An-Najah National University

Faculty of Graduate Studies

NET ZERO ENERGY IN PUBLIC BUILDINGS IN PALESTINE; CASE STUDY: THE ADMINISTRATION OF PALESTINIAN CROSSINGS AND BORDERS – JERICHO

By

Alaa Ibkar Hader Qatrawi

Supervisor

Dr. Imad Ibrik

This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Clean Energy Engineering & Conservation of Consumption, Faculty of Graduate Studies, An-Najah National University, Nablus, Palestine.

2024

NET ZERO ENERGY IN PUBLIC BUILDINGS IN PALESTINE; CASE STUDY: THE ADMINISTRATION OF PALESTINIAN CROSSINGS AND BORDERS – JERICHO

By

Alaa Ibkar Hader Qatrawi

This Thesis was Defended Successfully on 09/10/2024 and approved by

Dr. Imad Ibrik Supervisor	Signature
Dr. Mahmoud Ismail External Examiner	Signature
Dr. Abdelrahim Abusafa Internal Examiner	Signature

Dedication

الحمدلله الذي مَّن علي بالصبر والمثابرة لاستكمال هذا العمل الذي أرجو من الله أن يكون في ميزان حسناتي وأن ينفع به كل باحث عن خير و منفعة..

أما بعد ...

فما بي من نعمة فمن خالقي ... الله الواحد الاحد الفرد الصمد ...

الى من علمني المثابرة والتضحية ... والدي العزيز، أُهدي الى روحك الطيبة هذا الإنجاز ...

الى والدتي الغالية ... أطال الله بعمرك بالصحة والعافية ...

الى أخي وأخواتي ... أدامكم الله ذخراً وسنداً..

الى زوجتي وبناتي العزيزات ...

الى كل أولئك الذين قدر الله بيني وبينهم الخير والفضل ...

أُهدي اليكم جميعا هذا العمل ... امتناناً وشكراً ...

" وآخر دعوانا أن الحمدلله رب العالمين"

Acknowledgements

I would like to express my gratitude to my supervisor Dr. Imad Ibrik for his valuable guidance and generous manners.

Special thanks for Dr. Abdelrahim Abusafa and for all my teachers in An Najah National University.

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

NET ZERO ENERGY IN PUBLIC BUILDINGS IN PALESTINE; CASE STUDY: THE ADMINISTRATION OF PALESTINIAN CROSSINGS AND BORDERS – JERICHO

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher’s own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **Alaa Ibkar Hader Qatrawi**

Signature: *Alaa Qatrawi*

Date**:** **09/10/2024**

List of Contents

List of Tables

List of Figures

List of Appendices

NET ZERO ENERGY IN PUBLIC BUILDINGS IN PALESTINE; CASE STUDY: THE ADMINISTRATION OF PALESTINIAN CROSSINGS AND BORDERS – JERICHO

By
Alaa Ibkar Hader Qatrawi
Supervisors
Dr. Imad Ibrik

Abstract

The electrical demand for public buildings in Jericho is steadily increasing on an annual basis, particularly for cooling purposes and in view of the global warming challenge. Net zero energy aims to achieve balance of annual energy consumption with annual generation under more efficient conditions. Implementing the vision of net zero energy necessitates a comprehensive study for each case as an individual. The primary goal of this research is to highlight various opportunities and measures of energy conservation in Jericho's public buildings, with the goal of reducing annual costs by leveraging sustainable energy practices. The methodology in this work relies extensively on simulation software to evaluate multiple saving measures and scenarios. The findings reveal that implementing net zero energy can achieve about (33 %) as annual energy savings, and (1250 Tons) annual reduction of CO_2 after installation of a PV system. Moreover, the analysis shows that the simple payback period for achieving net zero energy status is less than four years, also the levelized cost of energy is about (0.06 $/kWh). These promising results motivate to adopt an effective strategy through the next twenty years in Jericho to support the transition toward the net zero energy building.

Keywords: NZEB, Energy auditing, Conservation measures.

Chapter One

Introduction and Theoretical Background

In 2021, the total electrical Energy consumption in Palestine is more than (6680 GWh), as reported by the Palestinian Central Bureau of Statistics [1], and approximately (23 %) of this amount was attributed to public & commercial sectors. The electrical energy needs are one of the main financial burdens, and the cost of energy is the highest in the region that in no way appropriately reflects the average income for Palestinians [2]. Non-availability of natural resources, unstable of political conditions, and 87% of electric energy is imported from other countries [3]; these three facts can describe the critical situation of energy sector in Palestine now, and cause a negative impact on quality of life of Palestinian residents and make them low interest in environmental issues. The State of Palestine is one of the developing countries that continually trying to enhance the concepts of energy security and independence of the energy sector, so it encourages investment in renewable energy fields, initiates projects, and formulates plans and strategies that contribute to achieving these goals [4]. Also, the Palestinian green building council (PGBC) has been established on the last few years as a non-governmental organization (NGO) which involves several qualified professionals from Palestine within this field [5].

The case study is "The General Administration of Crossings & Borders (GACB) – in Jericho", that will be presented as a sample of a public building, where the concept of Net Zero Energy Building (NZEB) will be applied and examined from technical, economic and environmental perspective. GACB is the authorized body responsible for managing the crossing points across the Palestinian borders, regulating and documenting the movement of travelers across the King Hussein Bridge (Al-Karama Bridge) that connects the West Bank with the Hashemite Kingdom of Jordan. Several facilities under the umbrella of GACB provide services to travelers and pilgrims through Al-krama Bridge, where significant annual consumption of electrical energy is required to run passenger halls, security offices, and other administrative facilities.

