs for storing and transferring through community infrastructure. Furthermore, on grid direction is providing more sustainable system for relying on the RE since it will neglect the variable factors that can affect achieving RE in most timings such the seasonal factor, day timing, weather status and others.

2.6 EPB Parameters

Transferring the building towards NZEB will require mainly enhancement for building passive energy specially for the solar radiation since the same is affecting directly the level of energy consumption, in addition to that, utilize the maximum energy for renewable resource so that energy balance can be achieved (AbuGrain & Alibaba 2017).

2.6.1 Reaching Internal Comfort Level

Humans through their body reaction are defining the level of required comfort within the space as a part of internal parameters of the building, the same is responsible directly for the required level of heating or cooling required as well as the amount and type of air to be provided or sucked from the building. This is eventually specifying the amount of consumed energy, noting that desired range of internal temperature within the space comes between nineteen and twenty-three Celsius centigrade and this differentiation resulted from the fact that humans body adapts to the current season living with. In addition to the thermal side, visual comfort is taking place especially during the night in the absence of natural day light.

Relative humidity (RH) level should be fundamentally considered once talking about comfort level since it is directly affecting wellbeing feeling, noting that RH should be existing within approximate range between thirty to seventy percentages since being less than such level could lead to body dryness while more than this will lead to perspiration.

As clear in Fig. (5), temperature and humidity are the main factors responsible for human comfort level and the same should be within range that varies slightly reference to several factors such as geographical location, space function, seasonal and day timing factors.

Figure 5 RH and Temperature Comfort Zone (Hollands & Korjenic 2021)

Improving the building materials specially the one used for the envelope will directly help in reaching the comfort level with less or without energy, starting from the thermal isolation that can manipulate the amount of heat gain and loss to stabilize the internal temperature within specific range. While using specific internal materials such loam characterized with ability of storing moisture and release it in the required rates will help in smoothing the RH from going beyond.

2.6.2 Considering Exterior Conditions

Building external envelope is influenced by the external climate either on macro or micro scale, keeping in mind the deference between weather and climate since the first is describing short period or momentary status while the other dealing with long term condition that could extend to decades without noticing that and yet witnessing extreme climate change derived by the greenhouse effect resulting unfortunately nowadays in the natural disasters. The earth spherical shape and distribution of land and water led to four main deferent regions once compared according to temperature, solar radiation humidity and wind speed. As clear in Fig. (6), UAE is located within the hot and dry region which is described also as subtropics region, including the other three regions tropic, temperate and polar zone have variable fluctuations that adversely increase reference to how far from the equator.

Considering the subtropics zone where UAE belongs and its location between temperate and tropical zones, it is characterized with hot summer accompanied with high intense of solar radiation during the day and medium to low level of temperature during the night, noting that RH varies between the comfort zone and the dry level once reaching low alarming levels like ten percentages. Moving to winter, where the whether usually considered mild with rare rainfall occasions but in the same time can be heavy rainfall.

Figure 6 Earth Climate Zones

Going back to building and construction style considered before the industrial revolution, it was built to have more relation with earth and designed to be passively optimized for facing the seasonal weather changes and benefit from available natural resources accompanied with each weather.

The new technologies used in the current buildings mainly considering the initial cost as the the main role, this unfortunately led to increase operational energy consumption required to reach the occupants comfort level. Figure (7) illustrates some passive solutions that was taking place to accommodate the climate conditions, it is not mandatory to follow these strategies since some of them is not applicable to nowadays and future building prospects, but it could be wisely integrated once studying the potential passive solutions.

Apart from the macroclimatic conditions, weather specific characteristics should be taken inconsideration mainly that geographic location and urban fabric which could deeply diverse the standard climate factors either in positive or negative direction. This will require alternative study and survey for plot location with all features prior to design or retrofit building, considering sun and amount of solar radiation reaching the building, wind velocity and direction, RH during the year and type of surrounding urban functions.

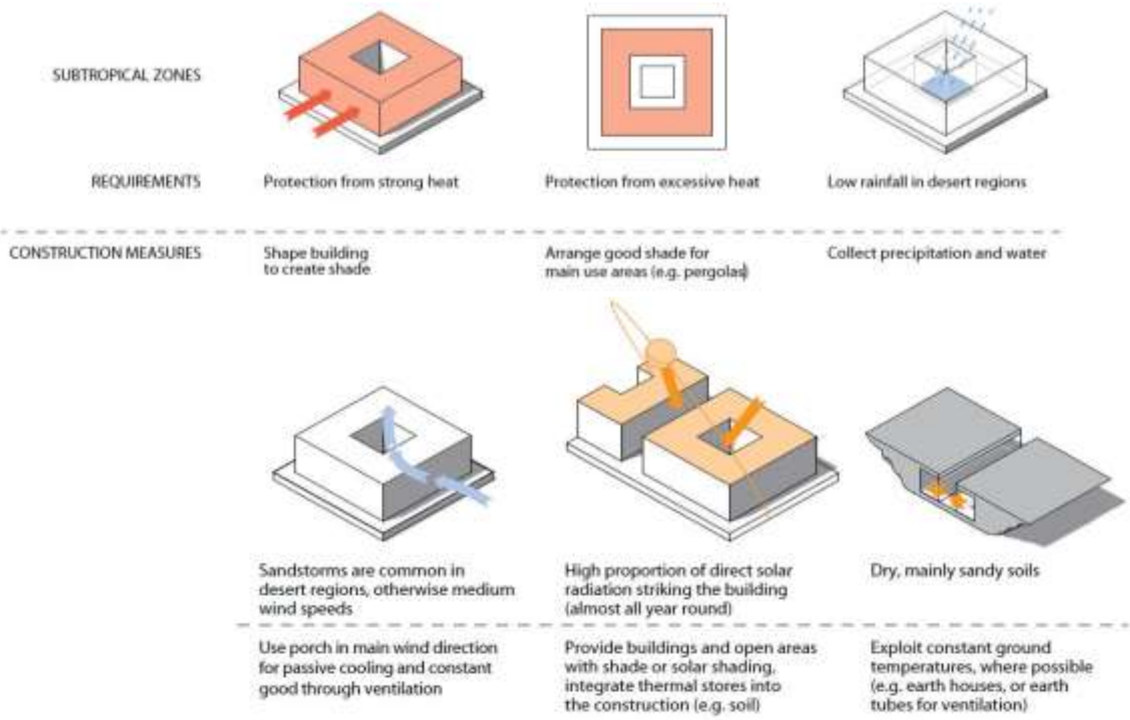


Figure 7 Subtropical Zone Traditional Building Features Before the Industrial Revolution

2.6.3 Enhancing Building Passive and Active Techniques

Passive elements integrated with the building design address potential benefits for energy efficiency specially for operation systems providing the thermal and lighting comfort and so reducing the energy consumption up to forty percentages (AbuGrain & Alibaba 2017). There should be balance for using the passive and active techniques along with the required energy as well as the commercial considerations; for example of passive technique is glazing size that can be manipulated in the south side which can be increased to get the required day lighting during the year and heating in cold areas in winter. While in summer it can be protected through fixed shading devices, on the other hand once turning to active design, the glazing can be reduced to minimum comfortable level in order to utilize the external envelope for collecting energy through PVs.

One of the fundamental roles derived by passive design that reducing the area of envelope to volume A/V will reduce the transmission and so reducing energy consumption. This concept can be diverted once considering the active design since it is relying on the external envelope for harvesting energy; this direction is offering obvious flexibility once dealing for either new building design or retrofitting existing building.

Reducing the energy demand can be resulted from the proper utilization of passive techniques through design stage followed by construction and selecting materials. While merging the active and passive components will lead to cover the main operational services within the building starting with ventilation, cooling or heating, lighting and ending with electricity, through balancing these factors the energy final performance will be recognized to reach plus level finally and considered as EPB.

2.7 Significance and Strategies to Develop EPB

2.7.1 Energy Efficiency

According to Bandeiras et al. (2020) limitations for achieving energy efficiency are addressed in any community reference to many reasons starting from the cost restrictions represented in the availability of capital either through investors or governmental subsidies in addition to high initial cost as well as the long payback period. Invisible costs could raise reference to low experience in the field, shortage or incredulity of information and lake of ambition with awareness. In addition to that, politics can defect the evolution process reference to internal or external pressures or competitive markets. Keeping in mind that ensure behavior and corporation by understanding energy saving proposes can be responsible reducing the energy consumption in noticeable amount that could reach up to fifteen percentages.

2.7.2 RE Storing and Distribution

One of the challenges facing the reliance on RE resources is regarding the difficulties of storing the energy when it is available excessively to be used later in the RE absence times (Marino et al. 2019). Using optimized methods of storing energy like short term process through onsite sophisticated batteries as well as long term storing considering hydrogen storing presents obvious reduction in the TLC specially for the remote areas (Sharma, Kolhe & Sharma 2020). Using direct batteries connected to the PV systems proofed how economically it could since the energy penetration is highly improved while it could be compulsory procedure for countries with no feed in tariff systems.

Produced RE could have negative impact on the environment incase not used immediately or have no proper storing tools (Zhang et al. 2020). The building site content and characteristics play important role in enhancing RE performance especially in the absence of feed in tariff facility like current UAE situation. Many applications could be benefited from the produced excessive RE such as transferring to electrical cars which will directly participate in reducing the gas emission, introducing agricultural farm that requires specific heating or cooling energy could be an indirect transfer of the achieved energy but with different shape of useful product.

2.7.3 Integrating Interaction with the Grid

Building energy management can be either depending directly on the grid power supply in a module called On-Grid system or relying on the Off-Grid system once the building is dependent from relevant power network, in both cases either it is compulsory or end-user decision is including all possible energy transferring (Ahmad & Khan 2020). The corporation between EPB and grid is recommended due to its supportive role in balancing the surplus produced RE and decreasing the potential losses in case of relying on batteries from storing energy (Zhang et al. 2020). However, the grid standards must be respected and taken in consideration to avoid affecting the voltage stability especially once the surplus energy exceeds the feeders' capacity. For more technical and economical solution, it is advised to mitigate both on-grid and off-grid systems by keeping the possibility of relying on on-grid system as backup once the off-grid option temporarily not available (Sharma, Kolhe & Sharma 2020).

2.8 Utilizing EPB principles for Retrofitting Existing Buildings

Gradually by time passing, existing building energy efficiency will decline due to many factors such as external wall erosion, cracks and uncontrolled joints between walls and windows, as well as moisture accumulation inside the envelope insulation materials resulted by humidity and rainfall and so forth (Park et al. 2020). Retrofitting the external envelope is mandatory not only reference to the previous factors, but mostly from the fact that it was built with lower thermal efficiency standards prior the green building regulations or with less requirements.

Unlike the new buildings, the scope of work in the retrofit process is concluding fewer actions and focussing more on enhancing the building energy efficiency mainly for the envelope part. The building materials and systems ahead with the design are affecting directly the building energy performance, this is including but not limited to the proper transparent elements within the envelope for introducing convenient day lighting while heat transfer can be manipulated through proper coefficient value for cold climates and angled shading devices in hot climates. Besides that, controlling the temperature of natural ventilation through developed process will reduce the heat loss or gain in the building, while relying on smart systems through sensors and actuators can increase the efficiency the artificial light performance (Bandeiras et al. 2020). It is very important to consider the end-user requirements prior proceeding with retrofit process, since the same will explore the function of the space which will identify the energy consumption during specific timing, it will also match end-user needs which could be vary from the standard levels either in positive or negative direction.

Building retrofit techniques must have limits according to the total available budget, the contribution of each technique will be positive until specific limits but exceeding that limits will decrease the efficiency of retrofitting procedure (García Kerdan et al. 2016). Commercial buildings is considered the second most consuming energy buildings after the offices, since it is concluding larger volumes for internal functions than others, it is worth to spend effort on retrofit since it will introduce larger saving than others (Park et al. 2020).

2.8.1 Shading Devises

Shading devises is leading the passive techniques that used for decades to overcome the heating resulted from direct solar radiation reaching the building envelope either walls or glazing as well as enhancing thermal performance (Abdullah & Alibaba 2017). Many aesthetic elements that could be derived through region or culture can be categorized under the shading devices including projections, pergolas and vegetation. Moreover, shading elements can be designed as fixed elements as well as kinetic features that could be controlled manually or through responsive sensors reference to the status of solar radiation. Some regions that characterized with overcast skies are diverting the scope of shaping elements to collect more natural light for the building, while in other cases shading elements are utilized to control the natural ventilation required for the building or even as wind breakers when needed.

PV shading devise is considered as one of the new techniques used that have extra benefit utilization by diverting the effect of solar radiation from consumption reason to energy providing technique, moreover, PV gradually being flexible to be used in many locations and shapes such as cladding and window integrated systems (Abdullah & Alibaba 2017).

2.8.2 Walls and roof thermal insulation

Building envelope is considered the first barrier facing the changing external environment, introducing the thermal insulation to cover all used habitable volumes of the building from outside in addition to reduce the temperature penetration to minimum will insure saving the internal environment from external climate fluctuations. By controlling envelope thermal insulation and building air tightness, a significant reduction of energy demand for heating and cooling could be achieved (Kim et al. 2019). The thermal insulation is measured through cumulating the amount of thermal transmittance know as U-Value for all envelope components including roof, windows and walls in addition to any other part deforming the envelope. The same is indicating the heat flow under standardized conditions between the envelope main internal and external surfaces as the main envelope surfaces represented in Watts per meter squared Kelvin (W/m2K).

According to Dubai, (Municipality 2016) is defining the thermal transmittance values for external envelope reference to the rating, the roof is fixed in all categories to be maximum three tenths watts per square meter. While the vertical walls varies between the Bronze and Silver Sa’fa once compared to Golden and Platinum Sa’fa as it should be maximum fifty-seven hundredths and forty-two hundredths watts per square meter respectively. Other than achieving the cumulative thermal transmittance values to be in line with the regulation, thermal bridges should be highly considered specially once related to the structure elements since it is not only affecting the envelope thermal efficiency, but also could lead to future failures resulted from improper condensation that eventually affect building safety. Autoclaved aerated concrete block (AAC) is being used in UAE to cover the external structure elements including columns and beams, the same not only have proofed thermal insulation properties, but also considered as fire rated element according to civil defense requirements.

Day by day insulation materials are being improved reference to its fundamental role in the building performance, many types of insulation being used such as rock wool, cellulose and cork as well as extruded polystyrene and even vacuumed space, while methodology of installation and material selection is relying on cost, availability of materials and regulations. One of the promising trends is the phase change materials (PCM) which can be easily added as separate layers or mixed with envelope construction materials (Park et al. 2020). Relying on heat storage of thermal energy process, PCM can with its noticeable high level of heat storage for specific time to be released later when it is convenient to do so. The flexibility of adding insulation materials either from internal or externally external envelope side offers a simple procedure once planning for envelope thermal retrofit.

2.8.3 Window thermal performance

Building function usually lead the designer while initiating the building design including the external envelope specially the glazing ratio to the windows (Alemi & Loge 2017), for example the office and commercial building which mainly conclude their activity during the daytime will include extra glazing areas within the envelope. So that it can benefit the maximum available natural light in addition to increase the productivity of employees once they have visual connection with external environment (Abdullah & Alibaba 2017), this indeed resulting in extra energy consumption once considering the heating, ventilation and air conditioning (HVAC) systems.

Windows are considered to be the building weak points once talking about energy loses and heat gain through the envelope since it usually have four times or more worst U-Value than walls (Ozel & Ozel 2020). Glass properties can be manipulated to offer the best efficiency reference to the climate and energy requirements by number of glass layers, thermal and light transmittance. For hot climate, it is preferred to rely on reducing the heat gain even that it will affect the light transmission level reference to the energy saved from reducing thermal transmission is less than the one used for artificial lighting. Reference to (Municipality 2016), the thermal transmittance and coefficient for shading in addition to the light transmittance values rely on the glazing percentages from the external wall conditioning that glazing area should be considered natural light source and not external cladding, Table (3) presenting the relation between glazing percentages and glass specifications reference to Dubai green building regulation.

Table 3 Relation Between Glazing Percentages and Glass Specifications according to Sa'fat Rating (Municipality 2016)

Glass Percentages from external wall	Thermal Transmittance	Shading Coefficient	Light Transmittance
Forty Percentages or Less	2.1 W/m2K	0.4	0.25
Between Forty and Sixty Percentages	1.9 W/m2K	0.32	0.1
Sixty Percentages or More	1.9 W/m2K	0.25	0.1

2.9 Introducing Renewable Energy - Solar Direction

In parallel with the increasing energy security concerns along with the environmental issues related fossil fuel consumption, renewable energy is being utilized more and more to fulfill the mentioned problems, accordingly building envelope is offering potential solution once utilized for energy harvesting specially from solar source. Solar energy can be presented in two main shapes, thermal and PV, although the old age of thermal approach, but it still presents a significant place in RE field specially for its high efficiency rating that could reach up to eighty percentages. Using the same concept, thermal and PVs have the flexibility of being added to existing building as part of renovation process or integrated within the building specially in the initiation process (Yip, Athienitis & Lee 2021). Recently, modified modules merging thermal and PV units together in PV-Thermal direction, the same is offering extra enhancement by utilizing fluids heat recovery procedure where hot water initiated from solar radiation and PV is being replaced with cold water after serving the building with the required domestic hot water and heat pumps requirements. The same also can maintain PV temperature within the required levels and so extend its efficiency for producing electricity.

2.9.1 PVs Efficiency

The concept used in PVs starting from the nineteenth century relies on considering the solar cells, which can be collected to perform the array, emitting electrons on the cells start once the light received causing a direct current in a phenomena call photovoltaic effect. Nowadays, four main types of PVs are being used, starting from crystalline system and thin film as well as compound and nanotechnology, these types have variant properties and specifications related to cost, fixation, materials, materials and level of light required to create energy (Salameh et al. 2020). On the other hand, many studies and experiments being held continually to achieve better efficiency with the minimum cost.

The location and orientation of installed PVs should be carefully studied according to sun path and surrounding environment. Moreover, it can be installed on the roof as well as the vertical walls as additional layer or integrated within the envelope construction. The angle of PV surface according to sun rays determine the amount of harvested light that will be changed to electricity and this amount can be considered the maximum once reaching the perpendicular status. Tracking PV system is maximizing the yield per unit meter since it is offering extra time of perpendicular status during the day timing and the same can be controlled through special motors derived by program software during the whole year. PVs are influenced directly with the surrounding temperature, twenty-five Celsius centigrade is considered the optimum production temperature while efficiency drops down with approximate four tenths percentages with each extra one Celsius centigrade. The same can be maintained as discussed previously through liquid integrated systems or by providing rear artificial or natural ventilation support while the dust can be avoided through inclining the PVs at least with three degrease so that it can be self-cleaned through rainwater.

2.9.2 PV Types

In the last two decades three main types of PV where the dominant in the domestic usage, research and improvements starting from monocrystalline and moving to polycrystalline in addition to amorphous, while the main variables that should be taken in consideration once comparing the types are energy produced, cost and environmental side effects (Allouhi et al. 2019).