1.1 A problem statement & Objectives

Palestine suffers from a lack of diversity of energy sources and shortage of energy, and the political issues prevent Palestinians from getting benefits of their natural resources, furthermore the annual population growth in Palestine increases the annual needs. Energy crisis – especially in electricity- increases year by year and causes the frequent outages that are often scheduled and managed in proportion to the available quantities and demand of electrical energy, in which negatively effects on quality of Palestinians' life and production rates.

On the other hand, the facilities of GACB were built over different periods of time and with different technical aspects, so a comprehensive study is necessary to identify fields of deficiency and explore the potential of improvements, furthermore show how sustainable systems can be employed in public buildings to achieve the NZEB concept to reduce the annual cost and improve the energy security concept.

On the other hand, the facilities of the (GACB) were constructed during different time periods and with varying technical specifications. So, a comprehensive assessment is required to identify deficiencies and evaluate potential areas for improvement. This study will also demonstrate how sustainable systems can be integrated into public buildings to implement the (NZEB) concept, with the aim of reducing annual operational costs and enhancing energy security.

Objectives can be summarized as:

1) Discuss the concept of Net Zero Energy Building (NZEB) through realistic case study.
2) Assessment of the loads and verify the performance of the systems.
3) Identify the squandering points of electrical system and explore the potential of improvements.
4) Exploit sustainable ideas and renewable systems to cover energy demand and reduce dependency on traditional sources.
5) Discuss the suggested solution from economic and environment perspective.

1.2 The importance of this study

This thesis aims to conduct a comprehensive study and perform calculations on the proposed case to assess the loads and verify the performance of the systems. Then proposed solutions and recommendations will be shown to enhance specific sectors where energy is squandered, to improve the overall efficiency of the building and reduce the energy consumption. On the other hand, renewable energy, especially solar systems, can be suggested to cover energy demand and reduce dependency on traditional sources. In addition, economic issues and environmental impact will be discussed through this sample.

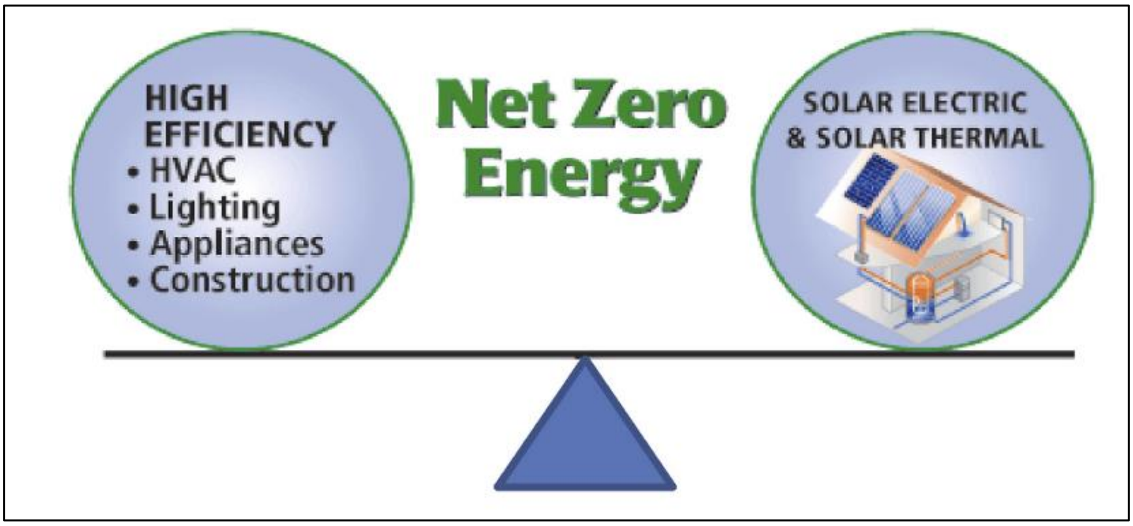
The case study can reflect the energy situations in other public buildings as institutions, ministries, municipalities…etc., where the energy loss must be considered a form of corruption and squandering of public funds. So, the importance of this study lies in bringing attention to a wide range of public buildings that should undergo examination and auditing to reveal weaknesses, especially the several governmental buildings that were built without taking into account the green building codes or conservation strategies, furthermore the main reasons for the loss in energy are due to old technical means used, low maintenance and less professional technicians [6]. Another motivation for this study is the hope that the results of this work can be considered as a good guidance plan for others in the journey of transition toward NZEB.

1.3 Concepts and Literature Review

In the 1970s, worldwide began to give attention to energy conservation concepts as a response to the effects of the energy crisis, which caused increasing in the demand and price of energy. At that time, keywords like: “Saving measures, energy saving” were discussed in studies, and throughout the years these terms evolved into subjects like: “Low energy building, nearly energy building, net zero energy building” [7].

Many definitions for the concept of “net zero energy buildings” can be found in the literature. In simple words, it can be defined as “The building that consumes total annual energy is equal to the renewable energy which is produced on site.”

Figure 1.1
Net zero energy concept



Source: R. K. Jaysawal, S. Chakraborty, D. Elangovan, and S. Padmanaban, "Concept of net zero energy buildings (NZEB) - A literature review," *Clean Eng Technol*, vol. 11, p. 100582, Dec. 2022, doi: 10.1016/J.CLET.2022.100582

A Net Zero Energy Building (NZEB) concept was discussed in the literature as one of the strategies to reduce greenhouse emissions and energy consumption by achieving a high level of energy efficiency. Iqbal (2004) considered the building as NZEB if it consumes from renewable energy technologies, where no fossil fuels are needed [9] ،[8]. While Corrado V. & others (2016), refer to the NZEB as a more energy-efficient building [10]. The research in this field referred to the feasibility of the transformation to NZEB to achieve high performance and low emissions [11], in which this concept became more available in technology, renewable systems, and knowledge.

The shortage of energy and the effects of climate change have raised people's concerns about the current trends in energy consumption [12]. Energy reduction and minimizing the carbon footprint of the building sector are essential requirements to meet worldwide environmental goals and avoid climate change risks [13], [14]. The NZEB concept can be discussed through several related terms like: high-performance building, smart and green strategies, renewable energy technologies, continuous monitoring, and energy management techniques in respect of achieving these goals and reducing the shortage.

The reduction of energy consumption in public buildings is a priority indicated in European Directive 2010/31/EU (EU Parliament 2010)[15]. The energy audit is an important activity in making energy control and operation costs [16]. An energy audit means to understand all circumstances of an electrical system and its components to achieve efficient use of resources and reduce the cost of operations. The energy sector is responsible for about 61% of greenhouse gases (GHG) [17], so the energy audit and other measures became take place to mitigate negative effects through improving the efficiency of energy use and energy management.

It is noteworthy, the law of regulation of energy auditing services that was issued by the Palestinian Energy and Natural Resources Authority, to emphasize the importance of energy performance in Palestine, in which the studies referred to the strong relationship between energy performance and the performance of regulations in the energy sector[18].

Through looking at several researches in the literature, good indications about many opportunities to achieve energy conservation and increase the efficiency of energy usage. Energy consumption in government office buildings of Bengkulu-Indonesia was improved by applying energy efficiency recommendations where about (13%) reduction of energy consumption [19]. In Oman, an energy audit was conducted for the governmental building to reduce the annual energy consumption, where the result was a 38.5% reduction in energy needs, through applying some measures as switching off the HVAC systems outside the occupancy hours, increasing the thermostat setpoint, reduction the infiltration of air, and the improvement of the lighting system [20]. (Ali Alajmi, Kuwait) suggested recommendations - in his research on education facilities – that can make a saving by 52% annually and reduce CO_2 by 648 tons/year, while the payback period is less than 6 months[21]. In the Assiut International Airport terminal building, Egypt, where the study was carried out to reduce energy consumption and improve human comfort, then the reduction equal to (24.5%) of total energy consumption during the hot months based on increasing HVAC set point temperature from (25 ℃) to (27 ℃) [22]. (M. Elnaggar) focused on solar water heater (SWH) and solar air heater (SAH) systems in Gaza, Palestine, and the results indicated that high potential for energy saving, good payback period, and in addition can reduce CO_2 emission by 17306.6 and 16378.57 kg/yr. respectively[23], so that represents good opportunities in public buildings if SWH and SAH are used, which prompt the energy security concept and sustainable environment by reduction of greenhouse gases. About (35%) reduction of electrical energy as a result of auditing and analysis work by (Sait H., 2013) that applied some recommendations for A/C systems and gave attention to building insulation [24]. (Ibrik & others) mention - through a study conducted in 2005 in Palestine – the most prominent measures that can be employed to improve energy efficiency through: efficient lighting systems, new technology of refrigerators, solar water heaters, high-efficiency motors, review HVAC settings and improve power factor[25]. Note that these measures represent the main options that can be applied to improve the overall consumption inside the public facilities. Also, another study was conducted for residential buildings in Palestine, where the result of the study was up to (59%) reduction of the total energy consumed in residential buildings by applying the three levels of the energy retrofitting plan [26].

Moreover, adopting conscious energy consumption behavior leads to energy savings, bill reduction, and preservation of natural and environmental resources. (Brounen D. & others) refers to the positive effect of user awareness, energy literacy and usage behavior as important issues in conservation topics [27].

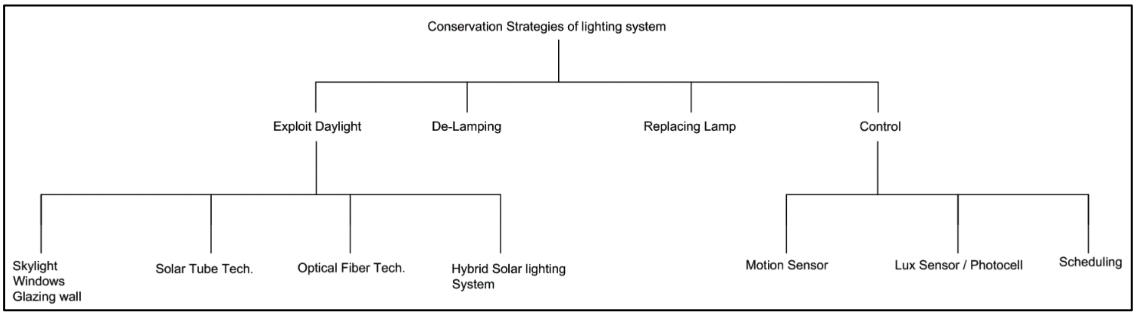
It is noteworthy, the transition to NZEB is closely related to employing renewable technologies to reduce cost and improve sustainability. In the worldwide, about 28% of global electricity generation depends on renewable resources – like hydropower, wind, biomass, CSP & solar energy- that represent an important alternative for reducing greenhouse gas emissions and energy poverty [28]. All types of renewable technology can be part of the NZEB case to achieve zero energy balance [29], but until now in Palestine, solar energy is the most realistic technology to produce electrical energy or thermal energy where 3000 sunshine hours yearly and (5.4 kWh/m^2/day) as average solar radiation[30]. Even though solar panel efficiency is still relatively low (18%) [31], it has become the most popular option and available technology that can contribute to meeting electricity demands and reducing reliance on traditional forms of energy. However, I think several renewable technologies can serve NZEB concept in Palestine if political restrictions and economic issues are treated in the future, thus promoting the concept of distributed generation and energy security.