Starting from the monocrystalline type that is manufactured from crystal shaped silicon presented as hexagonal profile that will lead extra initial cost but higher efficiency reference to its smoother and thicker surface. Moving to polycrystalline type, which has less efficiency reference to the procedure used to provide the components that characterized with the high reflectivity since it is coming from square silicon blocks, which is resulting in reducing the price for such module. Noting that the efficiency is calculated by the amount of watts that can be collected per square meter as maximum of one thousand, but the same is reduced reference to the PV panel efficiency and type. Moving forward to the thin type where the crystalline materials are replaced with amorphous components of silicon such as gallium, copper and cadmium. Reference to the low thickness and mentioned components, thin film is showing more flexibility for deformation. Following previous types, the efficiency level is directed with the price so thin film products present low energy efficiency.

2.9.3 Solar Energy Collection Trends

One of the trends that been recognized and increasingly used is the solar tracing PV technique showing optimum efficiency in harvesting energy from solar radiation in addition to be more effective once considering it as shading devise (Abdullah & Alibaba 2017). Another trending tool that successfully considered is the air collector direction as shown in Fig. (8), the same is relying on the thermal direction but with replacing fluid with air the system relies on providing transparent cladding for the vertical envelope that allows the solar radiation to pass through until reaching dark surface with high absorption properties that will heat air introduced from one end and keep moving until entering the building passively through the stack effect or forced mechanically. The hot air can either move directly to internal spaces or used as support for the ventilation systems. Air collectors commonly used in cold climates specially in winter since it could lead to overheating purposes, moreover and reference to its basis in utilizing the elevation and eliminating the windows, it is more preferred for industrial and agriculture projects that does not have natural light requirements.

Figure 8 Air Collector System In Cold Climates Hamm, Germany

Semitransparent thin PVs provide promising solutions for the envelope specially that it is not blocking the view and allowing partial day lighting to pass through. Moreover, it can reduce the un-wanted solar radiation from passing to internal space while conceptually it is working as energy harvesting device (Salameh et al. 2020). Finally, architect can introduce such type of PVs with coordination of engineer during the design so that it will be more integrated, noting

that the flexibility of adding transparent materials to the windows will highly allow thin PVs to be a part of retrofit tools. Keeping in mind, those semitransparent PVs can achieve more efficiency once considered one of the two or three layers used for the glass. Unlike the cold climates where the most energy demand is required for heating and fulfilled through burning fossil fuel, in the hot climate building energy demand is required to achieve the cooling requirements which can be provided through electrical supply and accordingly it is more visible to rely on PVs to provide the required energy (Friess & Rakhshan 2017).

2.10 UAE Energy Profiles and Climatic Factors

The main purpose of building energy retrofit is to reduce the gas emissions (García Kerdan et al. 2016). From world wild view, two of the three main fossil fuel are going to be depleted within the coming fifty years (Pillot et al. 2019) as shown in Table (4), this in addition to its environmental effects represented by the greenhouse emissions forcing and encouraging countries for adopting and adapting RE solutions. Reference to (Krarti & Dubey 2018), around ninety percentages of consumed electricity utilized by buildings not that the same can be reduced by around seven thousands and a half gigawatts hours once proper energy retrofit program settled. Along forty years since the UAE union in nineteen seventies, the energy consumption per capita doubled with growth of around two and twenty-four hundredths percentages per year (Said, Alshehhi & Mehmood 2018a). In parallel to the energy consumption, carbon dioxide emissions observed with about seven percentages yearly growth. While according to UAE ministry of environment, oil industries in addition to gas activities are leading the air pollution sources prior to desalination works required for water and electricity.

Table 4 Fossil Fuel Life Time (Pillot et al. 2019)

Fossil Fuel	Lifetime (Years)
Oil	50.6
Coal	153.0
Natural Gas	52.5
Uranium	285.1

Figure (9) illustrates the UAE population growth up to the middle of the current century, the same is showing rates reference to the expecting reduction in the emigration process and aging facts. Even thought, the increased population level is requiring additional energy demand and reference to UAE vision of twenty thirty, more renewable energy plans will be required to cover this increment and to reduce the current fossil fuel reliance.

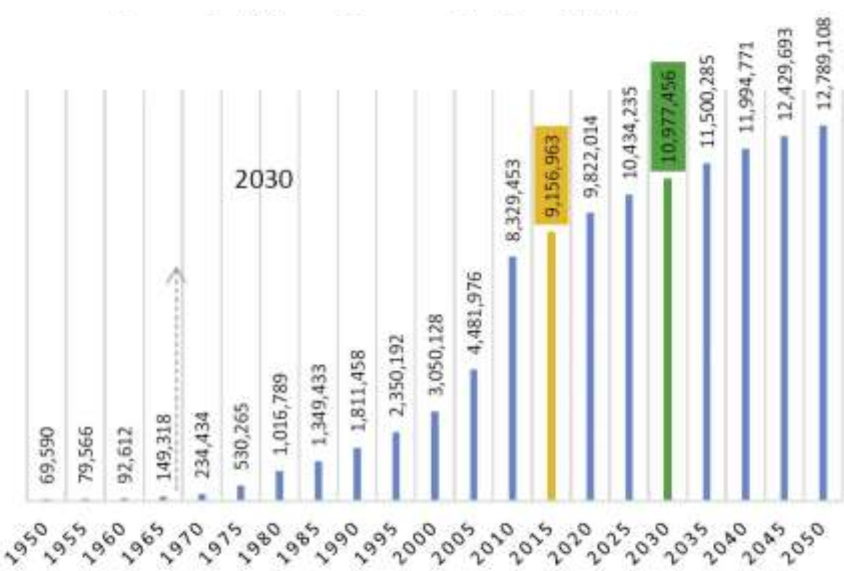


Figure 9 Population Statistics in UAE (Said, Alshehhi & Mehmood 2018a)

Considering the solar direction and biomass the main RE in UAE, the expected RE share from the total energy supply with year twenty thirty is seven and five percent in Abu Dhabi and Dubai respectively as clear in Table (5).

Table 5 RE Participation Targets in 2030 in UAE (Said, Alshehhi & Mehmood 2018a)

	Thermal Transmittance	Shading Coefficient
2013	1. Masdar City (PV) – 10 MW 2. Shams 1 (CSP) – 100 MW 3. Sir Bani Yas Wind – 28.8 MW	1. Phase 1: Dubai Solar Park (PV) – 13 MW 2. Rooftop Building (PV) – 4 MW
2020	1. Noor 1 (PV) – 100 MW 2. Noor 2 (PV) – 150 MW 3. Biomass – 100 MW	1. Phase 1: Dubai Solar Park (PV) – 13 MW
2030	No Announcement	1. Phase 1: Dubai Solar Park (PV) – 13 MW
Total	**488.8 MW**	**1317 MW**
Target	**7% RE by 2020**	**5% RE by 2030**

Moving forward to UAE twenty fifty energy vision targets to reach emissions reduction in the carbon dioxide by seventy percentages through relying more on clean energy represented by around forty-four and six percentages of RE and nuclear energy respectively from the total energy profile (Naqbi, Tsai & Mezher 2019). This indeed will require reliable infrastructure plans as well as feasible financial plans to succeed.

2.10.1 Solar Radiation

By receiving more than ten hours sunlight daily through the hall year, solar direction shows strong approach that can be improved and applied widely governmentally as witnessed in Shams Abu Dhabi and Dubai Solar Park projects (Naqbi, Tsai & Mezher 2019). Individually on the other hand, it can be succeeded with extra mental support for social awareness and governmental subsidies commercially and technically. Direct radiation level that is measured in watt per square meter is recording high levels of that can be profitably consumed in UAE as per Fig. (10), on the other hand the defused radiation presented usually in the building envelope elements that not facing the sun is recording feasible measures that could reach two hundred watts per square meter once compared to the direct radiation with three tomes more.

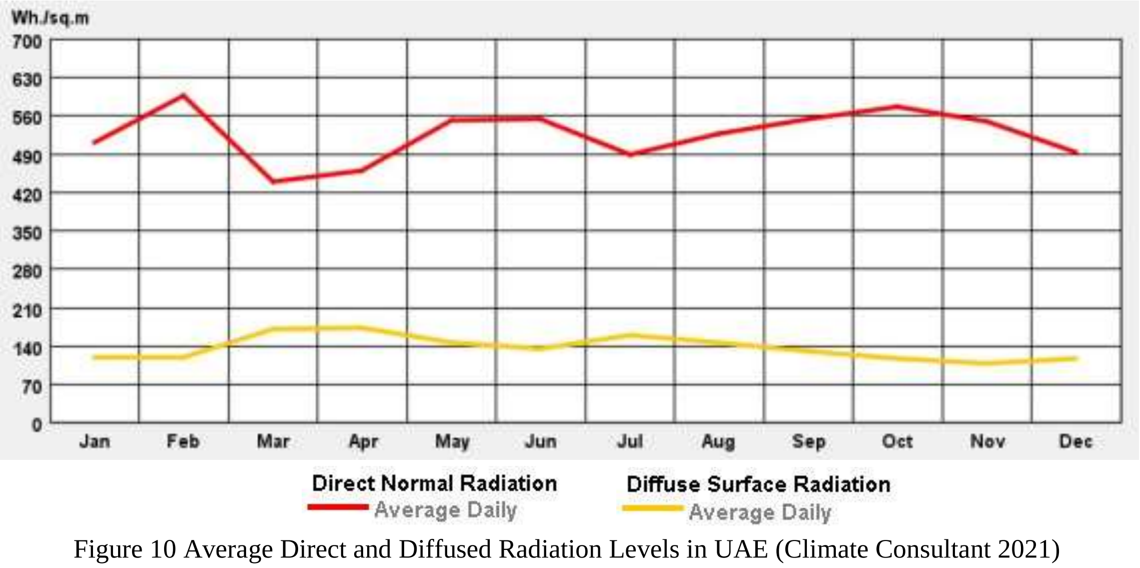


Figure 10 Average Direct and Diffused Radiation Levels in UAE (Climate Consultant 2021)

In addition to its desired position for providing the natural light with the building, direct and diffused radiation levels will effect on the PV efficiency (Zaimi et al. 2019), reference to Fig. (11), the PV yield can increase up to zero point one hundred twenty-five percentages for each extra hundred watts per square meter. Accordingly, in UAE in the direct radiation sides, the PV could achieve up to fourteen and half percentages yield on specific temperature levels while the diffused yield could reach up to thirteen percentages on the same temperature.

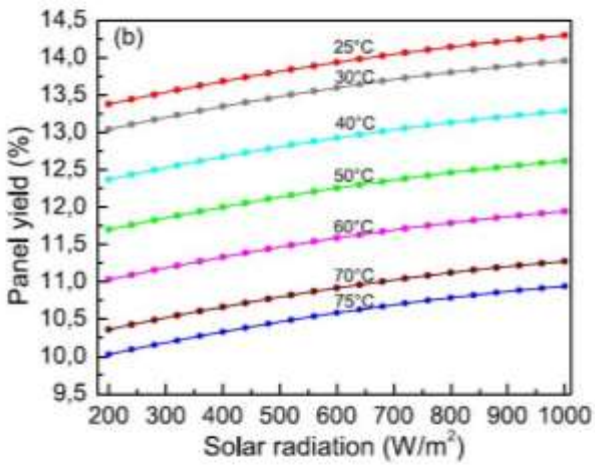


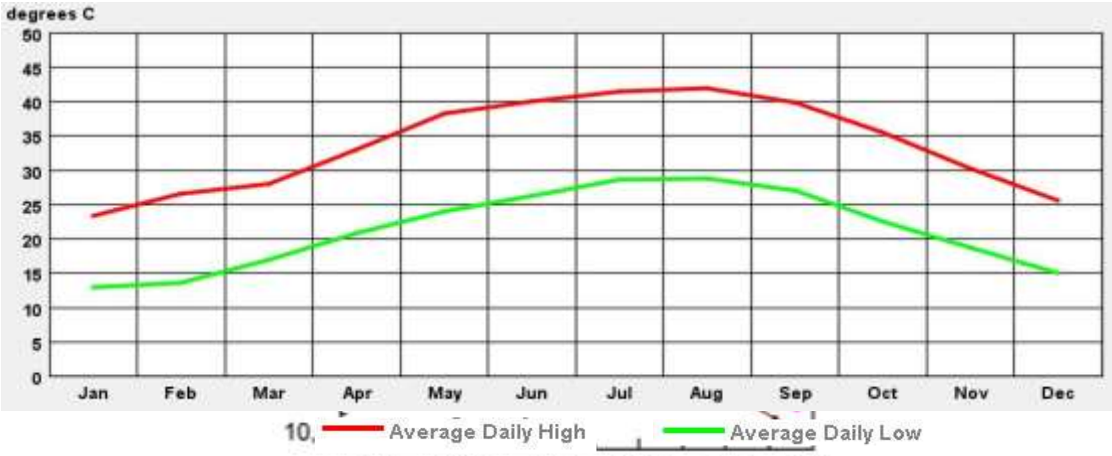
Figure 11 Relation between Radiation Level and PV Yield (Zaimi et al. 2019)

2.10.2 Temperature

UAE as a part of the Arabian Peninsula characterized with arid climate and high temperature levels during the most of the year, reference to Fig. (12), UAE can be within the comfort temperature levels for around seventeen percentages of the year (Zaimi et al. 2019) which will require several passive and passive techniques to make refine the internal environment for proper living.

Temperature have direct impact in the efficiency of PV yield since the maximum recoded level can be once temperature is less than twenty-five degrees centigrade and gradually efficiency will be decrease once temperature is going up as illustrated in Fig. (13).

Figure 12 Average Dry Bulb Temperature in UAE (Climate Consultant 2021)



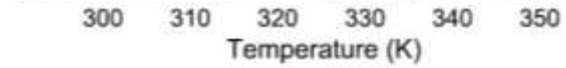


Figure 13: Relation between Ambient Temperature and PV Yield (Zaimi et al. 2019)

2.10.3 Wind Speed and Direction

Winds as passive strategy can be utilized for providing internal cooling and ventilation after taking the direction speed in consideration, more over it could be utilized to provide more convenient ambient temperature for PVs to maintain the efficiency. Generally, the wind directions during the year come from the southwest direction while the speed broadly ranges between three and four meters per second. Such a speed can support domestic wind turbines that have small cut speed that reach up to twenty-five hundredths meter per second with maximum speed of four meter per second and the same have point twenty-one watts and can produce up to one thousand and eight hundred watts per year.

2.11 Conclusion and Gap Analyzing

UAE witnessed in the last decade sharp increased levels of population accompanied with economy expansion, the same reflected on the energy demand and expected to continue increasing in the coming years. On the other hand, the hot arid climate in UAE presents the main factor for increasing the electricity consumption especially for building sector where more than forty percentages consumed for the mechanical ventilation and conditioning purposes, all of these figures contribute in directly in the global warming issues once relying on fossil fuel. Accordingly, proactive initiatives is highly recommended that can invert the carbon dioxide emissions through more reliance on the clean energy derived mainly by the RE resources that is available and can be feasibly used along with governmental support. The lake of FIT in UAE must not stand against the transformation to RE, also it must not give the pretext to adopt individual RE solutions for private projects, the same can be generated and implemented within the plot boundary limits after exploring the potentials (Naqbi, Tsai & Mezher 2019).

There are many gabs and lack of knowledge once dealing with the EPB in UAE, starting from the minimal number of research exploring the definition of positive energy, what are the limitations of being positive, the possibilities of applying EPB for either existing or new building. In addition, there is unclear differentiation between EPB and NZEB from many aspects like the energy balance criteria, financial principles and payback period, while FIT systems are barley activated or well-utilized reference to low public awareness and less experience in the field.

Most of the previous researches taking about EPB in a literature review basis without providing clear framework and structured steps to reach the desired level. The research is exploring a building potentials in UAE that need to be considered once transforming towards positive energy starting from enhancing building energy efficiency and reaching to introduce clean energy to contribute with daily operation activities in a way that insure the balance between the expenditures and revenues.

Chapter Three

Methodology

3. Methodology

3.1 Overview

As part of scientific research, enhancing building efficiency passed through several levels and recognized procedures that are being tested and proven its capability to improve building reaction to the variable environmental aspects. Passing through researches being held in past five years the chapter will take in consideration the most practical and proven methodologies that mainly concentrates on enhancing the efficiency for either existing or new building. In order to set clear figures for the improving the building from energy consumption direction, it is preferred to divide a whole year to several intervals based on the climate situation during the year so that the improvement in the building efficiency after renovation will be more clear, and so the weak points will be figured and solved easily (Gustafsson et al. 2019).

3.2 Literature Review Methodology

Literature Review is derived by investigating the previous articles where the researches taking in consideration the ways for enhancing building efficiency through literature review. Starting from (Hashempour, Taherkhani & Mahdikhani 2020) who investigated in the missing items once relying on retrofitting procedure with extensive debate on the development factor. Apart from the publishing year and in addition to the issued articles, the search conducted also papers issued in the conferences as well as authors with more than two publications focusing on the enhancement topic. Derived from the enhancement need, many methods, answers emerged prioritizing each technique advantages, and disadvantages until choosing the decision making as the preferred procedure. Utilizing the decision making procedure, two main criterion options emerged starting with the single criterion method which have less reliable percentage that is not reaching twenty percentages while the rest goes to the multi criterion as preferred in the past, present and coming future. After the criterion methodology, the optimization role and criteria comes in the second place since it is taking in consideration the basic roles represented in social aspects such as behaviour and human satisfaction for life level and surrounding environment as well as the life cycle aspects. TLC, location environment and polices are considered sub limitations that can affect the retrofit procedure success.

Moving forward to (Bandeiras et al. 2020), where achieving the building energy efficiency was studied based on concentration of architecture, construction and measurements of energy efficiency which will also have good benefits as cost wise. It claims that the main aspects that should be taken in consideration once transferring the building to be more efficient are summarized in three points, starting from the measures of energy efficiency and moving to the mechanism of net metering while the weighting factors as the last aspect derived by its effect on building energy balance. Variable definitions of NZEB and EPB were presented while the agreed definition that intersects between researchers that annual net energy must reach zero or more. Evaluation software using special algorithm was initiated to evaluate the outcomes and possibilities to reach the required energy that fulfil building demand from available RE within the plot boundary, keeping in mind the potential of relying on net metering procedure that can cover energy demand several plots in case shortage was highlighted in specific plot.

Hofler (2019) claimed that widening the research for new technologies and rapid decision for adopting them will affect the results reference to lake of knowledge for the new materials as well as shortage of specialists dealing with the same, this will also lead to not presenting the expresses of life cycle. Noting that consuming extra two percentages in the construction expenditure will save the cost of operational stage with up to forty percentages, this will require involvement of all decision makers during the construction stage to figure the possibilities and potentials from all sides of view.

Ana & Attia (2020) overviewed in their research the rehabilitation process being conducted for old buildings characterized with poor efficiency performance in addition figuring enhanced regulations to be applied for new buildings, the same relied on the international energy performance progress and new trends such passive house and NZEB. Reference to Fig. (14), polices and feasible technologies are the main aspects considered in the literature in addition to the pros and cons of adopting energy efficiency criteria, the same data was collected from several resources and publications with related topics, then a comprehensive survey that includes each article reference, parameters, scope, gaps and conclusion.