1.4 Energy conservation strategies for lighting

In worldwide, about (19 %) of electrical energy is consumed by artificial lighting, while 14 % in the European Union [32]. Commercial building needs about 20% of expenses for illumination goals [33]. Therefore, performing energy auditing for lighting systems may reveal the squandering points of energy and then lead to make reduction, through carrying out some measures and retrofitting to increase the overall efficiency.

Some strategies are simple or no cost, as awareness and some instructions can make a difference in electrical needs monthly. Also, selecting interior colors represents another axiomatic method to improve lighting inside the space. But the impact of these measures remains limited, so other measures will be drawn to attention as Figure (1.2) that summarize the main ways to improve the performance of the lighting system.

Figure 1.2
Conservation Strategies of lighting



1.4.1 Exploiting daylight

Several researchers refer to the advantages of using technologies that depend on daylight as a source to light up internal spaces, not from energy saving perspective only but from a healthy perspective too, where the natural light improves psychological well-being and the positive effects of biological process in human body to produce and absorb the vitamins…etc. Artificial light includes undesirable light spectra as UV and infrared rays that have negative effects. Windows and glazing walls are the axiomatic method and simplest way to utilize the daylight, but sometimes lighting from windows is not enough so skylight methods can be employed architecturally through domes or glazing roofs.

Solar Tube Technology and Optical Fiber Technology are new styles of skylight windows, that transfer the sun rays from the roof of the building to internal space and underground floors through tubes or Fiber cables in serpentine or zigzag paths. These technologies consist of three mains components: collector on the roof, tunnel or tube that includes reflection materials, and light diffuser located inside the space [34]. "Solar light duct" is another name that may be used to describe the same principle of lighting technology, where special ducts and components are used to transfer sun rays entire multi-floor building, as figure (J.1) in appendix J.

A hybrid solar lighting system is similar to tube technology, which combines sunlight and artificial light to guarantee a constant level of illumination inside space. The collectors -in this method- is divided into two parts: Photovoltaic panel and Fresnel lens, while the diffuser contains led lamp. And figure (J.2) -in appendix J- shows a simple configuration of the hybrid method.

(Han, Hyun Joo & others) refer to (174) kWh/annually saving by using a Hybrid system with (17 lm/W) efficacy LED lamp to light up small space (880) hours as a special experiment to examine the technical feasibility of this method [35].

1.4.2 De-lamping

This measure involves reducing the number of lighting fixtures or removing some of them entirely within the designated area. It is recognized as an effective and low-cost strategy for minimizing energy consumption and lowering maintenance expenses too. The procedures to carry out this method are not arbitrary processes, but sometimes it needs to redesign the lighting system according to rules and codes of illumination level to guarantee the visual comfort inside the space, table (1.1) shows illumination level for some spaces and activities.

Table 1.1
Illumination level for some spaces and activities

Type of interior, task or activity	Illuminance level (Lux)
Circulation areas and corridors	100
Rest rooms	100
Preparation, general machine work	300
Laboratories	500
Quality control area	1000
Conference rooms	500
Offices	300-500
Entrance halls	100
Indoor Parking areas	75
Outdoor Parking areas	5-20
Lecture hall	500
Examination, treatment and inspection area	1000
Arrivals and departures halls, baggage claim area, waiting areas at airports	200
Kitchen	500
Self-service restaurant, Buffet	200-300
Preparation rooms and workshops	500

[61]

1.4.3 Replacing lamp

After collecting detailed information about lighting systems in the location, another method to discover additional saving opportunities is through studying the performance of lighting units, which is expressed by the "Efficacy" term. In which the efficacy refers to the relation between the luminous flux (*Lumens*) that is emitted by individual lighting units and the value of power (*Watts*) that is consumed. Table (A.1) -in appendix A- compares between main types of lighting technologies according to efficacy, and it will be used later to prefer between the types of lighting devices in the case study.

$$\text{Efficacy (lm/W)} = \text{Luminous flux (lm)/Power consumed (W)} \tag{1.1}$$

Relighting process – in the study (Akanmu, Williams Paul, 2012)- can achieve from (37%) to (60%) savings, and the payback period is 10 months [36]. While in another research in Egypt, more than 10-million-kilowatt hours as an annual saving by replacing all lighting systems for 17 facilities with LED technology [37]. Therefore, it's certainly, the replacing of old technology lamp with a more efficient one is a great opportunity.

1.4.4 Control

Three parameters must be taken into account to create an efficient lighting system: the occupancy of the area, user preferences, and daylight availability. The sensors like occupancy sensors and lux level sensors will detect the conditions inside spaces and send feedback to the controller that will decide the operation mode according to special algorithms, and give the order to the dimmer unit to increase or decrease the luminance flux of lamps, the figure (J.3) -in appendix J- describes the configuration of controlling system in order to ensure efficient coordination between the three parameters above. It is noteworthy, the dimming system must utilize advanced technology that enables precise control by adjusting the output current and voltage, thereby minimizing power dissipation within the dimmer components. (Aussat Y. & others, 2022) refer to (40%) energy reduction in offices by using smart control for lighting system [38].

Furthermore, traditional switches, touch screens or mobile applications may be integrated with a controlling system for more flexibility. Also, ON/OFF scheduling – whether hardware scheduling by timer or software scheduling by computerized system - is another form of control according to operation time or any other user preferences.

Building Management Systems (BMS) represent another choice for large-scale projects, in which sensors, dimmer devices and efficient lamps will be integrated to enhance overall efficiency by centralizing all processes.

(Hailm M. & others) [33] compared the three previous strategies from an economical perspective and concluded that all of them can contribute to energy reduction, but shows the replacement method is the most feasible, as figure (J.4) in appendix J.

1.5 Energy conservation strategies for HVAC system

According to the increasing global warming, the cooling demand will increase year by year. Thus, it is necessary to be interested more in cooling system efficiency and take measures to improve energy consumption of HVAC in the future.

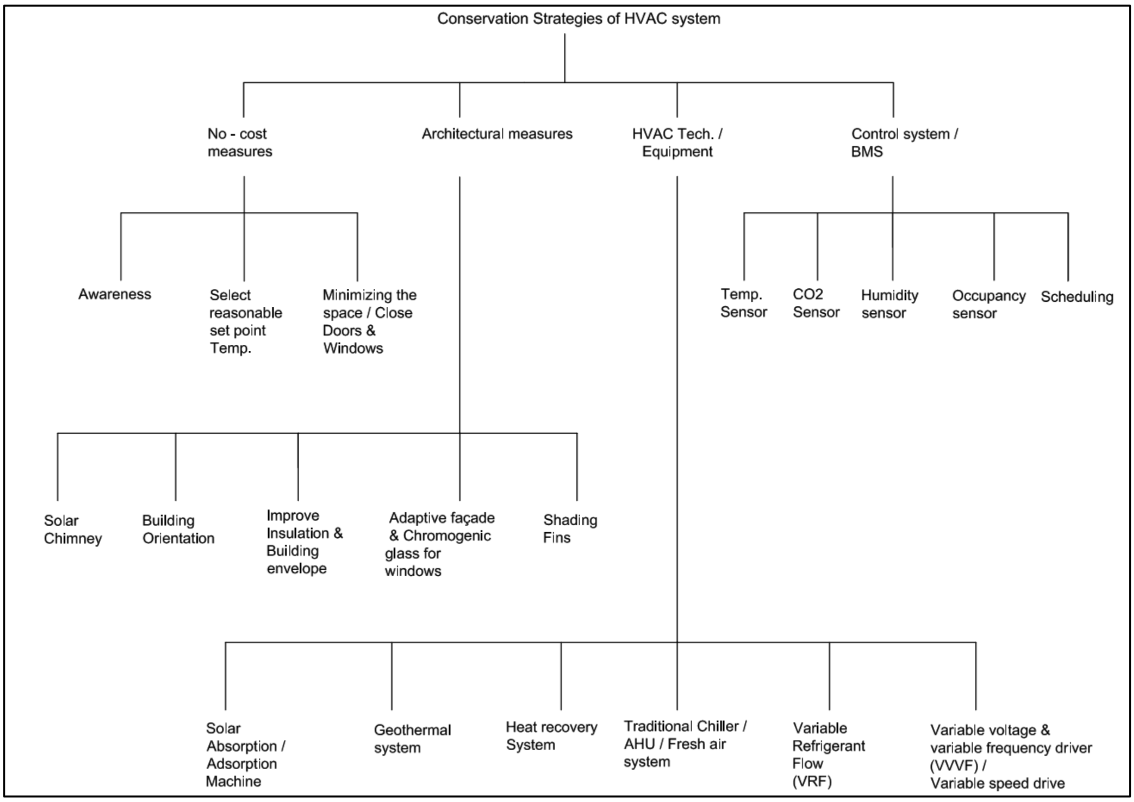
A good design of an HVAC system can find optimization point of internal thermal comfort and energy consumption. There are several methods and ideas to treat the HVAC mechanism and the effects of surrounding conditions, in which figure (1.3) shows several measures to do that.

No-cost measures can contribute to the reduction of energy consumption, for instance through research for (Spyropoulos & others) [39], shows about (34%) annual savings through regulating of indoor setpoint temperature of HVAC in non-residential buildings. (Bienvenido-Huertas, David & others) [40] mention that the increasing of setpoint temperature by (2-4 °C) can reduce annual consumption by one-third.

There are other measures and rules - must be taken into account during the design phase - that are considered as precautionary measures, for instance the applying of green building codes will improve the surrounding conditions and reduce the thermal loads. Also, using the automation system or building management system (BMS) will increase the ability to achieve thermal comfort with a minimum amount of energy, in which the different types of sensors can collect instantaneous data from the space to contribute to achieving optimization in operation load. CO_2 sensors and occupancy sensors are vital parts of the smart HVAC system, because can reduce the amount of required ventilation air and then reduce the thermal loads according to occupants and operation rate.

On the other hand, highly efficient cooling equipment is another level of conservation strategies, in which multiple options are available, as Figure (1.3). This study will focus on some innovative ideas and clean methods, and then will be discussed in detail.