Figure 14 Strategic Elements Impacts Building Efficiency (Ana & Attia 2020)

3.3 Simulation Methodology

Tapper & Dokka (2019) explored in their work the design of an office building in Norway through advanced simulation dynamic programs called Simien and 6.009 that not only evaluate building energy consumption, but also conduct the embodied energy consumed on the materials and construction since the article claims that embodied energy must be paid pack through the plus energy achieved from the building operation. Also, there was consideration for developing the temperature supplied for cooling and heating systems as well as regulating the rates of flow for different zones. Part of the work concentrated on decreasing the losses of energy by enhancing insulation systems and eliminating as much as possible thermal bridges. During the operation stage, intelligent program called LOWEX that is calculating the required slab temperature that could achieve the best energy performance once applying heating or cooling systems for the coming two days.

Moving to (Synnefa et al. 2017) who Examined through simulation programs including IES-VE and energy plus the procedure to equalize the energy demand with the production during the building operation as well as in the construction stage in a system called Zero-Plus Project. Offering practical and intelligent solutions specially for the envelop of the building in addition to energy generation and management for the building itself as well as on the neighbourhood level. Taking inconsideration four European countries with different climates and building functions where the simulation methodology applied testing the energy and environment in addition to cost side. The simulation took inconsideration the energy generation and performance by covering the main aspects related to the building it terms of air and water heating and cooling in addition to lighting. This step was followed by recognizing and reducing energy consumption to the lowest accepted level, which is annually equal or less than twenty-kilowatt hour per square meter. Finally, increasing the RE production to its optimum level targeting fifty-kilowatt meter per square meter yearly.

Iqbal, Himmler & Gheewala (2017) examined the energy performance for three identical houses considering the first house as typical base case that is totally electrical supplied from the network while the second house as nearly zero energy and partially supported from the grid connection. The final sample to be considered as positive energy building with totally RE reliance through PV panels during the day timing. TRNSYS as a developed simulation tool was utilized on the three cases after dividing each house to ten thermal zones and simulate its energy performance for one complete year with time interval of fifteen minutes for registering the readings. This off course increased the model efficiency that recognized all possible thermal fluctuations that could happen in addition to figure exactly peak timing for each. The excessive energy produced in the plus energy house is transferred directly to the grid to be partially used in the evening timing. However, the required electricity used in the nearly aero and plus energy house for cooling in the day is totally covered from PV, in addition to that, during the day, part of generated electricity utilized to form ice storage that used to supply cooled resource instead of chiller during the night.

3.4 Experimental Methodology

As a part of retrofitting process, (Parker et al. 2019) examined through in situ measurement prior to and after retrofitting procedure for existing concrete building through avoiding traditional procedures. The process initiated by creating proper insulated chamber within existing building with high efficient insulation materials while the internal temperature will be manipulated to match external real condition so that more accuracy will be conducted once applying the enhancement. Reference to the common building process used in the previous century, the concrete showed an insufficient energy performance properties reference to the missing fine materials such as sand. Two identical buildings were considered in the experiment, starting from applying insulation through composite panels with the same sequence for both building but with extra air gap for one of them. Several measurement tools were used each ten minutes for two and half weeks, starting from calculating the electricity consumption by ELSTER, while temperature tested by VAISALA tool, proper air, and temperature distribution was controlled through air fans. More than half of energy consumption was achieved in both buildings with slight enhancement for the one with air gap either between the dwellings or with the external envelop.

On the contrary of common field test procedures, (Lassen 2019) contributed the occupants in observing and enhancing the energy performance to insure achieving the comfort level, reference to the occupants complaining regarding an uncomfortable cold level. The test was conducted during winter months precisely between November and February while occupants offered online access for raising their feedback continually through their smartphones. The first stage considered as base case where energy input taken with no additional instruments within the building. Using the smart phone, the users in stage two, which lasted for eleven days, have the possibility to rate their comfort from one to four and according but without any interruption from the researcher. In the third stage, heating set point reduced from twenty-two to nineteen while heaters were added below occupants' tables where it will be turned on for half hour once the occupant send form the smart phone that it is too cold, the test lasted for twelve days. In addition to occupants' feedback, temperature sensors were distributed in low and high level conducting the temperature reading. Reducing the temperature set point decreased the energy consumption by one fourth of total consumption, which has major contribution for transferring the building energy plus level.

Evangelisti et al. (2020) commenced their investigation with figuring the field inputs including internal and external temperature for internal and external air and surfaces in addition to heat flux measurements, same data is used as base case reference to understand the required enhancements; also, these data will lead to calculate the thermal transmittance. Relying on special sensors called heat flow plate as shown in Fig. (15), heat flux calculations can be achieved, noting the sensitive location that these sensors must be placed to avoid cold bridges affecting the results. After measuring the external and internal temperature, U-Value can be achieved by dividing the heat flux on temperature difference between internal and external, the data collected for at least three to seven days to insure the steady values. The observed U-Value should be within specific range decided by the relevant authority reference to climatic features and regulations, the same should be enhanced if it is more than the standard. While it could be used during the retrofit stage through applying materials and test the feasibility during the construction until reaching the desired performance, the procedure can be applied for all parts of envelope regardless its location, orientation or material.

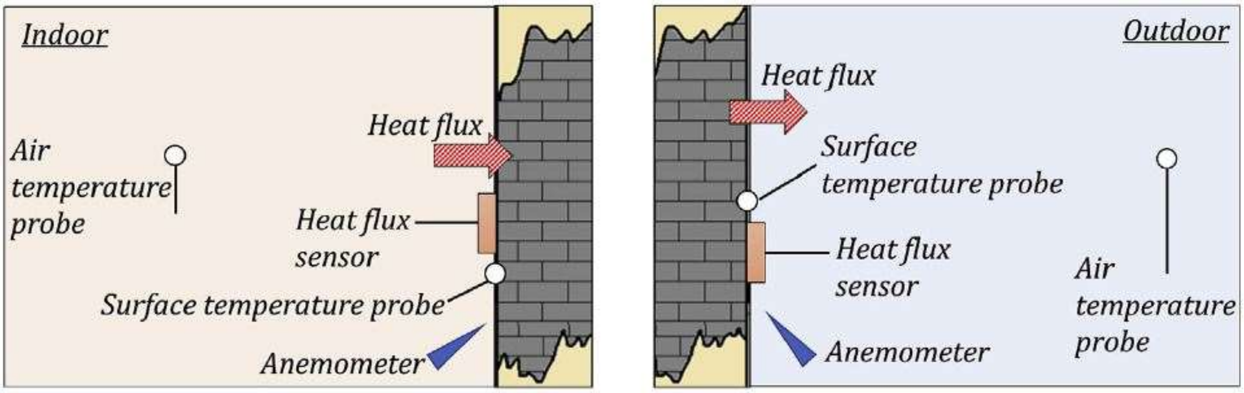


Figure 15 Site Inputs and Tools for Measuring the Thermal Transmission Through External Wall (Evangelisti et al. 2020)

3.5 Methodologies Pros and Cons

Literature review considered as one of the basics for handling any research, however once talking about methodology it could offer wide range of previous cases and information with specific gaps to be filled, accordingly the investigation will not be initiated but will be continued. Apart from being cost saving, literature described to be time consuming for gathering finding and sources, while the new materials and trends will not have enough information to rely on. Variable opinions could be found for the same topic; the same should be classified properly before considering it while the writer for one direction against others could manipulate it. Finally, no numerical data can be tested or extruded for specific project.

Apart from the cost efficiency, simulation methodology is characterized with its speed process with high flexibility in manipulating parameters and conditions in addition to accuracy once talking about surrounding environment. Furthermore, there is always possibility to repeat the tests with flexibility of modifying the inputs including occupancy and weather profiles to reach the optimum results. On the other hand, there is no need to have existing building to handle the investigation, it can be applied virtually for any shape, size, orientation and function which make it more preferred tool for new and retrofitting process. Noting that cost saving eliminated by the manpower, tools, time duration, location will provide potential factor in widening the research or covering extra parameters. Being unrealistic by not covering all probable hidden factors could affect the credibility of simulation process, also, testing new material through simulation could be not reliable since the should pass through physical tests and study before applying the same on software.

Field study is fundamental way to validate the active and passive techniques; it also presents real and accurate figures after being affected with all possible surrounding parameters, presenting realistic climatic features and building properties. Unfortunately, it can be applied only on the existing building and will conduct special results that are related specifically to the same building, noting that these results can be generalized but still will have low accuracy reference to each building special characteristics and surrounding environment. Taking recommendation and apply it on new building will have the risk of uncertainty, while it can be more affective once conducted on existing building especially if the implementations were applied during the investigation. Time and cost showing dilemma specially once talking about specific climate condition during the year or specific building location and properties, keeping in mind the possibility of tools error that could be accrued incase no proper calibration for the same handled. Finally, occupants' existence within the space could affect the results, which could require evacuation of the building during the process.

3.6 Methodology Selection and Tools

Reference to the scope required and data available regarding enhancing existing building efficiency and try to transfer to be energy plus, simulation methodology is showing an advanced performance once compared with other methodologies, with its capability and flexibility to control, improve and contrive available parameters no matter how the scale, location or properties of the project area. The highlighted weak points can be verified through more tests and computerized enhancement utilizing the comparison with the realistic results until reaching the desired level. With the easy process of overcoming the cons and with the advances pros, simulation can be the best direction for handling the research.

The research is aiming to test the possibilities of converting the net energy within the building plot boundary to be in plus level through verifying building envelope efficiency to figure the required enhancements. While the RE will be introduced, utilizing the available resources and site potential characters to produce the maximum possible energy, that not only covered the annual demand but also contribute in supporting the community with the excessive production. Selecting the simulation tool must be referred to several aspects that should be taken in consideration, starting from the capability of introducing wide range of construction materials specially the one available in UAE market. So that research outcomes will be more visible and possible to be applied, on the other hand integrating the RE options and expected energy production according to the chosen site will be fundamental once choosing simulation program.

The software will be involved in all stages of the improvement, starting from modeming the existing building after taking in consideration the properties and parameters involved such as the thermal insulation and envelope materials, mechanical and lighting systems, this will lead to provide the expected energy consumption with the current situation. This off course will validate and proof the efficiency of the selected software once compared with the actual authority bills. Moreover, software will figure the available day lighting for building space and check the possibilities of reducing electricity lighting usage during the day. While proposing shading devices will be more flexible and feasible especially once energy consumption results introduced. Finally, introducing the RE will be more controlled once understanding the required amount, distribution and orientation.

Numerous number of researches relied on modelling and simulation procedures for the seek of building energy enhancement and retrofit, the same was utilized through several types of software reference to the available resources and potentials for each project. Starting from (Salameh et al. 2020) who used PVSYST for orienting the PV panels on the best direction to achieve maximum production of electricity and minimum cooling loads. On the other hand, (Ghenai et al. 2017) adopted software called HOMER concentrating on law environmental impact advanced PVs to achieve the required environmental and economic requirements for UAE residential buildings. IESVE used with (Ji, Lee & Swan 2019) used for figuring the dynamic feedback relying on timely manner weather data information, while (Chen et al. 2020) simulated through the same software the yearly expenditure of main energy parameters including electricity and heating systems. Iqbal, Himmler & Gheewala (2017) explored through TRNSYS the yearly-required energy after running the software to cover the full year with fifteen minutes set points. Moving to (Tapper & Dokka 2019) who conducted the calculations related to embodied energy by software SIMIEN v 6.009 for the materials and construction period in order to evaluate the required plus energy for covering the embodied energy pushing the building to the neutral position before being characterized as EPB.

3.7 Software and Simulation Process

Reference to several researches, Integrated Environmental Solutions – Virtual Environment (IES-VE) is considered as a high quantitative computer program that innovative energetic enactment utilized under engineers control and applied for building exploration models and energy optimization with integration of RE options, which will finally lead to quantify and qualify building environment results. The software can assist through available built in climatic features related to each would zone and imported envelop data to observe the best solutions for energy enhancement in parallel with internal comfort level to convert the building finally to EPB.

IES-VE simulation initiated by modeling the building with real dimensions and distribution, the same is accompanied with identifying the required construction details and specifications, the flexibility of the software will allow later during the enhancement stage to manipulate the materials selection and sequence with proposing and eliminating elements in the process of figuring the best solutions. The simulation process passes through several tools with specific outputs, starting from SUNCAST which illustrates the shading status during the day timing through locating the accurate location of the sun according to the building, this will lead to exploring the thermal criteria utilizing APACHE tool. While other energy and thermal calculations can be figured through APACHECALC and SIM after referring to data observed for the weather while special tools are designated for heat, ventilation and air conditioning.

The software will explore several inputs and outcomes related to building energy performance covering the consumption and production within the plot boundary. Starting from identifying the building structure and envelope materials to investigate the weakness to be enhanced through suggesting different materials and solutions. After the reaching to the optimum efficiency level, the shortage electricity will be identified in order to propose the required RE that need to be proposed within the site boundary. Keeping in mind that the minimum produced energy during one day should fit with the peak registered energy consumption day during the year, this will lead to a guaranteed transformation towards EPB.

Chapter Four

Base case Building and Energy Performance

4. Base case Building and Energy Performance

4.1 Overview

This chapter is considering the selected building located in Dubai UAE as the case study where the proposed transformation to EPB will be applied including enhancing envelope efficiency and introducing the required RE that will fulfill the building maximum energy demand. Starting from current actual situation observed from the authority bills, which will be validated through the chosen software to understand the level of credibility. Weather data will be explored and assessed within the software in addition to other parameters that directly affect the simulation outputs for different profiles, while the materials used in constructing the building will present the base case template that could be modified later. The same will be used in this chapter to present the building energy performance since the proposed solutions in the next chapter will be related to the maximum figured energy demand.

4.2 Case Study Validation

Dubai Hills Golf Club (DHGC) is the selected building for the study, the building with its five thousand and five hundred square meters built up area and two floors contains several activities serving surrounding community such as two restaurants, gym, shops located in the first floor while ground floor is including main building services and logistic utilities related to the golf course functions as clear in Fig. (16).

Selected building as a land mark in Dubai Hills is located on the highest point in order to give clear view for the surrounding golf course and remarkable landscaping, besides it is showing many potentials that can help the transformation process towards EPB. Starting from the available landscaping areas and external parking that can be utilized for initiating PV farms, Table (6) showing more information about the main contents included with the plot boundary.

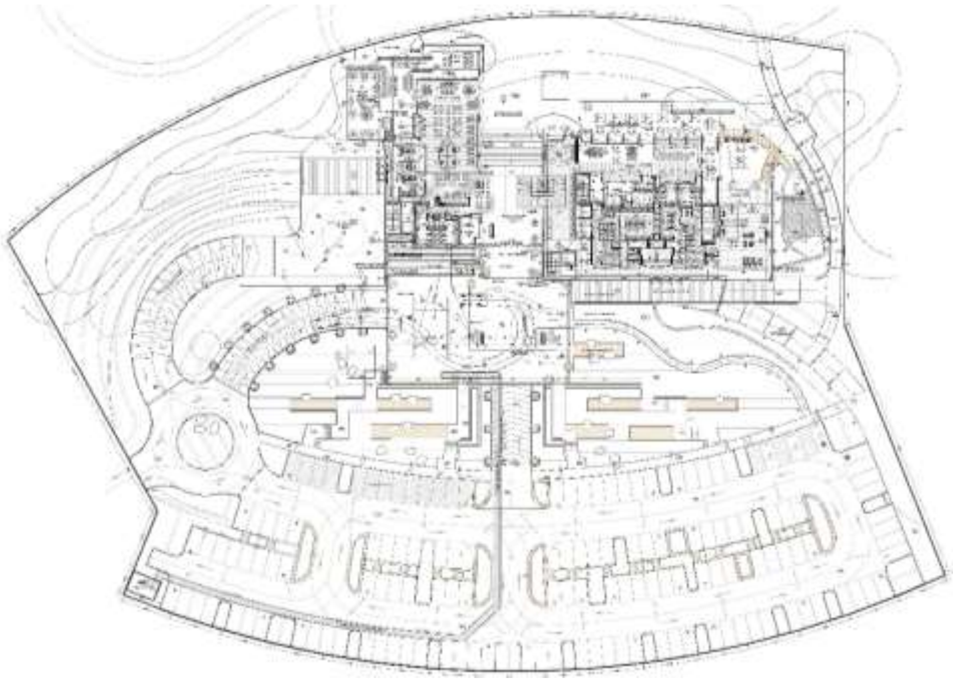


Figure 16 Site Plan Showing Plot Limits and First Floor Plan (Author 2021)

Table 6 Dubai Hills Golf Clubhouse Main Contents (Author 2021)

No.	**Content**	**Area** Square Meters
	General information	
1	Plot Area	19,796
2	Total Built Up Area	5,500
	Ground Floor	**2,927**
3	Drop Off Area (Covered)	560
4	Buggies Parking	975
5	Retail Shop	92
6	Kitchen Services	167
7	Vertical and Horizontal Circulation	833
8	Mechanical and Electrical Services	300
	First Floor	**2,573**
9	Entrance Lobby	215
10	Restaurant One	312
11	Restaurant Two	463
12	Retail Shop	167
13	Gymnasium and Facilities	523
14	Covered Terra	599
15	Services and Management	101
16	Vertical and Horizontal Circulation	193
	External Facilities	
17	Landscaping and Open Terraces	8,028

18	Car Parking, Drive ways and Drop off	9,195

The building reference to its function is being used during specific hours of the day starting from five A.M tell ten P.M by several types of occupants including restaurant customers, gym subscribers and staff, with average occupancy of one hundred person per day during summer days and up to two hundred fifty in the winter during the operational hours which means in the average ten persons per hour. Several activities being held within the building spaces, the ground floor plan which is mostly considered as the back of house (BOH) as clear in Fig. (17) includes most of the operational spaces and tools while Fig (18) is showing the first floor as the front of house (FOH) includes all daily activities related to costumers and visitors.

The electrical bills related to the building located in Dubai Hills were observed through the facility management office located in the same building. While the several inputs were considered in the simulating the building energy consumption including occupancy outlines and cooling loads as well as electrical and lighting loads during the full year, while reference to (DEWA 2020) the cooling level was set to be twenty three Celsius centigrade. The previous building floor plans presented in Figs. (17 and 18) are extracted from as built drawings for the building through AutoCAD software; this will help in providing the final dimension to initiate the model in IES-VE using MODELIT tool as clear in Fig. (20) where the blue colour illustrates the envelope including walls and roof, the transparent shapes are presenting the windows while the green masses are identifying the shading elements.

Figure (19) illustrates part of the monthly utility bills as issued by the provider DEWA while Table (7) presents the consumed electricity reference to actual bills for the building conducted in the duration starting from September of year two thousand twenty for one year, monthly consumption gradually increased once being more close to the summer months.