Figure 1.3: Conservation strategies of HVAC
Conservation strategies of HVAC



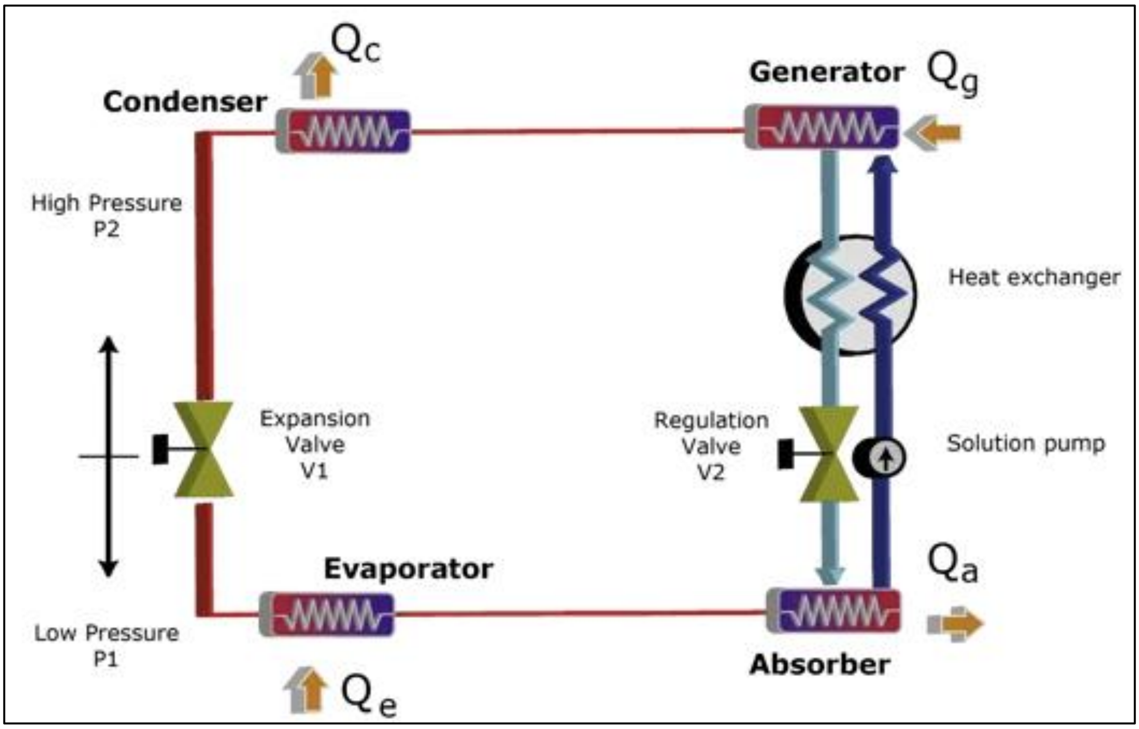
1.5.1 Solar chimney

One of the passive methods for cooling, depends on warming the air inside the chimney then the hot air will rise and get out from the top of the chimney, as figure (J.5) in appendix J. The effect of this technique is continuous movement of the air inside the building that cause reduction of temperature and make natural ventilation by exploiting sun rays that fall on the chimney tower. Various numerical and experimental researches in literature refer to the benefits of this method that can make saving up to (50 %) [41].

1.5.2 Absorption / Adsorption Cycle

Mostly, this method of cooling exploits waste heat as a source of energy to heat the solution inside the generator and convert the refrigerant to vapor, as figure (1.4). Another configuration depends on renewable resources such as solar energy through using efficient type of solar water collectors - as evacuated tubes - to drive this cycle, in which the thermal energy will be transferred from collectors to the generator by hot water to start process in the absorption cycle. (Al-Falahi A. & others) refers that the COP of this type of cooling system is about (0.5) [42]. (Jahangir, M. & others) said that the coupling this type of HVAC with other renewable source as biofuel heater will promote the overall performance of green HVAC system [43].

Figure 1.4: Absorption Cycle
Absorption Cycle



Source: https://www.araner.com/blog/how-do-absorption-chillers-work

The distinct advantage of solar absorption chiller is that the refrigerant of the absorption chiller is water and does not include the chemical chlorine that causes ozone depletion, and the operating costs at long term are less than conventional system. But the high initial cost of system components represents the main challenge.

1.5.3 Geothermal cooling

The principle of this technology depends on the constant temperature underground at depth (1–1.5 m) throughout the year [45], where – in summer – the soil temperature is lower than ambient air. There is a multi-structure to exploit this renewable source, but in general, heat exchanger can be used to diffuse the collected heat from the inside to the ground, then the inside air will be cooled or pre-cooled and a result will reduce the thermal loads.

Several studies in the literature refer to the savings that can be achieved by using geothermal as a cooling or heating system, in which the study [46] concluded that (30 %) energy saving through exploiting shallow geothermal in fresh air pre-handling system.

1.5.4 Air-conditioning energy recovery systems

A recovery system in HVAC is important method to recapture energy from exhaust air and reuse it to pre-cool or pre-heat inlet air. This technique improves HVAC performance and reduces energy demand through partially transferring of the exhausted energy to input again.

There are several types of recovery methods:

- Energy recovery wheel (Enthalpy wheel)
- Plate Heat Exchangers
- Heat Pipes with refrigerant fluid
- Run-Around coils

These methods can achieve multiple benefits as energy efficient, reduce running cost, environmental impact and improve indoor comfort.

1.6 Smart building

There are many definitions in literatures about smart building. The Intelligent Building Institute (IBI) defines an intelligent building as 'one which provides a productive and cost-effective environment through optimization of its four basic elements including structures, systems, services and management and the interrelationships between them'.

These types of buildings are designed to gather data from different corners by several types of digital sensors and connect with computerized system that can make decision and control of building resources in order to increase the productivity and reduce energy.

Many famous buildings around the world, like: Frasers Tower in Singapore, Empire State in New York, The Edge in Amsterdam, Tottenham Hotspur Stadium in London, Burj Khalifa in Dubai and Beeah Headquarters in Sharjah ...etc., all of them designed with intelligent ideas to collect real-time data and make continuously accurate control on its lighting and HVAC systems to achieve their goals and save a lot of millions of dollars annually as cost of energy and maintenance.

The benefits of smart buildings can be summarized as:

- Optimized energy
- Optimized resource usage
- Cost-savings
- Predictive maintenance
- Real-time monitoring
- Real-time insights and analysis
- Automation and integration with other systems
- Increased productivity
- Improved space utilization
- Enhanced security
- Increased value
- Reduce carbon footprint of the entire building lifecycle.

1.7 Adaptive façade

One of creative architectural idea can be exploited to improve the concept of sustainability and enhance efficiency of building, also known as a dynamic facade, that is designed to adapt with the changing in external conditions, such as temperature and day-light, then that will improve internal comfort and reduce the energy demand of the building.

There are two strategies of adaptive façade: the first one is the using of the shadow effects -such as the shadow of Photovoltaic panels- and the second strategy depends on thermal transmittance (U-value) of façade systems such as using electrochromic glass.