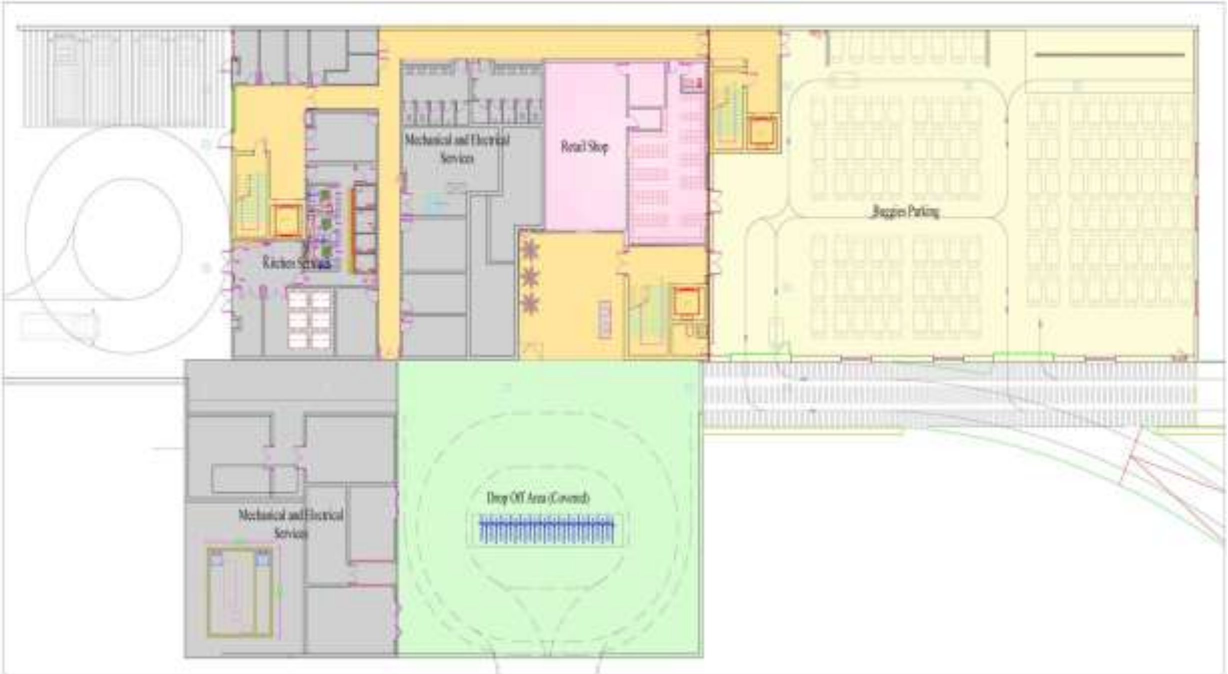


Figure 17 Ground Floor Layout (Author 2021)

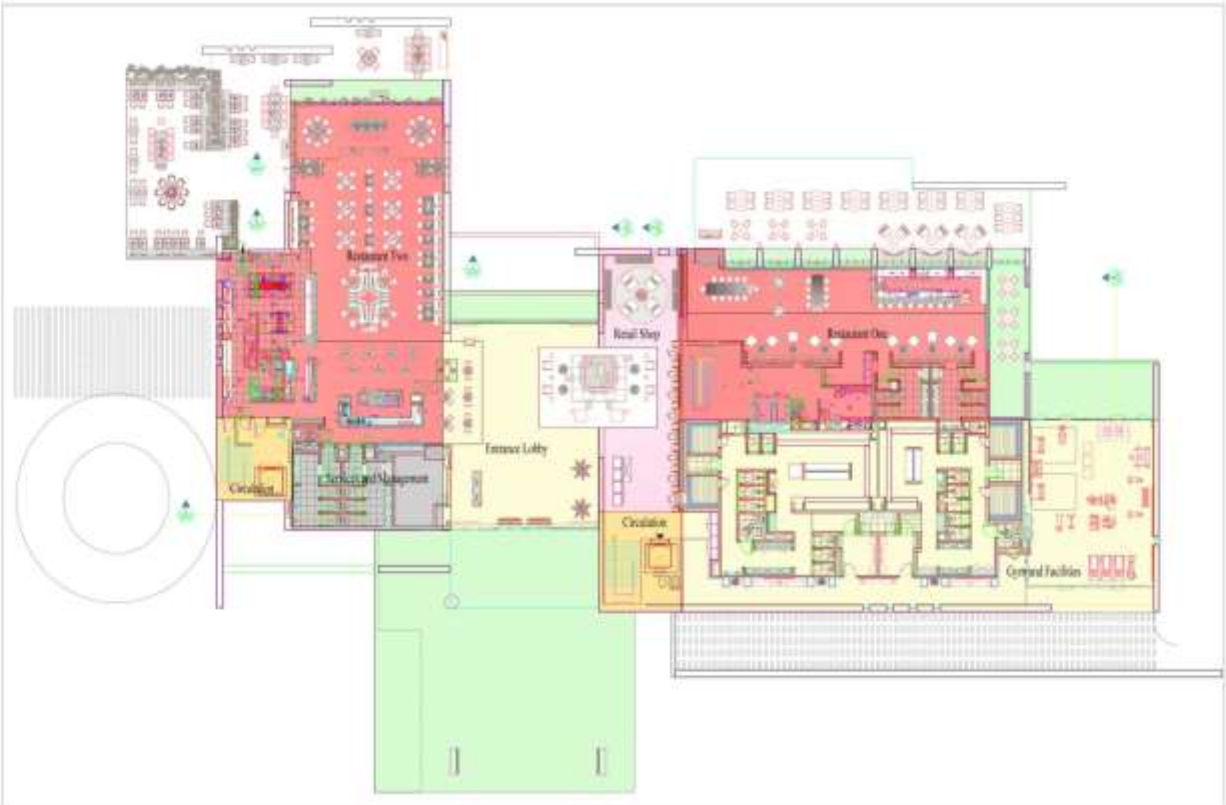


Figure 18 First Floor Layout (Author 2021)

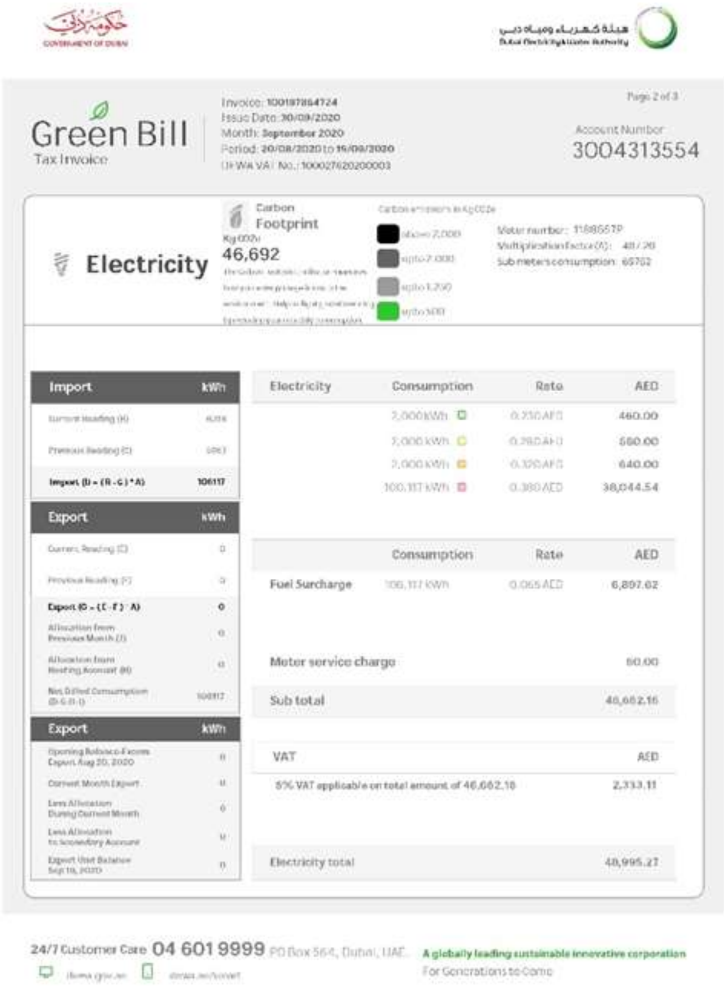


Figure 19 Utility Bill/ Electricity as issued monthly from DEWA (DEWA-Author 2021)

Table 7 Monthly Energy Consumption as per DEWA Bills (DEWA-Author 2021)

Month	**DEWA Bills** Kilowatt Hours
January 2021	49,267
February 2021	56,831
March 2021	64,296
April 2021	85,938
May 2021	94,415
June 2021	123,488
July 2021	114,037
August 2021	122,149
September 2020	106,117
October 2020	90,905
November 2020	72,410
December 2020	69,932
Total	**1,049,785**
Average	**87,482**

4.3 Introducing Simulation Software

Table (8) presents comparison between consumed electricity reference to actual bills for the building conducted in the duration starting from September of year two thousand twenty for one year in parallel with the results observed from the simulation process using the IES-VE, noting that table arrangement started from January to match with IESVE results.

Table 8 Monthly Energy Consumption Comparison between DEWA bills and IESVE simulation (IESVE-Author 2021)

Month	**DEWA Bill** Kilowatt Hours	**IESVE Results** Kilowatt Hours	**Difference** Kilowatt Hours	**Difference** Percentage
January 2021	49,267	16,645	32,622	66.2 %
February 2021	56,831	13,776	43,055	75.8 %
March 2021	64,296	21,614	42,682	66.4 %
April 2021	85,938	36,796	49,142	57.2 %
May 2021	94,415	56,924	37,491	39.7 %
June 2021	123,488	64,306	59,182	47.9 %
July 2021	114,037	73,024	41,013	36.0 %
August 2021	122,149	74,679	47,470	38.9 %
September 2020	106,117	63,011	43,106	40.6 %
October 2020	90,905	47,231	43,674	48.0 %
November 2020	72,410	27,018	45,392	62.7 %
December 2020	69,932	14,597	55,335	79.1 %
Total	**1,049,785**	**509,621**	**540,164**	
Average	**87,482**	**42,468**	**45,014**	**51.5 %**

As observed from the energy table, authority bills showing an average extra monthly amount of forty-five megawatts from the simulation tool and the explanation for that is the criteria and function of the building. Starting from the heavy duty kitchens that is relying on electricity for operating the daily activities including cooking and cooling food, on the other hand, more than one hundred and ten buggies serving golf course daily activities are being charged every day in the ground floor area. Finally, during the night and off hours some instruments and tools will remain working unlike data inserted in the software, such factors are not included in the IESVE simulation. However, the energy difference noticed in June and December is showing slight fluctuations as being more than the average and the same was subjected to maintenance issues and the COVID-19 protocols and sanitization, keeping in mind that percentages between the actual bills and simulation is increased once going closer to winter months.

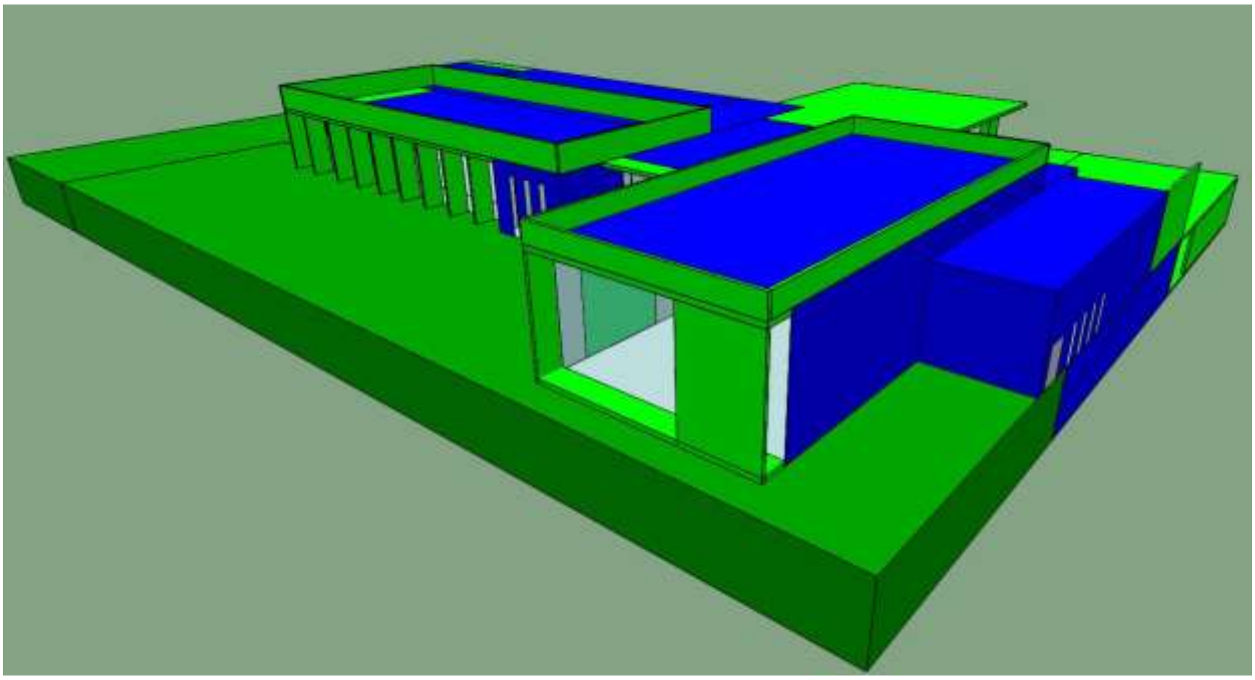


Figure 20 Building Masses (IESVE-Author 2021)

4.4 Weather and Site Data

Similar to most of the countries, UAE weather data can be extracted from IES-VE once identifying the location through APLOCATE tool, after identifying the latitude and longitude of the building which is figure as 25.12°N and 55.26°E as clear in Fig. (21), the tool helps in offering the actual weather conditions that building could face in any time of the year. Dubai Weather cane can be identified by two main periods, the temperature varies between twenty to twenty-three Celsius centigrade between December and March while for the rest months it is going up reaching the forties which stating the climate to be a hot arid.

As clear in Table (9), the preferred orientation for PV should face as much as possible where the sun explorer varies between nine to thirteen hours per day, while as figured from software simulation, Table. (10) is showing the amount of solar radiation that could reach up to two hundred kilowatt hour per square meter showing reasonable amount that could easily benefited for harvesting energy. while as per Fig. (22) which illustrates the temperature measurement types during the year helps in figuring the required mechanical systems to push the building towards the comfort level.

Figure 21 Sun Path diagram for the building located in Dubai (IESVE-Author 2021)

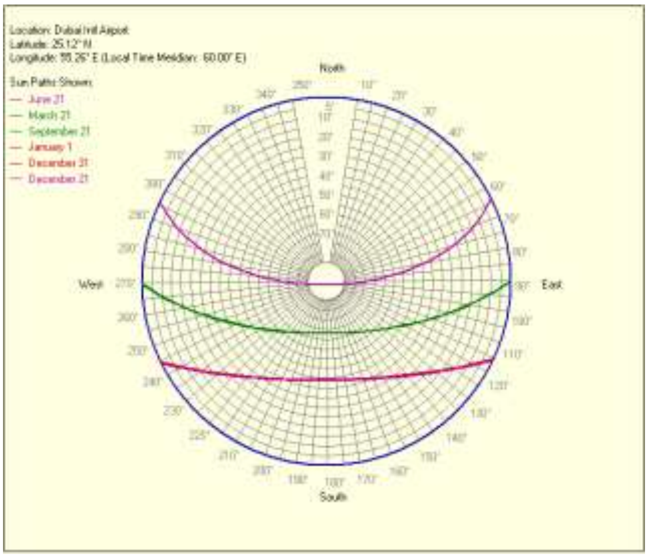
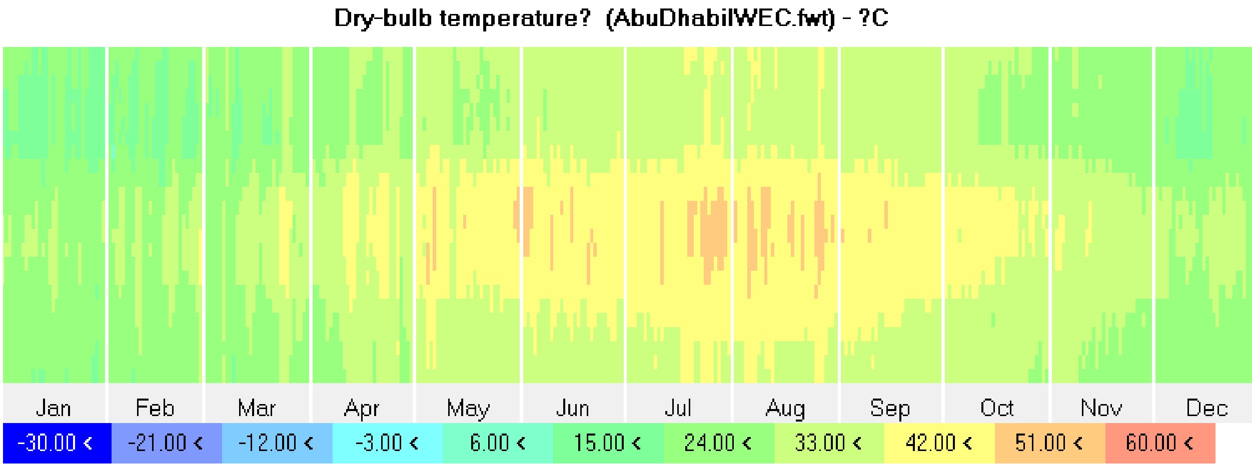


Table 9 Sun cast Azimuth During the Year (IESVE-Author 2021)

Time	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15
05:00												
06:00					71.38°	66.87°	67.96°	75.10°				
07:00		104.82°	95.91°	85.65°	77.05°	72.25°	73.56°	81.13°	92.97°	104.77°	113.23°	
08:00	119.35°	111.72°	102.81°	91.94°	82.34°	76.97°	78.55°	86.99°	99.87°	112.31°	120.71°	122.80°
09:00	127.88°	120.20°	111.13°	99.22°	87.84°	81.35°	83.36°	93.43°	108.31°	121.91°	130.22°	131.71°
10:00	138.92°	131.36°	122.38°	109.19°	94.60°	85.83°	88.62°	101.82°	120.19°	135.11°	142.74°	143.21°
11:00	153.27°	146.67°	139.26°	126.37°	106.24°	91.56°	96.17°	116.25°	139.49°	153.84°	159.05°	157.89°
12:00	170.97°	167.05°	165.03°	162.97°	150.16°	111.44°	121.31°	153.36°	171.52°	178.27°	178.57°	175.37°
13:00	190.13°	190.28°	196.35°	213.49°	240.83°	261.13°	247.91°	219.19°	208.00°	203.18°	198.36°	193.56°
14:00	207.67°	211.19°	221.69°	241.21°	260.63°	270.81°	265.58°	248.11°	232.52°	222.76°	215.21°	209.80°
15:00	221.81°	227.08°	238.24°	254.90°	269.01°	275.83°	272.41°	260.43°	247.02°	236.58°	228.22°	222.87°
16:00	232.68°	238.65°	249.31°	263.59°	274.94°	280.21°	277.52°	268.17°	256.66°	246.56°	238.10°	232.99°
17:00	241.08°	247.38°	257.53°	270.38°	280.25°	284.67°	282.33°	274.38°	264.09°	254.31°	245.81°	240.89°
18:00		254.42°	264.39°	276.56°	285.67°	289.59°	287.40°	280.23°	270.60°			
19:00						295.31°	293.14°					
20:00												