In literature, several studies discussed the different issues of adaptive façade and referred to positive impact of employing Adaptive façade in buildings to reduce energy consumed by (18–20%), improve shading, protect against glare and improve visual comfort. In addition, some studies discussed the improving of day-light effect inside the building and make reduction in energy needed for lighting. Others studied the components that can be used in Adaptive façade -such as photochromic and thermochromic windows- to make reduction in visible light and solar transmittance by (25- 65%) and (12- 25%), respectively.

1.8 Benefits of NZEB

NZEB is an eco-friendly and a promising solution to improve energy efficiency and sustainability, in which reduce of using fossil fuel and leads to reduce greenhouse emission and global warming that can make saving of expenses of carbon footprint penalty too [47].

Several benefits can be discussed from perspective of energy security dimensions, where NZEB promote the independency in energy sector and availability of energy, furthermore improvement of power quality entire the network. On the other hand, it can reduce vulnerability of power infrastructure towards terrorism activities and military disputes [48].

Social impacts of NZEB are represented in improving life quality and healthy issues for end-user inside these types of buildings, where more comfortable level and low concentration of pollutants inside [49]. Also, that can contribute stabilize the country's economy where will reduce costs and taxes that paid by end-user for energy usage.

Chapter Two
Methodology for NZEB

The study and analysis of the proposed case was divided into four stages. Stage one represents the data collection by walk-through and inspection survey, and if there is a shortage of data in this stage then additional visits and surveys must be done. It is noteworthy, some numerical values and assumption will be recorded according to the nature of daily work and personal experience in the location.

In stage two, the analysis of collected data will show the current status of the proposed case and determine which type of loads consume the most amount of energy. After that, energy auditing for the overall system is very important to reveal squandering points of electrical energy and to reduce consumption by applying some measures. Also, in this stage, simulation software - like HAP and DiaLux evo – will help us to build a model and examine the suggested measures.

Stage three will focus on renewable systems to replace traditional sources and make reduction of annual operation costs. PVSYST will simulate the suggested solar system.

Finally, stage four will discuss the economic issues and refer to economic indicators like cash flow, net present value, simple payback period, saving-to-investment ratio, rate of return, and the levelized cost of energy. Environmental aspects will be discussed too, especially carbon reduction.

The high consumption of electrical energy in Jericho district especially in summer where the cooling is the main load, while the lighting can be considered as a secondary load in public buildings, also amount of hot water is required in the winter. So, three system (Lighting, HVAC and SWH) will be treated through different methods that will be shown here.

2.1 Methodology for lighting system

There are several buildings in the suggested case, and some of these buildings are similar, so the lighting system in the Arrivals Hall will be studied and simulated in detail, and then the results will be reflected on the other buildings, to calculate the annual savings through applying the suggested measures. Also, parking areas and other similar areas will be treated by the same method. The measurements of the lighting level in several corners will be conducted by using a LUX-meter device (TES-1334A LIGHTMETER).

Simulation of the lighting system will be conducted by DiaLux-Evo, which it is considered as a professional software in the lighting field, so it will be used to show the lighting situation in our case before and after applying the suggested modifications to the lighting system.

2.2 Methodology for HVAC system

In the first phase, collect and study the current conditions of the arrivals hall that influence the cooling load, and conduct a simulation by HAP under these conditions, that will show the cooling load at its initial state. On the other hand, the suggested measures will be applied virtually and then repeat the simulation to compare the cooling loads in the two different states. After that, it is important to study the cooling device and discuss innovative ideas to cover the cooling load, so some scenarios will be suggested in the HVAC section, to examine and compare different cooling methods.

It is noteworthy, HAP v5.10 is a specialist software that can record HVAC parameters and weather data, then make an analysis for all components of the HVAC system to calculate thermal loads by simulation throughout the year.

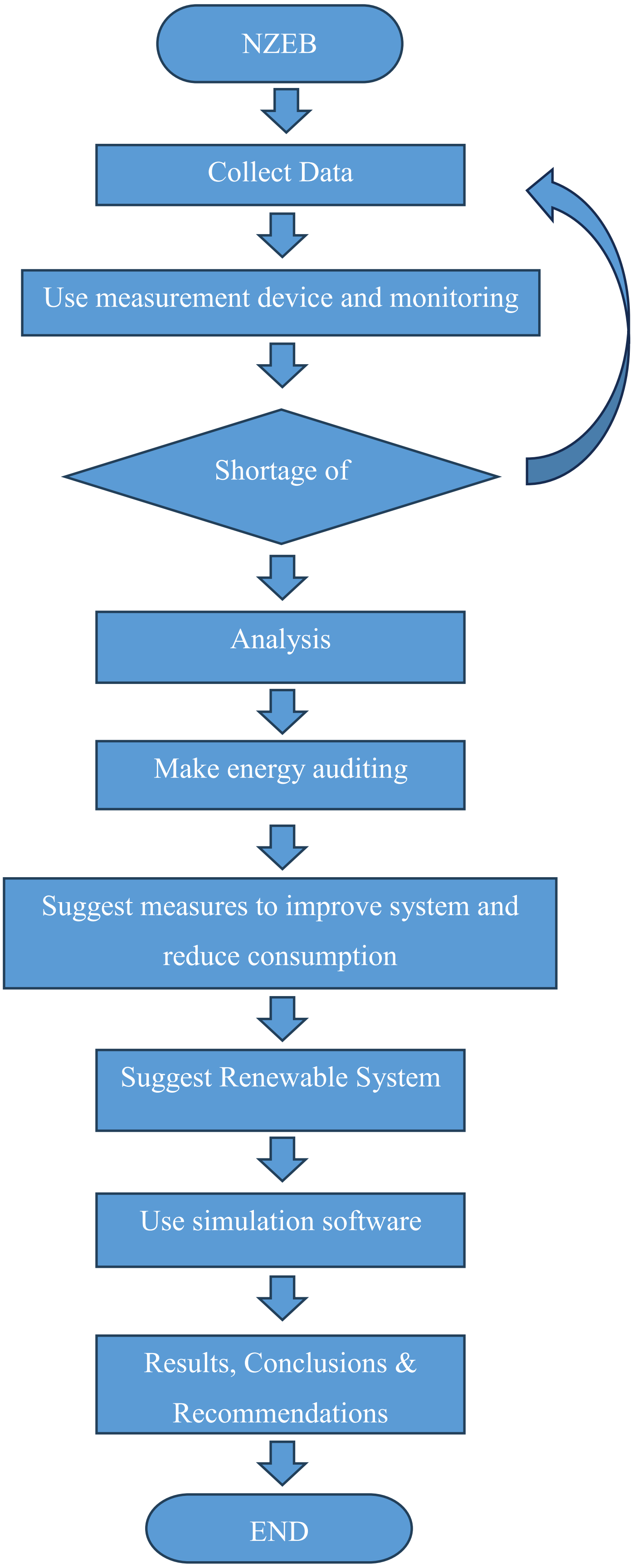
2.3 Methodology for solar water heating system