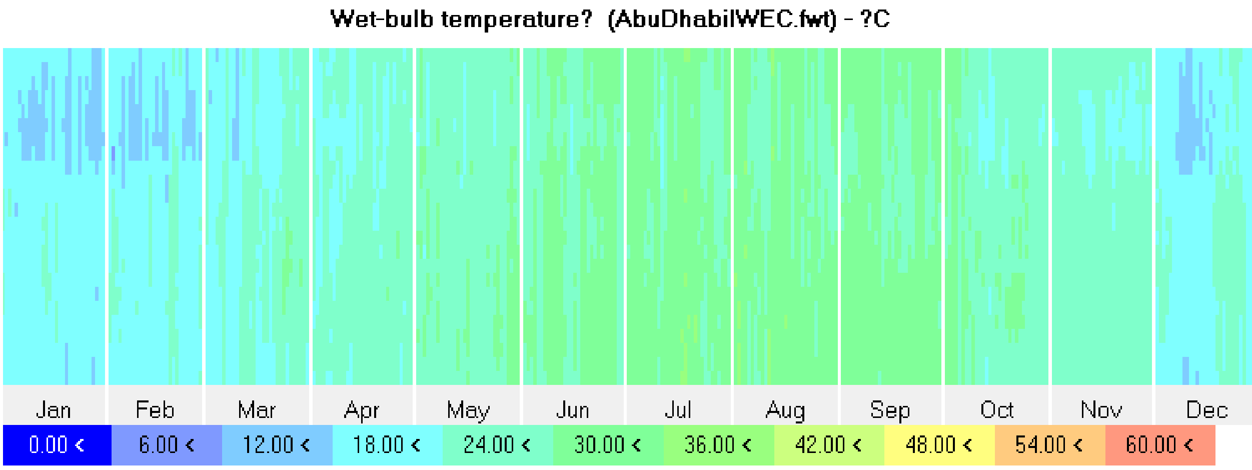


Figure 22 Dry and Wet Bulb Temperature (IESVE-Author 2021)

Table 10 Direct and Diffused Radiation (IESVE-Author 2021)

Month	**Direct Radiation** Kilowatt Hours/m^2	**Diffused Radiation** Kilowatt Hours/m^2
January	169.24	39.53
February	186.12	37.35
March	161.24	62.62
April	173.44	65.08
May	226.09	59.39
June	223.75	54.83
July	202.91	65.96
August	209.05	58.40
September	201.37	47.89
October	203.22	41.70
November	177.55	35.57
December	160.93	38.41
Total	**2,294.92**	**606.72**

Figure (23) is illustrating the solar radiation reaching the building envelope as illustrated by IES-VE, noting that reference to program basis, the coloured areas presents the envelope covering habitable areas with mechanical control for internal temperature and air ventilation.

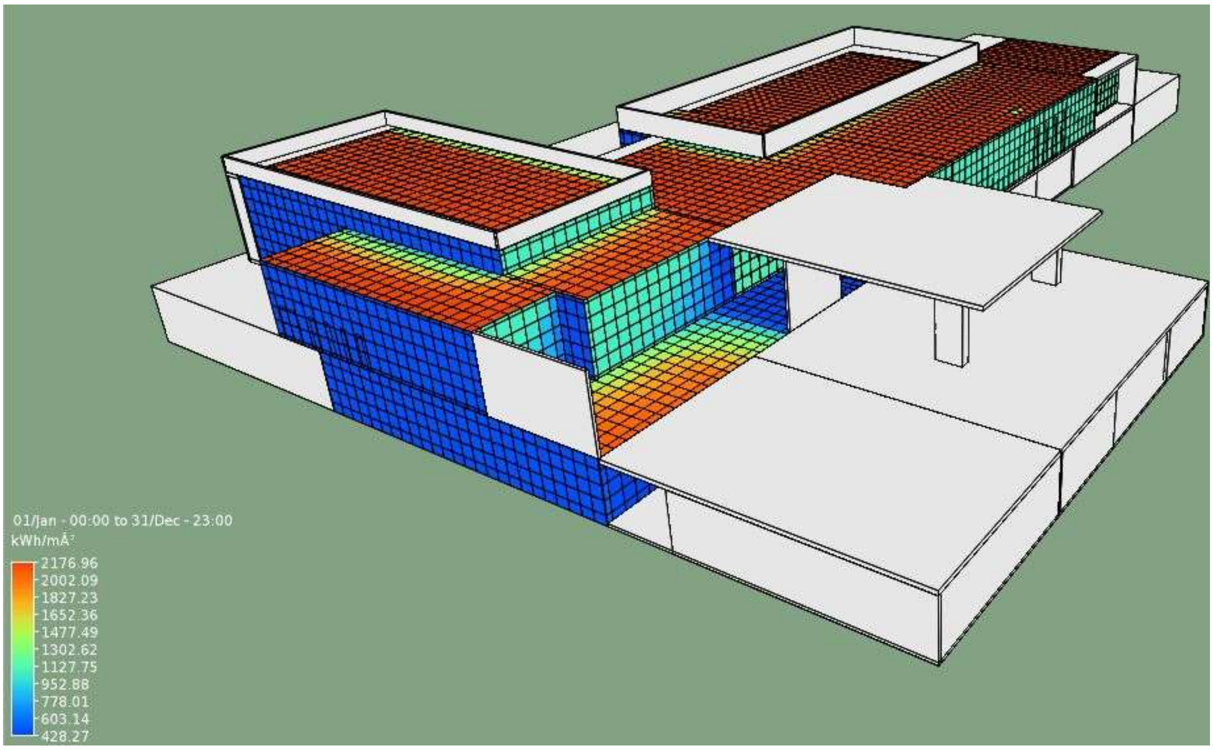


Figure 23 Radiation Level reaching Building Envelope (IESVE-Author 2021)

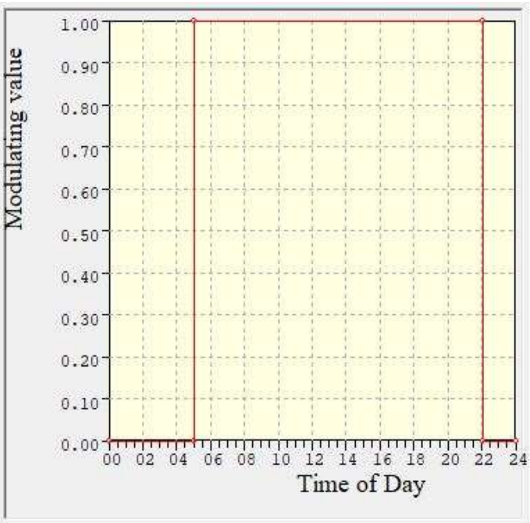
4.5 Simulation Profiles

The building reference to its function is being used during specific hours of the day starting from five A.M tell ten P.M, the same is identified in IESVE the value one once occupied where operational consumption will cover all required energy and zero for no occupancy where no energy consumption will be considered as clear in Fig. (24). On the other hand, and reference to the building function, it will be considered under operation stage for all days of the week, and the same will be presented in the annual energy consumption.

The usual exercise for presenting the energy profiles is relying of the occupancy and mechanical systems, starting from the mechanical which identified by default within the software referring to the climatic data registered for each zone. Regarding the occupancy profile and reference to the big difference in energy consumption once comparing the software with the actual bills, it is showing huge deference that need to be identified. However, many variables are participating in this procedure, including complicated instruments serving the main kitchens to fulfill the restaurants requirements, variable occasions and ceremonies could take place in the restaurants lead to more complication on identifying the consumption level per time. Moreover, variable participation levels are being conducted in the gym and its facilities depending on season and tournaments conducted in DHGC, which will include also utilizing the buggies. All these fluctuations can be considered in general direction by adding the average variation calculated in Table. (5) as forty-two Megawatts to the simulation results.

Figure 24 Daily Energy Consumption Profile (IESVE-Author 2021)

	Time	Value
1	00:00	0.000
2	05:00	0.000
3	05:00	1.000
4	22:00	1.000
5	22:00	0.000
6	24:00	0.000



4.6 Construction Template

IESVE through the template tool is offering flexible way to match the building materials with the real existing through number, thickness, type and properties of each layer until reaching the desired U-Value for the envelope including walls, roof, glazing and any other building element that could affect the energy performance. Considering the existing building materials as the base case that is referring to Dubai green building regulation is offering for external walls 0.52 Watts per meter squared Kelvin as clear in Fig. (25) while in the roof the value is 0.58 reference to Fig. (26).

Figure 25 Base Case External Wall Thermal Transmittance value (IESVE-Author 2021)

Figure 26 Base Case Roof Thermal Transmittance value (IESVE-Author 2021)

U-value: 0.5207 W/mÂ²Â·K Thickness: 280.000 mm Thermal mass Cm: 137.9200 kJ/(mÂ²Â·K)

Total R-value: 1.7506 mÂ²K/W Mass: 397.3000 kg/mÂ² Mediumweight

Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[USPM0000] CEMENT PLASTER - SAND AGGREGATE (ASHRAE)	15.0	0.7200	1860.0	800.0	0.0208	140.000	Plaster
[BRI] BRICKWORK (INNER LEAF)	100.0	0.6200	1700.0	800.0	0.1613	35.000	Brick & Blockwork
[MFSL] MINERAL FIBRE SLAB	50.0	0.0350	30.0	1000.0	1.4286	6.000	Insulating Materials
[BASEBK01] Brickwork (Outer Leaf)	100.0	0.8400	1700.0	800.0	0.1190	40.000	Brick & Blockwork

Net U-value (including frame): 2.8777 W/mÂ²Â·K U-value (glass only): 2.8221 W/mÂ²Â·K

Net R-value: 0.3543 mÂ²K/W g-value (EN 410): 0.5045 Visible light normal transmittance: 0.76

U-value: 0.3032 W/mÂ²Â·K Thickness: 410.000 mm Thermal mass Cm: 230.0000 kJ/(mÂ²Â·K)

Total R-value: 3.1579 mÂ²K/W Mass: 683.6500 kg/mÂ² Heavyweight

	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[CC] CAST CONCRETE	50.0	1.1300	2000.0	1000.0	0.0442	500.000	Concretes
[MFSL] MINERAL FIBRE SLAB	105.0	0.0350	30.0	1000.0	3.0000	6.000	Insulating Materials
[STD_MEM] Membrane	5.0	1.0000	1100.0	1000.0	0.0050	-	Asphalts & Other Roofing
[STD_CC2] Reinforced Concrete	250.0	2.3000	2300.0	1000.0	0.1087	-	Concretes

Once considering the first floor where most of the FOH activities are being conducted, the glass percentages are reaching around thirty-eight percentages, which require as per Table. (01) related to Sa’fat requirements minimum thermal transmittance of 2.1 Watts per meter squared Kelvin while as presented in Fig. (27), the actual used U-Value is around three.

Figure 27 Base Case Glass Thermal Transmittance value (IESVE-Author 2021)

Chapter Five

Strategies, Results & Discussion

5. Transformation towards EPB

5.1 Overview

The chapter will go deeply in proposing enhancement tools that can push the building towards energy plus criteria through two main steps. Starting from enhancing the building envelope by reducing the U-Value, the same will offer energy saving as it will be conducted using the software where the peak day can be recognized. Peak day will be considered as the milestone in which the generated RE will be studied to cover, RE options will be figured in order to select the optimum criteria with the minimum cost including PV types, orientation and inclination.

5.2 Improving Envelope Materials

DHGC is considered the landmark and focal point within that community, with the remarkable materials used in the facade especially stone slabs used in the external elevation as clear in Fig. (28) and iconic metal elements covering the windows, while it is not feasible financially to modify the façade since the same will face obvious rejection from the decision makers, same as the unique interior design features which are highly integrated with the interior function. From such point of view, roof and glazing are showing most potential sides for retrofit.

5.2.1 Roof Improvement

Starting from the building roof which is dedicated for MEP services, the U-Value as presented and required by Sa'fat is 0.3 W/m^2K in all categories, however Pearl system adopted in Abu Dhabi is requesting more attractive input to be less than 0.12 W/m^2K. This for sure will show fundamental energy consumption saving while in the same time afforded within the county since it is mandatory in one emirate. IES-VE will be used to assess this transformation by adding thermal insulation layers to the roof with the minimum thickness that achieve the desired value as illustrated in Fig. (29) showing the at least extra twelve centimeter of polyurethane board will be applied on the roof and exposed slab level from below like the buggies space in ordered to reach 0.123 W/m^{2}K.

Figure 28 DHGC Exterior and Interior Features (Author 2021)

Applying improvements on the envelope thermal insulation is contributing in decreasing the annual energy consumption by twenty-one percentages as clear in Table. (11) with more than one hundred and six megawatts annual saving. Keeping in mind, the additional fixed forty-five megawatts monthly presented previously in Table. (8) will remain presented once calculating the final consumption.

Figure 29 Improved Roof and U-Value after adding Insulation Layers (IESVE-Author 2021)

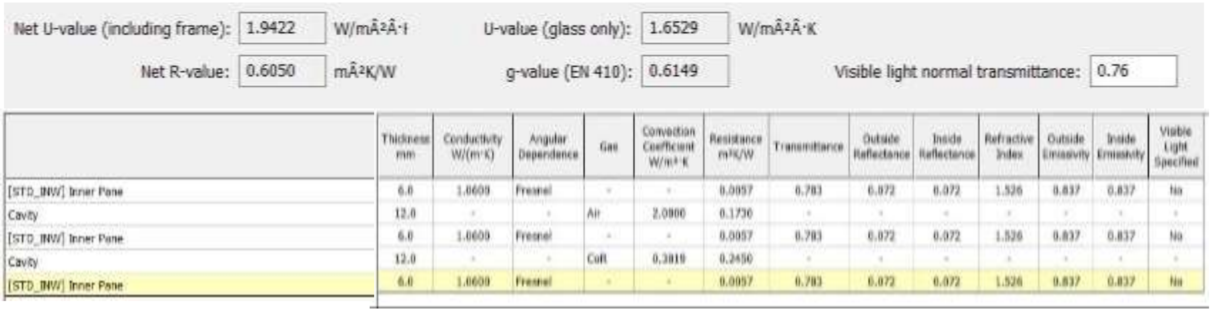
Table 11 Monthly Energy Consumption Comparison for Base Case and Improved Case (IESVE-Author 2021)

Month	**Base Case** Kilowatt Hours	**Improved Roof** Kilowatt Hours	**Difference** Kilowatt Hours
January	16,645	15,862	783
February	13,776	19,054	-5,278
March	21,614	23,833	-2,219
April	36,796	31,862	4,934
May	56,924	42,021	14,903
June	64,306	44,697	19,609
July	73,024	48,725	24,299
August	74,679	49,809	24,870
September	63,011	44,147	18,864
October	47,231	37,598	9,633
November	27,018	26,912	106
December	14,597	18,788	-4,191
Total	**509,621**	**403,308**	**106,313**
Average	**42,468**	**33,609**	**8,895**

The additional thermal insulation considered as feasible process reference to the reasonable achieved savings, the same will be assessed in details in coming sections.

5.2.2 External Glazing

Moving forward to the external glazing whereas mentioned in Sa’fat the required U-Value to be less than 1.9 W/m^{2}K and for achieving the same, additional glass layer will be added with gab, so that it will be transformed to triple glassing system. However, once the additional layer installed in IES-VE, it was required to provide special treatment by adding the Capron dioxide gas (CoR as used in IES-VE) in the cavity as clear in Fig. (30) which unfortunately complicated process and will have high initial cost and unfeasible commercially since the PBP will be very long and finally applying such process will affect or hold the building operation since applying argon gas will require special treatment in specific factories.


Net U-value (including frame): 1.9422 W/mÂ²Â·I U-value (glass only): 1.6529 W/mÂ²Â·K
Net R-value: 0.6050 mÂ²K/W g-value (EN 410): 0.6149 Visible light normal transmittance: 0.76

	Thickness mm	Conductivity W/(m·K)	Angular Dependence	Gas	Convection Coefficient W/m²·K	Resistance m²K/W	Transmittance	Outside Reflectance	Inside Reflectance	Refractive Index	Outside Emissivity	Inside Emissivity	Visible Light Specified
[STD_INW] Inner Pane	6.0	1.0600	Fresnel	-	-	0.0057	0.783	0.072	0.072	1.526	0.837	0.837	No
Cavity	12.0	-	-	Air	2.0900	0.1730	-	-	-	-	-	-	-
[STD_INW] Inner Pane	6.0	1.0600	Fresnel	-	-	0.0057	0.783	0.072	0.072	1.526	0.837	0.837	No
Cavity	12.0	-	-	CoR	0.3819	0.2450	-	-	-	-	-	-	-
[STD_INW] Inner Pane	6.0	1.0600	Fresnel	-	-	0.0057	0.783	0.072	0.072	1.526	0.837	0.837	No

Figure 30 Minimum U-Value Achieved after applying additional glass layer with CO2 Gas Fill (IESVE-Author 2021)

5.3 Energy Production Strategies through Solar Photovoltaic.

Introducing the PV panels must go through several scenarios to figure the optimum results that can offer the best energy supply to the building. Accordingly, and through IES-VE, the process will start by choosing one of the three PV types available on the software no matter of its efficiency level and test the best orientation and inclination, after figuring the best position the three PV will be tested to select most effective type.

5.3.1 PV Orientation

The direction of PVs will be tested through the four main azimuth angles where the inclination will be proposed tentatively on fixed angle as twenty degrees from horizontal and the type is monocrystalline silicon noting that type and inclination will be verified in the next two sections. As clear in below Table (12) where the monthly and annual energy production will be generated from one squared meter of PV panel. As observed from the results, south direction illustrates the best orientation for PV producing energy, even though east and west orientations shows potential results and even exceeding the south direction results specially in June and July. The same proves that during the year and according to the sun location south could be not always the optimum direction especially once relying on fixed PV systems. This gives the smart orienting PV systems more credit for the amount of collected energy, while such systems will require complicated procedures related to software, maintenance and cost wise.

The south direction annual energy production could reach more than three hundred and eighty kilowatt hour per square meter once relying on the specified inclination and type; this means the number still varies according to the other two configurations that will take place.

Table 12 Monthly Generated Energy from PVs in KWh/m2 Reference to PV Orientation (IESVE-Author 2021)

Month	East	South	West	North
January	20.6	28.2	21.0	12.1
February	23.6	30.3	24.0	16.2
March	27.1	31.3	28.1	23.1
April	31.0	32.8	30.7	28.4
May	36.3	36.8	37.1	36.5
June	35.7	35.0	36.2	36.9
July	35.2	35.0	35.6	35.7
August	34.1	35.7	34.3	32.6
September	30.5	34.4	30.7	26.1
October	26.9	33.3	27.3	19.9
November	21.1	28.3	21.3	13.1
December	19.1	26.5	19.1	10.9
Total	**341.2**	**387.7**	**345.3**	**291.6**

5.3.2 PV Inclination

As per (Jafarkazemi & Saadabadi 2013), the best inclination angle for PVs to harvest the maximum solar energy is around 24.4 degrees, however the same angle is pressing two seasons of the year including spring and autumn while the angle decreased reaching zero in summer where the sun is almost perpendicular and increased to reach around fifty decrease in winter. According to IESVE, the tilt angle is flexible but must not have any binaries, accordingly twenty-five degrees will be figured. As clear from Table (13) the best PV performance proportioned with the inclination and as clear the degree should go towards zero as once going close to the summer months. However, for the same reason discussed in the previous section, it is not feasible to rely on manual or smart tracking systems reference to several issues related to maintenance and cost. Even that twenty-five degrees showing best performance only in three months, it is showing most convenient results during the full year and accordingly it will be used in the coming simulations. Finally, the results still need to be verified for the third constant related to PV type in the next section.

Table 13 Monthly Generated Energy From PVs in KWh/m2 Reference To PV Inclination (IESVE-Author 2021)

Month	Zero Degree	25°	50°	Best Result
January	21.8	29.4	31.9	31.9
February	24.8	31.1	32.0	32.0
March	28.7	31.4	29.3	31.4
April	32.5	32.4	27.2	32.5
May	38.6	35.7	26.7	38.6
June	37.9	33.7	23.7	37.9
July	37.2	33.8	24.9	37.2
August	36.1	35.0	28.0	36.1
September	32.4	34.4	30.7	34.4
October	28.4	34.3	34.0	34.3
November	22.1	29.3	31.3	31.3
December	20.0	27.7	30.6	30.6
Total	**360.6**	**388.3**	**350.4**	**408.2**

5.3.3 PV Selection

Reference to (Allouhi et al. 2019), three main factors must be addressed once selecting the PV technology including the energy yield, system cost and environmental impact. Starting from the economic side which is important to understand the PBP for any installed system, poly crystalline is considered the lowest PBP with range of 16 years followed by the monocrystalline which higher by around twenty-six percentages, and finally the thin film showing in average more than thirty years for PBP.

Moving to the environmental aspects presented in the carbon dioxide emissions reduced once relying on PV systems, where the polycrystalline is proving the highest results that reach up to fourteen hundred tons of carbon dioxide per kilowatt peak power yearly. Relying on IES-VE for the available PV types, Table (14) presents the third factor showing the annual energy production for five different types including polycrystalline, monocrystalline, amorphous and thin films. Unlike the previous results, monocrystalline is showing more yield energy than polycrystalline, which could be potentially utilized once the affordable areas are limited and budget is flexible. Reference to DHGC, and reference to the huge energy demand required to be covered, it is more feasible to considered the highest energy producer from PV types, accordingly, monocrystalline type will be the chosen approach.

Table 14 Monthly Generated Energy from PVs in KWh/m2 Reference to PV Type (IESVE-Author 2021)

Month	**Poly-crystalline**	**Mono-crystalline**	**Amorphous**	**Cadmium-Telluride**	**Copper Indium Gallium Diselenide**
January	24.7	29.4	13.1	17.6	19.0
February	26.1	31.1	13.9	18.6	20.2
March	26.4	31.4	14.0	18.8	20.4
April	27.2	32.4	14.4	19.4	21.0
May	29.9	35.7	15.9	21.4	23.2
June	28.2	33.7	15.1	20.2	21.9
July	28.4	33.8	15.1	20.3	22.0
August	29.3	35.0	15.7	21.0	22.7
September	28.8	34.4	15.4	20.6	22.3
October	28.8	34.3	15.3	20.6	22.3
November	24.6	29.3	13.1	17.5	19.0
December	23.3	27.7	12.3	16.6	17.9
Total	**325.7**	**388.3**	**173.3**	**232.4**	**251.8**

5.4 Peak Day Demand

The energy demand for any building during the day varies according to the occupancy and external weather situation. As for the case study, the building has no activities or occupancy for seven hours daily during the night, which can be omitted from the daily consumption hours. Based on IES-VE simulation and considering the roof improvements, as clear in Table (15) the energy consumption peak day during the year is the twenty sixth of August whereas presented previously in Table. (9) the sun radiation will be available for around thirteen hours starting from six A.M tell seven P.M that identifies the availability duration of RE that can support the building. Going forward to the daily energy consumption illustrated on the peak day in Table (16) it is important to highlight the extra energy consumption that need to be considered and added to the IES-VE calculation to reach actual energy consumption by adding forty-five megawatts monthly as described earlier in Table. (8), it is clear that around 2.643 Megawatt-hour being consumed during the sun availability while the rest 0.484 Megawatt-hour are being consumed during sun absence either during the morning or night.

Table 15 Base Case Peak Energy Selection (IESVE-Author 2021)

	Peak Date	Peak Time	Total system energy? (kW)
Model	26 Aug	10:30	127.5712

Table 16 Peak Day Building Energy Consumption and Energy Production per Square Meter (IESVE-Author 2021)

Timing	**Solar Radiation**	**IES-VE Consumption** Kilowatt Hours	**Actual Consumption** Kilowatt Hours	**PV Production** Watt Hours/m²	**PV Production** Kilowatt Hours/2841 m²
00:00 – 05:00 Off Hours	Not Available	0.0	0.0	0.0	0.0
06:00	Not Available	96.9	186.2	0.0	0.0
07:00	Available	77.1	148.2	6.9	19.6
08:00	Available	88.5	170.1	26.1	74.2
09:00	Available	109.4	210.3	61.3	174.2
10:00	Available	126.0	242.2	102.9	292.3
11:00	Available	127.6	245.2	136.3	387.2
12:00	Available	118.8	228.3	155.8	442.6
13:00	Available	115.1	221.2	161.0	457.4
14:00	Available	115.1	221.2	152.4	433
15:00	Available	116.9	224.7	130.1	369.6
16:00	Available	110.0	211.4	95.6	271.6
17:00	Available	98.4	189.1	53.8	152.8
18:00	Available	88.7	170.5	20.2	57.4
19:00	Available	83.5	160.5	5.5	15.6
20:00	Not Available	79.0	151.8	0.0	0.0

21:00	Not Available	76.1	146.3	0.0	0.0
22:00 – 00:00 Off Hours	Not Available	0.0	0.0	0.0	0.0
Total		**1,627.1**	**3,127.2**	**1,101.0**	**3,147.5**

As clear in Table (13), produced energy is not always higher than consumed one that explains the need of being connected to the grid which helping in balancing the income and outcome. From the previous information, PV should produce during the thirteen hours of sun radiation the required energy that cover the operational seventeen hours, noting that the extra unrequired energy during the day timing will be transferred to the grid and used in the night timing.

Once recognizing the peak day energy demand, it will be clear the required energy to be covered relying on RE, around one thousand four hundred seventy-eight PV panel must be provided within the plot boundary specified as monocrystalline type, facing the south, with twenty-five degrees' inclination and one square meter area.

5.5 Area optimization Strategy

It is preferred to locate the PV panels as close as possible to the building in order to reduce the produced electricity within the long wires, so the building roof presents the best location for placing the panels. Figure. (31) presents the PV distribution on the available space above the building, achieving eight hundred and thirty square meters. The same area is achieved after subtracting the roof services area and useful spaces that could not receive sufficient direct solar radiation, in addition to that two-meter periphery provided all around the roof to insure the safety measurements and reducing ruining the building view. Finally, specific spacing is provided between arrays for maintained and periodical cleaning purposes. Around eight hundred and thirty square meters provided on the roof covering around thirty percentages of the total peak energy demand.

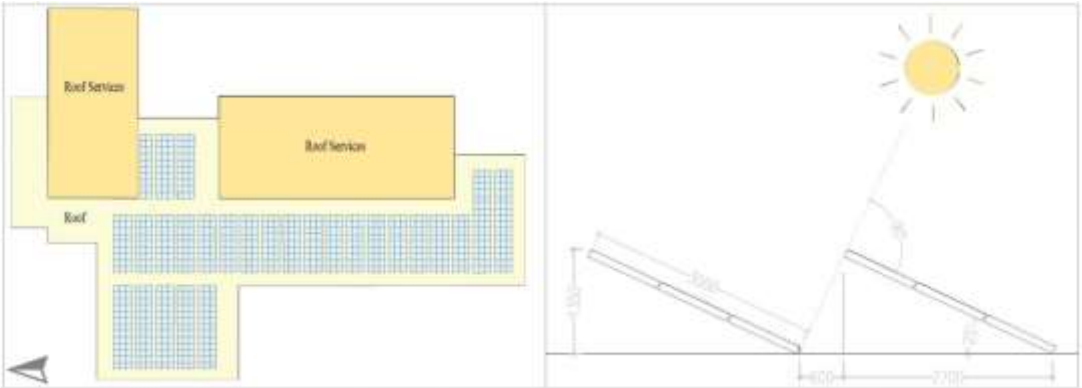


Figure 31 DHGC PV Roof Distribution (Author 2021)

Additional location to be figured for assisting the PV panels' distribution in order to fulfill energy demand of the building, external car parking area is showing potential space for creating supportive PV farm reference to the available spacious space and being adjacent to the building. PVs will be distributed on the parking area as clear in Fig. (32) covering all parking slots and offering one thousand and eight hundred PV panels. The balance panels required to cover the peak day demand which is around two hundred eleven square meter will be distributed on the kids play area and pedestrian footpaths.

Figure 32 DHGC PV Site Distribution (Author 2021)

5.6 Extra produced energy utilization.

The decision of providing specific number of PV panels was based on the peak day energy demand; the demand of the building is descending before and after that date until reaching lowest energy demand in winter days. The formula is not applicable on the provided PV panels, since PVs will continue collecting energy as long as the solar radiation is available all over the year, this situation will cause extra collected energy in monthly and yearly basis once compared to building needs as clear in Table (17).

Table 17 Monthly IES-VE and Actual Energy Consumption VS Generated Energy from PVs (IESVE-Author 2021)

Month	**IES-VE Consumption** Kilowatt Hours	**Actual Consumption** Kilowatt Hours	**PV Production** Kilowatt Hours /m²	**PV Production** Kilowatt Hours/2841 m²	**Surplus** Kilowatt Hours
January	15,862	60,862	29.4	83,525.4	22,663
February	19,054	64,054	31.1	88,355.1	24,301
March	23,833	68,833	31.4	89,207.4	20,374
April	31,862	76,862	32.4	92,048.4	15,186
May	42,021	87,021	35.7	101,423.7	14,403
June	44,697	89,697	33.7	95,741.7	6,045
July	48,725	93,725	33.8	96,025.8	2,301
August	49,809	94,809	35.0	99,435.0	4,626
September	44,147	89,147	34.4	97,730.4	8,583
October	37,598	82,598	34.3	97,446.3	14,848
November	26,912	71,912	29.3	83,241.3	11,329
December	18,788	63,788	27.7	78,695.7	14,908
Total	**403,308**	**943,308**	**388.2**	**1,102,876.2**	**159,568**

The excess of produced energy is not constant and varies reference to radiation level and external temperature that affect directly on the energy demand. As clear in Fig. (33), gab between produced and required energy increased once going closer to winter months. However, there are plenty of direction to utilize excessive energy specially in the parking area that can be considered as transition zone between building plot and neighbors. Turning over towards electric cars can support the transformation process by installing charging machines in the parking area for public and the same will provide a considerable profit talking about PBP.

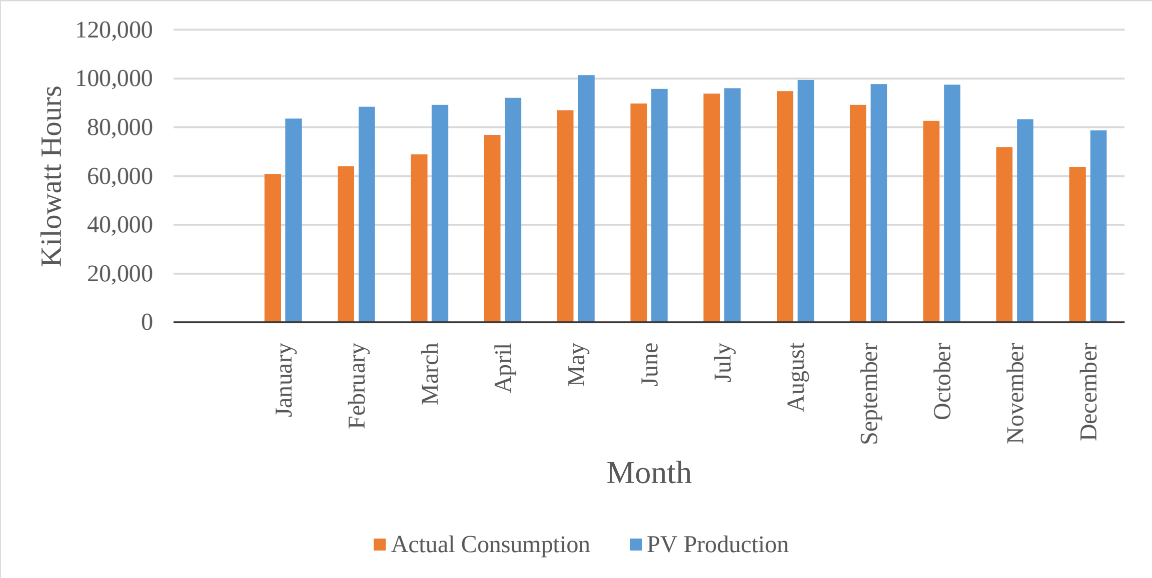


Figure 33 Monthly Actual Energy Consumption VS Generated Energy from PVs (IESVE-Author 2021)

5.7 Payback Period

For any retrofit procedure, clear plan must be presented to the client including detailed revenue plan and expected duration to cover the expenditures so that feasibility of modifications with pros and cons will clear, the same can be presented here on high level to figure the expected period for transferring the building towards EPB.

5.7.1 Initial Cost

Starting for the enhancement procedure applied on the building envelope for the roof and buggies parking high level slab, and reference to market level and investigation with main contractors, the required insulation material presented in twelve centimeters of polyurethane boards and five centimeters of cement screed will cost around one hundred and twenty Arab Emirates Dirhams (AED) per square meter including materials and execution fees. Moving forward to PV panels considering the monocrystalline type which cost in average around five

AED per square meter, noting that rates are subjected to many variables that can raise or lower the price such as quantity of installed panels, in addition to the location either on the roof as direct on concrete or on the parking area where steel structure will be required.

Table (18) presents the expected initial cost for the mentioned modifications including annual expenditures starting from renovation of roof and exposed ground slab as well as introducing the RE tools which will be part of PBP calculation. Side effects are not expected specially that all transformation works are external and not affecting building internal operation.

Table 18 Initial Cost Including Renovation and Introducing RE (Author 2021)

Item	**Area** Square Meter	**Rate** AED/ Square Meter	**Expenditures** AED
Thermal Insulation (12cm Polyurethane + 5cm Cement Screed)	2,816	120	337,920
Monocrystalline PV Panels	2,841	500	1,420,500
Total			**1,787,060**

5.7.2 Running Cost

Reference to (Zhao et al. 2019), dust presents a continuous challenge affecting the efficiency of PV panels by minimizing the glass transmittance by around thirteen percentages after one month of exposure. However, cleaning cycle should be properly set to avoid extra running cost and maintain in the same time the PV surface in acceptable level of transparency, the duration will also vary from region to other based on climatic conditions and panel inclination. Figure (34) showing the optimum interval duration as ten days, while cleaning price for each time will be considered as 0.28 AED per square meter for each cycle (Zhao et al. 2019), this will lead to the annual cleaning cost as 10.08 AED per square meter. Noting that PV Maintenance is excluded from the running cost since it is part of purchase warranty.

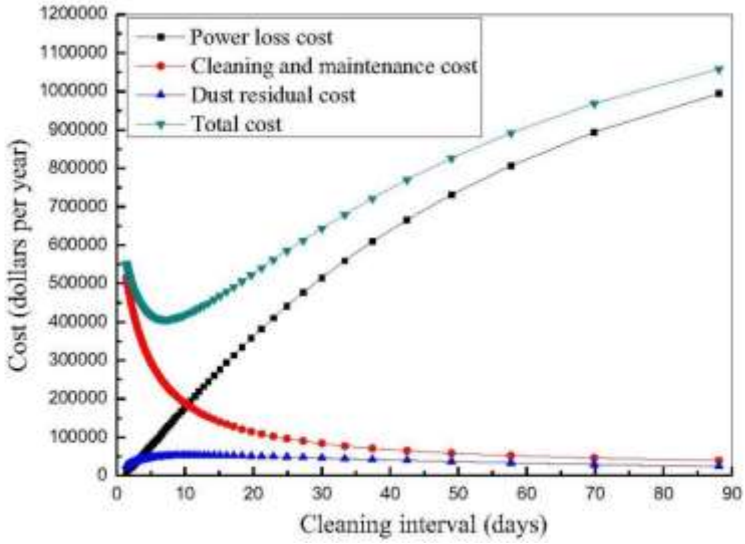


Figure 34 Cleaning cycle optimization and cost evaluation (Zhao et al. 2019)

5.7.3 Energy Cost

Relying on DEWA system for issuing bills, special procedure is being considered for motivating customers for enhancing their consumptions by offering low rates for the first two megawatts of consumption as twenty-three fills per kilowatt. while the rate will increase by five fills for each extra two megawatts and will be fixed on thirty-eight fills per kilowatts for the consumption exceeds the six megawatts as observed in Table (19).

Table 19 Monthly Electricity Consumptions and Bills (Author 2021)

Month	**Actual Consumption** Kilowatt Hours	**< 2 MW** 0.23 AED/ Kw	**2-4 MW** 0.28 AED/ Kw	**4-6 MW** 0.32 AED/ Kw	**> 6 MW** 0.38 AED/ Kw	**Price** AED
January	60,862	460	560	640	20,848	22,508
February	64,054	460	560	640	22,061	23,721
March	68,833	460	560	640	23,877	25,537
April	76,862	460	560	640	26,928	28,588
May	87,021	460	560	640	30,788	32,448
June	89,697	460	560	640	31,805	33,465
July	93,725	460	560	640	33,336	34,996
August	94,809	460	560	640	33,747	35,407
September	89,147	460	560	640	31,596	33,256
October	82,598	460	560	640	29,107	30,767
November	71,912	460	560	640	25,047	26,707
December	63,788	460	560	640	21,959	23,619
Total	**943,308**	**5520**	**6720**	**7680**	**331,097**	**351,017**

The surplus energy presented before in Table. (17) is showing around one hundred and sixty megawatts yearly, the same amount as discussed can be purchased to specific customers who are relying on electricity in their daily external activates like the electric cars. Assuming that rate will be matching with DEWA lowest rate as twenty-three fills per kilowatt then annual income will reach around 36,700 AED, on the other hand, cleaning cost will be subtracted from the total saving amount as clear in Table (20) in order to calculate the total annual saving which will be reaching around 359,080 AED. The annual saving amount will lead to understand the payback period after dividing the transformation cost on the annual saving as clear in Eq. (1) which is parley reaching five years.

Table 20 Annual Savings and Costs for PVs (Author 2021)

Item	**Area** Square Meter	**Rate** AED/ Square Meter	**Expenditures** AED
Energy Cost Provided by PVs			+ 351,017
Income from Surplus Energy			+ 36,700
Cleaning Cost	2,841	10.08	- 28,637
Total			**+ 359,080**

$$Payback\ Period\ = \frac{Total\ Expenditures}{Anual\ Saving} = \frac{1{,}787{,}060}{359{,}080} = \ 4.98\ Years \qquad \textit{Equation 1}$$

5.8 Discussion

From the first look, introducing thousands of solar panels could be considered as overestimated solution for the transformation especially once the initial cost is high. For the case taken, the huge monthly bills presented in the research are considered as supportive side especially once noticing the short payback period which is less than five years. Reference to UAE market, any investment will be considered as successful once achieving PBP less than ten years. Keeping in mind that transformation will have not only financial benefits, but also environmental side by eliminating the carbon emissions for the building and beyond.

One of the hidden factors that could affect the transformation procedure is insuring the continuity of building operation during the retrofit without affecting the daily activities, specially that case taken is commercial building. As discussed previously, the affected locations from transition process will be external only and related to roof insulation and PV fixation where both can be executed in smooth way align with building daily activities without clashing. Another hidden factor related acceptance and awareness of the process potentials which should be highly considered to make the client and decision makers accept the proposal so that funding the initial cost will be secured. Noting that, several parties can participate in the same specially the restaurant and gym tenants in case they are looking to benefit from the retrofit plan.

Chapter Six

Conclusion and Recommendation

6. Conclusions and Recommendations

Day by day, adopting the principles of green buildings is becoming more crucial as one of the leading methods facing the carbon emissions by introducing the natural energy resources that can be more reliable, renewable and with clean effects. Locally, UAE showed impressive response to the global calls for the transformation in the direction of sustainable thinking. Many trends and initiatives emerged during the last two decades seeking for enhancing the energy performance of buildings and providing the best solutions for benefiting from the natural available renewable resources such as sun radiation, wind energy and hydropower. One of the most recent and promising initiatives is the EPB which is considered as advanced level of NZEB. EPB is considered to be more safe category system since it is not only avoiding the reliance on fossil fuel, but also exceeds the plot boundary by providing the power directly or through the available network.

The research investigated in the current situation of EPB including the technologies being used in addition to exploring the obstacles and solutions for achieving the required level of clean energy in monthly and annual basis. Starting from current building materials and comparing the same with the local authority requirements and testing the alternative solutions throw simulation. The same program tool used for testing the best available RE in the country through testing the PV criteria with the best energy yield to make the selection and required quantity.

6.1 Conclusion

The research aimed to check in the possibilities of transferring an existing multipurpose building in Dubai to be a positive energy status through applying optimum green building regulations used in the country. The computerized simulation tool was the selected methodology after deep investigation in several methodologies. At the beginning, IES-VE was verified through introducing current building materials, areas, heights and openings in order to get the monthly and annual energy consumption so that it can be compared with the actual utility bills. An average of extra forty-five megawatts were recognized for each month reference to the special functions and services provided by the building, the same additional amount was considered as constant for later results after modifying the design.

The transformation began with enhancing building envelope specially the roof by applying Sa'fat code where the thermal transmittance must not exceed 0.12 W/m^2K and the same solution was applied to buggies parking slab in ground since it was increasing the possibilities of thermal bridging with upper areas. On the other hand, enhancing the glazing properties showed unfeasible retrofitting results especially from economic side. The envelope improvement showed impressive results by around twenty-one percentages reduction in the building energy consumption which proves how vital is the building envelope thermal transmittance and tightness towards energy consumption. The next step was introducing the RE to the building through most common and available procedure in UAE, after understanding the best production of one square meter of PV according to direction, inclination and type. The required panels provided within the plot boundary either utilizing the available space on the roof, parking and landscaping area.

Three main variables were tested to find the optimum criteria for the PV panels, starting from the orientation where the four main directions were tested and shown in cumulative that south direction has the maximum solar radiation, even though in specific months south was not showing the maximum results. Moving forward to the inclination which is mandatory since the maximum solar gain will be achieved as long as the solar radiation more close to ninety degrees, accordingly the angle twenty-five illustrated the best cumulative annul results. The previous two variables could have extra radiation collection results in case the PV is controlled by tracking system either manual or computerized, unfortunately tracking system will require special periodical maintenance and higher initial cost that could be not feasible in usage. Finally, PV types were tested reference to the available types on the IES-VE which is in line with UAE market, literature review was conducted about PVs in the market covering the financial and environmental aspects along with simulation tests to understand the best energy yield that could be generated under the same conditions. Mono-crystalline showed potential results especially regarding the energy side although it is not the pioneer selection once considering the environmental and financial aspects.

The research concentrated on transferring the building to EPB on daily basis which is considered more reliable than monthly or annual basis. Starting from the beak day demand, where the energy required by the building will be covered through the available radiation hours determined the required PV area that will serve the building during the working hours. Although the energy demand will be descending once moving closer to winter days, PV production will continue producing energy in higher levels that will lead to surplus energy as figured previously, this extra energy can be added to the financial study of transformation process since it can be easily purchased either for customers or utility. Once applying all expected expenses and incomes resulted in the transformation process, it was clear that payback period would not exceed five years, which is highly considered a successful investment either commercially or environmentally.

6.2 Recommendations and Further Research

Building transformation towards sustainable status is not limited to one procedure, continuously more efficient solutions and new technologies being introduced in the market. Accordingly, since the research is a continuation on the enhancement procedures conducted previously, many procedures will follow, so that it is advisable to highlight some points that can be explored widely in future researches. Start from thinking more about alternative advanced procedures for storing and conserving the extra produced energy from PVs especially in winter seasons to insure the financial benefits that should support any future retrofit or enhancement plan. As discussed in the research, extra energy could be sold to specific customers like electric cars users, so that the solution is flexible to extended and go beyond the plot boundary.

Double glazing is the common used material in UAE, besides it is matching with the authorities' requirements. Some existing projects have considerable percentage of the glass covering the external envelop that could reach in some cases to eighty percentages, by relying on the required U-Value, considerable energy losses presented through the glass. Triple glazing system with special gas as filler between layers is showing potential solution. Unfortunately, high cost of replacing double glazing with triple glazing make the retrofit procedure unfeasible, while it will be worthy if an alternative solution figured utilizing the existing glass and adding third layer with gas between, the same will require deep investigation in the window profiles design and manufacturing along with involving the specialists in this field.

The impressive results reached in the research regarding the short PBP could form basis for specialized firm or even governmental party for retrofitting the projects and putting feasibility plans for intruding RE, the same will be controlled by agreed contracts with the stakeholders. For example, the specialized firm will handle financially the transformation process while the owner will pay the energy consumption bills for certain period, after that the additional RE system will be under the client command.

Involving the local authorities in the transformation process could be the best solution for avoiding future obstacles, especially that DEWA and other energy authorities in UAE are insisting to maintain their control on the energy production, transformation and usage so it will be more guaranteed to involve them to insure the success of any future transformation.

Eventually, for any alteration process, all parties should contribute to insure the success including the stakeholders, policy makers, energy providers and final users, where the people awareness of energy consumption rationalizations is most fundamental role in pushing the community towards the desired sustainable level since the cheapest energy is the one that is not used.

References

Abdullah, H. K. & Alibaba, H. Z. (2017). Retrofits for energy efficient office buildings: Integration of optimized photovoltaics in the form of responsive shading devices. *Sustainability (Switzerland)*, vol. 9(11), pp. 1–22.

AbuGrain, M. Y. & Alibaba, H. Z. (2017). Optimizing existing multistory building designs towards net-zero energy. *Sustainability (Switzerland)*, vol. 9(3), pp. 1–15.

Ahmad, A. & Khan, J. Y. (2020). Real-Time Load Scheduling , Energy Storage Control and Comfort Management for Grid-Connected Solar Integrated Smart Buildings. *Applied Energy*. Elsevier, vol. 259(November 2019), p. 114208.

Ala-juusela, M., Rehman, H. U., Hukkalainen, M. & Reda, F. (2021). Positive energy building definition with the framework, elements and challenges of the concept. *Energies*, vol. 14(19).

Alemi, P. & Loge, F. (2017). Energy efficiency measures in affordable zero net energy housing: A case study of the UC Davis 2015 Solar Decathlon home. *Renewable Energy*. Elsevier Ltd, vol. 101, pp. 1242–1255.

Allouhi, A., Saadani, R., Buker, M. S., Kousksou, T., Jamil, A. & Rahmoune, M. (2019). Energetic, economic and environmental (3E) analyses and LCOE estimation of three technologies of PV grid-connected systems under different climates. *Solar Energy*. Elsevier, vol. 178(December 2018), pp. 25–36.

Ana, A. & Attia, S. (2020). Energy e ffi ciency in the Romanian residential building stock : A literature review, vol. 74(February 2017), pp. 349–363.

Andreas Jaeger. (2020). Stocktaking of PEB Examples; Deliverable 1.2 EXCESS. *EXCESS Consortium*, vol. 1(July), pp. 1–41 [online].Available at: https://positive-energy-buildings.eu/resource?t=Report on the Stocktaking of PEB Examples.

Antonakakis, N., Chatziantoniou, I. & Filis, G. (2017). Energy consumption, CO2 emissions, and economic growth: An ethical dilemma. *Renewable and Sustainable Energy Reviews*. Elsevier, vol. 68(October 2015), pp. 808–824.

Antonov, Y. I., Heiselberg, P. K. & Pomianowski, M. Z. (2021). Novel methodology toward nearly zero energy building (NZEB) renovation: Cost-effective balance approach as a pre-step to cost-optimal life cycle cost assessment. *Applied Sciences (Switzerland)*, vol. 11(9), pp. 1–30.

Bandeiras, F., Gomes, M., Coelho, P. & Fernandes, J. (2020). Towards net zero energy in industrial and commercial buildings in Portugal. *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, vol. 119(November 2019), p. 109580.

Chastas, P., Theodosiou, T., Kontoleon, K. J. & Bikas, D. (2018). Normalising and assessing carbon emissions in the building sector: A review on the embodied CO2 emissions of residential buildings. *Building and Environment*. Elsevier, vol. 130(November 2017), pp. 212–226.

Chen, X., Qu, K., Calautit, J., Ekambaram, A., Lu, W., Fox, C., Gan, G. & Riffat, S. (2020). Multi-criteria assessment approach for a residential building retrofit in Norway. *Energy and Buildings*, vol. 215, pp. 1–18.

Chen, X., Yang, H. & Wang, T. (2017). Developing a robust assessment system for the passive design approach in the green building rating scheme of Hong Kong. *Journal of Cleaner*

Production. Elsevier Ltd, vol. 153, pp. 176–194.

DEWA. (2020). ANNUAL STATISTICS 2020, pp. 1–9.

Di, E., Iannaccone, M., Telloni, M., Orazio, M. D. & Di, C. (2017). Probabilistic life cycle costing of existing buildings retrofit interventions towards nZE target : Methodology and application example. *Energy & Buildings*. Elsevier B.V., vol. 144, pp. 416–432.

Evangelisti, L., Guattari, C., Asdrubali, F. & Vollaro, R. D. L. (2020). Developments in the Built Environment In situ thermal characterization of existing buildings aiming at NZEB standard : A methodological approach. *Developments in the Built Environment*. Elsevier Ltd, vol. 2(February), p. 100008.

Fayyad, M. & John, J. (2017). Defining Nearly Zero Energy Buildings in the UAE. *EmiratesGBC*, pp. 1–34.

Fayyad, M. & John, J. (2020). Advancing Deep Retrofits in the UAE. *EmiratesGBC*, (October), pp. 1–11.

Firlag, S. (2019). Cost-optimal plus energy building in a cold climate. *Energies*, vol. 12(20), pp. 1–20.

Friess, W. A. & Rakhshan, K. (2017). A review of passive envelope measures for improved building energy efficiency in the UAE. *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, vol. 72(November 2016), pp. 485–496.

García Kerdan, I., Raslan, R., Ruyssevelt, P. & Morillón Gálvez, D. (2016). An exergoeconomic-based parametric study to examine the effects of active and passive energy retrofit strategies for buildings. *Energy and Buildings*. Elsevier B.V., vol. 133, pp. 155–171.

Ghenai, C., Salameh, T., Merabet, A. & Hamid, A. K. A. (2017). Modeling and optimization of hybrid solar-diesel-battery power system. *2017 7th International Conference on Modeling, Simulation, and Applied Optimization, ICMSAO 2017*. IEEE, pp. 1–5.

Giourka, P., Sanders, M. W. J. L., Angelakoglou, K., Pramangioulis, D., Nikolopoulos, N., Rakopoulos, D., Tryferidis, A. & Tzovaras, D. (2019). The smart city business model canvas—A smart city business modeling framework and practical tool. *Energies*, vol. 12(24), pp. 1–18.

Gustafsson, M. S., Myhren, J. A., Dotzauer, E. & Gustafsson, M. (2019). Life cycle cost of building energy renovation measures, considering future energy production scenarios. *Energies*, vol. 12(14), pp. 1–15.

Hall, M. & Geissler, A. (2017). Different balancing methods for Net Zero Energy Buildings - Impact of time steps, grid interaction and weighting factors. *Energy Procedia*. Elsevier B.V., vol. 122, pp. 379–384.

Hashempour, N., Taherkhani, R. & Mahdikhani, M. (2020). Energy performance optimization of existing buildings: A literature review. *Sustainable Cities and Society*. Elsevier, vol. 54(November 2019), p. 101967.

Hofler, R. (2019). Stakeholder related fields of action for process optimization of nearly zero energy and plus energy buildings. *IOP Conference Series: Earth and Environmental Science*, vol. 323(1), pp. 1–8.

Hollands, J. & Korjenic, A. (2021). Indirect economic effects of vertical indoor green in the context of reduced sick leave in offices. *Sustainability (Switzerland)*, vol. 13(4), pp. 1–19.

Iqbal, M. I., Himmler, R. & Gheewala, S. H. (2017). Potential life cycle energy savings through a transition from typical to energy plus households: A case study from Thailand. *Energy and Buildings*. Elsevier B.V., vol. 134, pp. 295–305.

IRENA. (2020). *Renewable Power Generation Costs in 2020*. *International Renewable Energy Agency* [online].Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf.

IRENA. (2021). *RENEWABLE CAPACITY STATISTICS 2021*.

Jafari, A. & Poshtiri, A. H. (2017). Passive solar cooling of single-storey buildings by an adsorption chiller system combined with a solar chimney. *Journal of Cleaner Production*. Elsevier Ltd, vol. 141, pp. 662–682.

Jafarkazemi, F. & Saadabadi, S. A. (2013). Optimum tilt angle and orientation of solar surfaces in Abu Dhabi, UAE. *Renewable Energy*. Elsevier Ltd, vol. 56, pp. 44–49.

Ji, Y., Lee, A. & Swan, W. (2019). Building dynamic thermal model calibration using the Energy House facility at Salford. *Energy and Buildings*, vol. 191, pp. 224–234.

Kim, M. H., Kim, J. K., Lee, K. H., Baek, N. C., Park, D. Y. & Jeong, J. W. (2019). Performance investigation of an independent dedicated outdoor air system for energy-plus houses. *Applied Thermal Engineering*. Elsevier, vol. 146(September 2018), pp. 306–317.

Krarti, M. & Dubey, K. (2018). Review analysis of economic and environmental benefits of improving energy efficiency for UAE building stock. *Renewable and Sustainable Energy Reviews*, vol. 82(April 2016), pp. 14–24.

Lassen, N. (2019). Case study of personal heaters in a Plus energy building - Simulations of potential energy savings and results from a field test. *IOP Conference Series: Earth and Environmental Science*, vol. 352(1), pp. 1–8.

Malik, K., Rahman, S. M., Khondaker, A. N., Abubakar, I. R., Aina, Y. A. & Hasan, M. A. (2019). Renewable energy utilization to promote sustainability in GCC countries: policies, drivers, and barriers. *Environmental Science and Pollution Research*. Environmental Science and Pollution Research, vol. 26(20), pp. 20798–20814.

Manrique Delgado, B., Cao, S., Hasan, A. & Sirén, K. (2018). Energy and exergy analysis of prosumers in hybrid energy grids. *Building Research and Information*, vol. 46(6), pp. 668–685.

Marino, C., Nucara, A., Panzera, M. F. & Pietrafesa, M. (2019). Towards the nearly zero and the plus energy building: Primary energy balances and economic evaluations. *Thermal Science and Engineering Progress*. Elsevier, vol. 13(August), p. 100400.

Melgar, S. G., Bohórquez, M. Á. M. & Márquez, J. M. A. (2018). UhuMEB: Design, construction, and management methodology of minimum energy buildings in subtropical climates. *Energies*, vol. 11(10), pp. 1–34.

Municipality, D. (2016). Al Sa'fat - Dubai Green Building Evaluation System. *Government Of Dubai*, vol. 1.1, pp. 1–50.

Naqbi, S. Al, Tsai, I. & Mezher, T. (2019). Market design for successful implementation of UAE 2050 energy strategy. *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, vol. 116(August), p. 109429.

Ozel, M. & Ozel, C. (2020). Effect of window-to-wall-area ratio on thermal performance of building wall materials in Elazığ, Turkey. *PLoS ONE*, vol. 15(9 September), pp. 1–15.

Park, J. H., Yun, B. Y., Chang, S. J., Wi, S., Jeon, J. & Kim, S. (2020). Impact of a passive retrofit shading system on educational building to improve thermal comfort and energy consumption. *Energy and Buildings*. Elsevier B.V., vol. 216, pp. 1–10.

Parker, J., Farmer, D., Johnston, D., Fletcher, M., Thomas, F., Gorse, C. & Stenlund, S. (2019). Measuring and modelling retrofit fabric performance in solid wall conjoined dwellings. *Energy and Buildings*. Elsevier B.V., vol. 185, pp. 49–65.

Passer, A., Ouellet-Plamondon, C., Kenneally, P., John, V. & Habert, G. (2016). The impact of future scenarios on building refurbishment strategies towards plus energy buildings. *Energy and Buildings*. Elsevier B.V., vol. 124, pp. 153–163.

Pillot, B., Muselli, M., Poggi, P. & Dias, J. B. (2019). Historical trends in global energy policy and renewable power system issues in Sub-Saharan Africa: The case of solar PV. *Energy Policy*. Elsevier Ltd, vol. 127(November 2018), pp. 113–124.

Reda, F. & Fatima, Z. (2019). Northern European nearly zero energy building concepts for apartment buildings using integrated solar technologies and dynamic occupancy profile: Focus on Finland and other Northern European countries. *Applied Energy*. Elsevier, vol. 237(January), pp. 598–617.

Rehman, H. ur, Reda, F., Paiho, S. & Hasan, A. (2019). Towards positive energy communities at high latitudes. *Energy Conversion and Management*. Elsevier, vol. 196(March), pp. 175–195.

Said, Z., Alshehhi, A. A. & Mehmood, A. (2018a). Popula on Growth in UAE. *Renewable Energy*. Elsevier Ltd, vol. 118, pp. 779–789.

Said, Z., Alshehhi, A. A. & Mehmood, A. (2018b). Predictions of UAE's renewable energy mix in 2030. *Renewable Energy*. Elsevier Ltd, vol. 118, pp. 779–789.

Salameh, T., Assad, M. E. H., Tawalbeh, M., Ghenai, C., Merabet, A. & Öztop, H. F. (2020). Analysis of cooling load on commercial building in UAE climate using building integrated photovoltaic façade system. *Solar Energy*. Elsevier, vol. 199(February), pp. 617–629.

Sharma, P., Kolhe, M. & Sharma, A. (2020). Economic performance assessment of building integrated photovoltaic system with battery energy storage under grid constraints. *Renewable Energy*. Elsevier Ltd, vol. 145, pp. 1901–1909.

Shirinbakhsh, M. & Harvey, L. D. D. (2021). Net-zero energy buildings: The influence of definition on greenhouse gas emissions. *Energy and Buildings*. Elsevier B.V., vol. 247, p. 111118.

Sougkakis, V., Lymperopoulos, K., Nikolopoulos, N., Margaritis, N., Giourka, P. & Angelakoglou, K. (2020). An Investigation on the Feasibility of Near-Zero and Positive Energy Communities in the Greek Context. *Smart Cities*, vol. 3(2), pp. 362–384.

Sun, X., Gou, Z. & Lau, S. S. (2018). Cost-effectiveness of active and passive design strategies for existing building retro fi ts in tropical climate : Case study of a zero energy building. *Journal of Cleaner Production*. Elsevier Ltd, vol. 183, pp. 35–45.

Synnefa, A., Laskari, M., Gupta, R., Pisello, A. L. & Santamouris, M. (2017). Development of Net Zero Energy Settlements Using Advanced Energy Technologies. *Procedia Engineering*. The Author(s), vol. 180, pp. 1388–1401.

Tapper, C. S. F. & Dokka, T. H. (2019). Powerhouse Telemark : A plus energy building with a low exergy heating and cooling system, pp. 1–9.

Wells, L., Rismanchi, B. & Aye, L. (2018). A review of Net Zero Energy Buildings with reflections on the Australian context. *Energy and Buildings*. Elsevier B.V., vol. 158, pp. 616–628.

Yip, S., Athienitis, A. K. & Lee, B. (2021). Early stage design for an institutional net zero energy archetype building. Part 1: Methodology, form and sensitivity analysis. *Solar Energy*. Elsevier Ltd, vol. 224(March), pp. 516–530.

Yu, Z., Gou, Z., Qian, F., Fu, J. & Tao, Y. (2019). Towards an optimized zero energy solar house: A critical analysis of passive and active design strategies used in Solar Decathlon Europe in Madrid. *Journal of Cleaner Production*. Elsevier Ltd, vol. 236, p. 117646.

Zaimi, M., El Achouby, H., Ibral, A. & Assaid, E. M. (2019). Determining combined effects of solar radiation and panel junction temperature on all model-parameters to forecast peak power and photovoltaic yield of solar panel under non-standard conditions. *Solar Energy*. Elsevier, vol. 191(July), pp. 341–359.

Zhang, B., Wang, B. & Wang, Z. (2017). Role of renewable energy and non-renewable energy consumption on EKC : Evidence from Pakistan. *Journal of Cleaner Production*. Elsevier Ltd, vol. 156, pp. 855–864.

Zhang, Y., Zhang, X., Huang, P. & Sun, Y. (2020). Global sensitivity analysis for key parameters identification of net-zero energy buildings for grid interaction optimization. *Applied Energy*. Elsevier Ltd, vol. 279(April 2020), p. 115820.

Zhao, B., Zhang, S., Cao, S. & Zhao, Q. (2019). Cleaning cycle optimization and cost evaluation of module dust for photovoltaic power plants in China. *Clean Technologies and Environmental Policy*. Springer Berlin Heidelberg, vol. 21(8), pp. 1645–1654.

Appendices

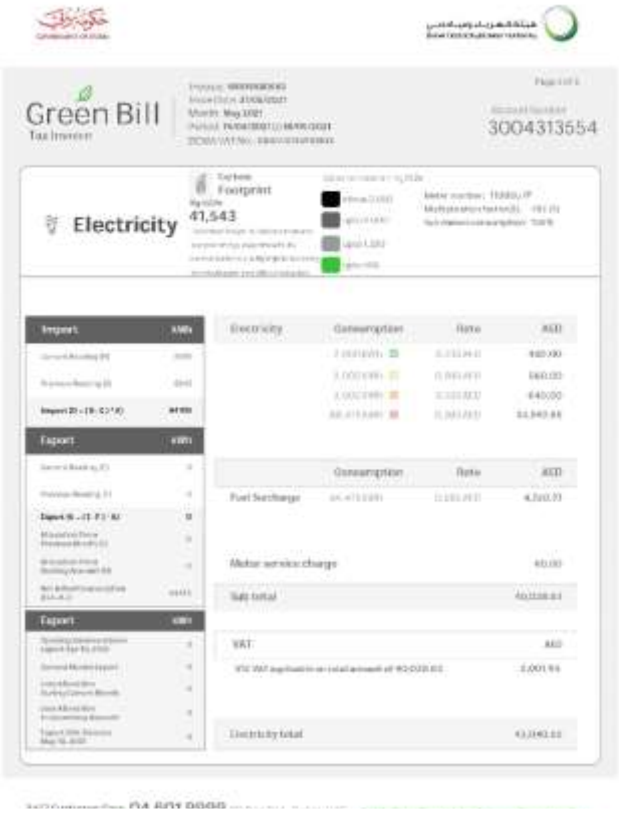
Appendix 01 – Electricity bills of DHGC as per DEWA.


Green Bill
Tax Invoice
3004313554
Electricity
Carbon Footprint
21,678
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total
24/7 Customer Care 04 601 9999


Green Bill
Tax Invoice
3004313554
Electricity
Carbon Footprint
25,006
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total
24/7 Customer Care 04 601 9999


Green Bill
Tax Invoice
3004313554
Electricity
Carbon Footprint
28,291
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total
24/7 Customer Care 04 601 9999


Green Bill
Tax Invoice
3004313554
Electricity
Carbon Footprint
37,813
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total
24/7 Customer Care 04 601 9999


Green Bill
Tax Invoice
3004313554
Electricity
41,543
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total


Green Bill
Tax Invoice
3004313554
Electricity
49,396
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total
24/7 Customer Care 04 601 9999


Green Bill
Tax Invoice
3004313554
Electricity
45,615
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total
24/7 Customer Care 04 601 9999


Green Bill
Tax Invoice
3004313554
Electricity
48,860
Import
Export
Electricity
Consumption
Rate
AED
Fuel Surcharge
Meter service charge
Sub total
VAT
Electricity total
24/7 Customer Care 04 601 9999

Appendix 02 – IES-VE Simulations

01. Base Case Annual Energy Consumption

	Total system energy? (MWh)
	Base Case Energy Consumption .aps
Date	
Jan 01-31	16.6447
Feb 01-28	13.7761
Mar 01-31	21.6135
Apr 01-30	36.7963
May 01-31	56.9236
Jun 01-30	64.3063
Jul 01-31	73.0241
Aug 01-31	74.6790
Sep 01-30	63.0110
Oct 01-31	47.2314
Nov 01-30	27.0117
Dec 01-31	14.5969
Summed total	509.6145

02. Direct and Diffused Radiation

	Total system energy? (MWh)	Total system energy? (MWh)
	updated roof & ground energy.aps	Base Case Energy Consumption .aps
Date		
Jan 01-31	15.8616	16.6447
Feb 01-28	19.0453	13.7761
Mar 01-31	23.8334	21.6135
Apr 01-30	31.8624	36.7963
May 01-31	42.0205	56.9236
Jun 01-30	44.6966	64.3063
Jul 01-31	48.7245	73.0241
Aug 01-31	49.8093	74.6790
Sep 01-30	44.1473	63.0110
Oct 01-31	37.5980	47.2314
Nov 01-30	26.9119	27.0117
Dec 01-31	18.7876	14.5969
Summed total	403.2984	509.6145

03. Monthly Energy Consumption Comparison between Base Case and Improved Case

	Direct radiation? (kWh/m?)	Diffuse radiation? (kWh/m?)
	AbuDhabiIWEC.fwt	AbuDhabiIWEC.fwt
Date		
Jan 01-31	169.24	39.53
Feb 01-28	186.12	37.35
Mar 01-31	161.24	62.62
Apr 01-30	173.44	65.08
May 01-31	226.09	59.39
Jun 01-30	223.75	54.83
Jul 01-31	202.91	65.96
Aug 01-31	209.05	58.40
Sep 01-30	201.37	47.89
Oct 01-31	203.22	41.70
Nov 01-30	177.55	35.57
Dec 01-31	160.93	38.41
Summed total	2294.92	606.72

04. Monthly Generated Energy from PVs in KWh/m^2 Reference to PV Orientation

	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)
	PV East .aps	PV South .aps	PV west .aps	PV North .aps
Date				
Jan 01-31	-0.0206	-0.0282	-0.0210	-0.0121
Feb 01-28	-0.0236	-0.0303	-0.0240	-0.0162
Mar 01-31	-0.0271	-0.0313	-0.0281	-0.0231
Apr 01-30	-0.0310	-0.0328	-0.0307	-0.0284
May 01-31	-0.0363	-0.0368	-0.0371	-0.0365
Jun 01-30	-0.0357	-0.0350	-0.0362	-0.0369
Jul 01-31	-0.0352	-0.0350	-0.0356	-0.0357
Aug 01-31	-0.0341	-0.0357	-0.0343	-0.0326
Sep 01-30	-0.0305	-0.0344	-0.0307	-0.0261
Oct 01-31	-0.0269	-0.0333	-0.0273	-0.0199
Nov 01-30	-0.0211	-0.0283	-0.0213	-0.0131
Dec 01-31	-0.0191	-0.0265	-0.0191	-0.0109
Summed total	-0.3412	-0.3877	-0.3453	-0.2916

05. Monthly Generated Energy from PVs in KWh/m2 Reference to PV Inclination

	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)
	50 degrees.aps	25 degrees.aps	0 degrees.aps
Date			
Jan 01-31	-0.0319	-0.0294	-0.0218
Feb 01-28	-0.0320	-0.0311	-0.0248
Mar 01-31	-0.0293	-0.0314	-0.0287
Apr 01-30	-0.0272	-0.0324	-0.0325
May 01-31	-0.0267	-0.0357	-0.0386
Jun 01-30	-0.0237	-0.0337	-0.0379
Jul 01-31	-0.0249	-0.0338	-0.0372
Aug 01-31	-0.0280	-0.0350	-0.0361
Sep 01-30	-0.0307	-0.0344	-0.0324
Oct 01-31	-0.0340	-0.0343	-0.0284
Nov 01-30	-0.0313	-0.0293	-0.0221
Dec 01-31	-0.0306	-0.0277	-0.0200
Summed total	-0.3504	-0.3883	-0.3606

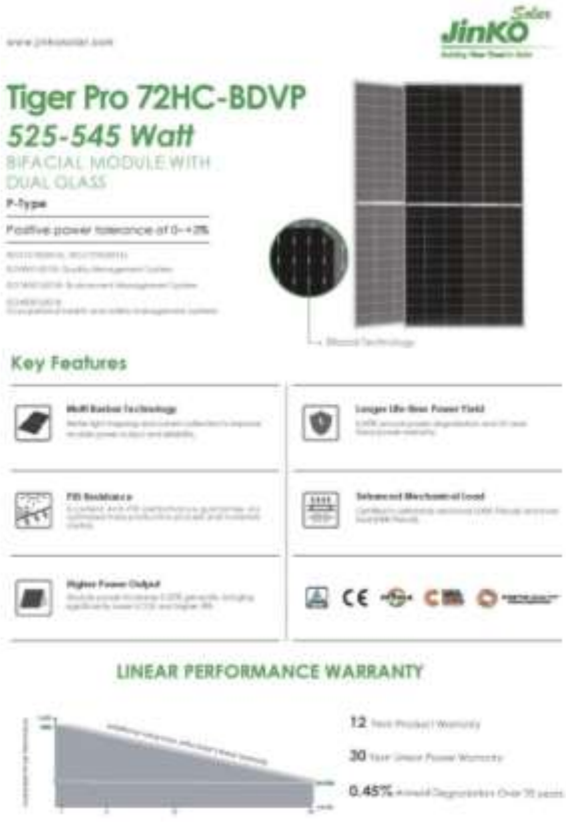
06. Monthly Generated Energy from PVs in KWh/m2 Reference to PV Type

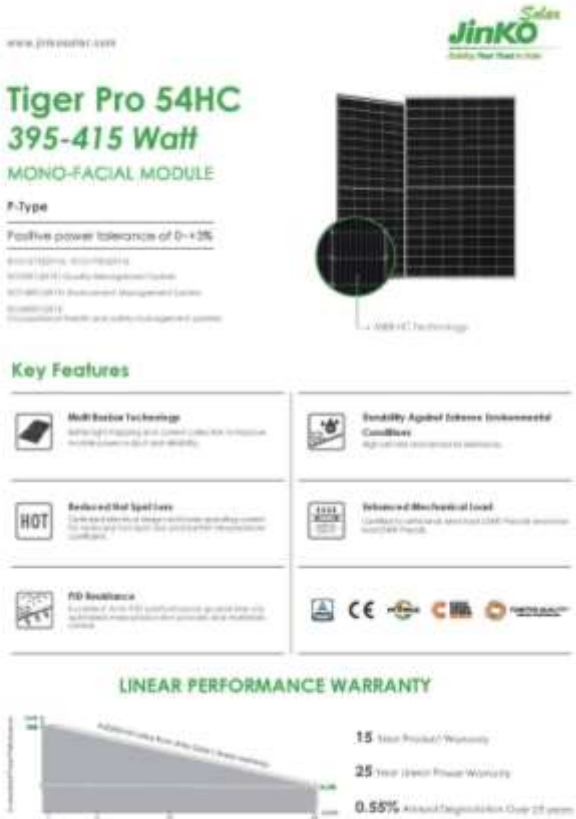
	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)	Grid Displaced Electricity: Meter 1? (MWh)
	Cadmium-Telluride.aps	Copper Indium Gallium	polycrystalline .aps	monocrystalline .aps	Amorphous.aps
Date					
Jan 01-31	-0.0176	-0.0190	-0.0247	-0.0294	-0.0131
Feb 01-28	-0.0186	-0.0202	-0.0261	-0.0311	-0.0139
Mar 01-31	-0.0188	-0.0204	-0.0264	-0.0314	-0.0140
Apr 01-30	-0.0194	-0.0210	-0.0272	-0.0324	-0.0144
May 01-31	-0.0214	-0.0232	-0.0299	-0.0357	-0.0159
Jun 01-30	-0.0202	-0.0219	-0.0282	-0.0337	-0.0151
Jul 01-31	-0.0203	-0.0220	-0.0284	-0.0338	-0.0151
Aug 01-31	-0.0210	-0.0227	-0.0293	-0.0350	-0.0157
Sep 01-30	-0.0206	-0.0223	-0.0288	-0.0344	-0.0154
Oct 01-31	-0.0206	-0.0223	-0.0288	-0.0343	-0.0153
Nov 01-30	-0.0175	-0.0190	-0.0246	-0.0293	-0.0131
Dec 01-31	-0.0166	-0.0179	-0.0233	-0.0277	-0.0123
Summed total	-0.2324	-0.2518	-0.3257	-0.3882	-0.1733

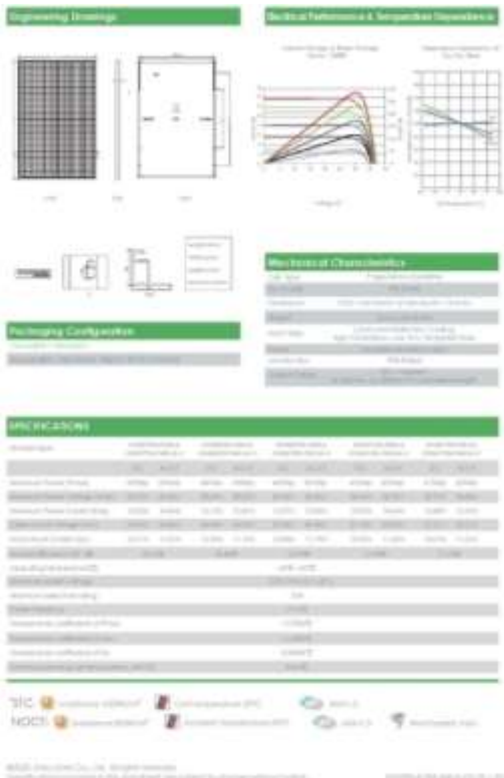
07. Peak Day Building Energy Consumption

		Total system energy? (kW)
		updated roof & ground energy.aps
Date	Time	
Thu, 26/Aug	00:30	0.0000
	01:30	0.0000
	02:30	0.0000
	03:30	0.0000
	04:30	0.0000
	05:30	96.9497
	06:30	77.0611
	07:30	88.5266
	08:30	109.3726
	09:30	126.0289
	10:30	127.5712
	11:30	118.8050
	12:30	115.0988
	13:30	115.1257
	14:30	116.8767
	15:30	116.9184
	16:30	110.0189
	17:30	98.3546
	18:30	88.6944
	19:30	83.5432
	20:30	78.9878
	21:30	76.0746
	22:30	0.0000
	23:30	0.0000

Appendix 03 – Photovoltaic Selections and UAE Market







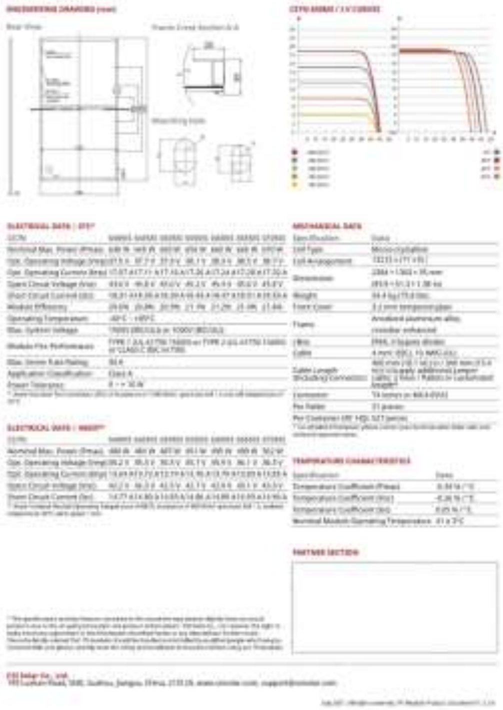
NEW

CanadianSolar

HiKu7 Mono PERC

640 W ~ 670 W

CS7N-640|645|650|655|660|665|670MS



NEW

CanadianSolar

BiHiKu7

BIFACIAL MONO PERC

635 W ~ 660 W

CS7N-635|640|645|650|655|660MB-AG