According to collected data, the needs of hot water contribute of consuming a part of electrical energy because it depends on electrical heater, so the SWH system can be suggested to cover these needs through flat plate collectors. Some calculations will determine the size of the SWH, then can determine the annual savings in this field.

2.4 Methodology for Renewable system

After applying energy auditing and suggested conservation strategies in our case study, then the next step - on the road of NZEB – is a selection of suitable renewable systems to cover the energy needs. In reality, the high solar radiation -in Palestine- motivates us to use solar energy, so the suggested system will depend mainly on the thermal and lighting energy of the sun. Some calculations and simulations by PVSYST to make sizing of the system.

Figure 2.1
Methodology Flow chart



2.5 About the case study and general description

The buildings of GACB are located in (31.8 deg.) latitude and (35.4 deg.) longitude, Jericho, where the elevation is (230 m) under sea level and the climate is very hot in May-August and it's warm in Oct-Mar, as figure (J.6) in appendix J.

The total area is (57,000 m^2), include multiple buildings such as departures hall, arrivals hall, service hall, and other buildings - as shown in figure (J.7) in appendix J - in addition to large spaces are used as parking. These facilities were built as separated objects through different periods, to serve (1.8) million passengers yearly.

Each building contains the main electrical distribution board and all boards are connected finally to the main electrical room, where the main connection with the electricity grid of JDECo Figure (J.8) – in appendix J- shows the single line diagram of the main electrical board.

Chapter Three
The Results & Analysis of NZEB

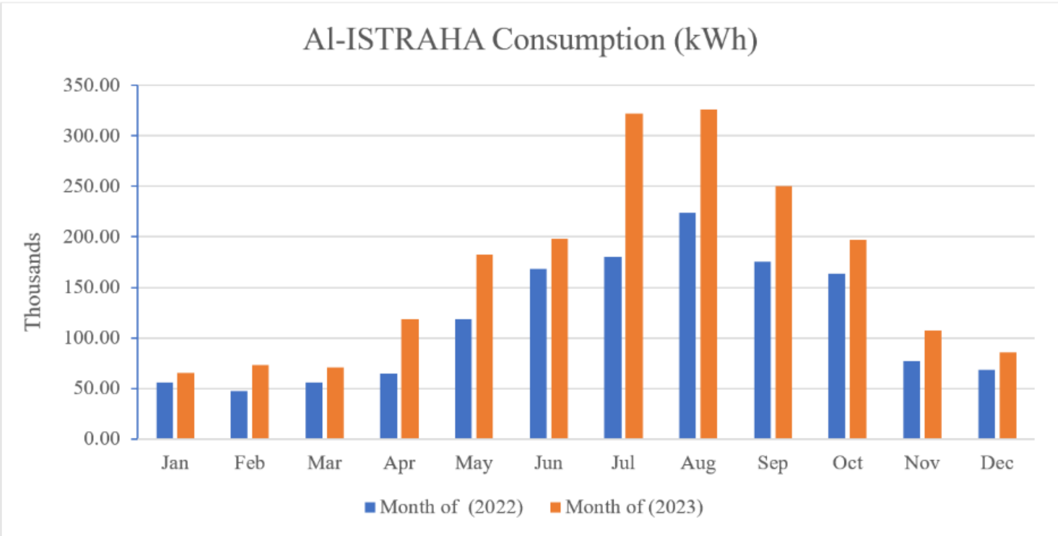
The main objective of NZEB is to make a balance between energy consumption and annual generation of energy. Multiple steps and deep analysis must be conducted to perform this goal professionally, through collecting accurate data about the case, then making good analysis for loads to discover the overall weakness points of the system to take action against these points and to treat the additional consumption that caused by inefficient systems.

This chapter will show all collected data from the location, and the results of an investigation that will reveal the energy problems of the current situation. After that will show the simulation results of applying different conservation strategies, and then can see the economic and environmental analysis of implementing the suggested solutions as integrated manner.

3.1 Current situation in GACB

The collected data from the location can draw accurate images about the problem. Figure (3.1) illustrates the actual monthly consumption of electricity of all loads in the location for two years, in which the maximum value is in August usually, which means the cooling in summer is the most influential burden.

Figure 3.1
Consumption of electricity for two years



All Collected data about the loads in the location were arranged and summarized in table (3.1), which shows the main types of loads and annual energy needs for each one. As shown in table (3.1), the “Demand factor” column was estimated according to the nature of work and personal experience in the location, and the formula (3.1) was used to estimate the value of demand factor for each load then can calculate the value of actual demand. However, the result of estimated values of demand factor within the range of standard values in literatures.

$$Demand\ Factor\ = \frac{Maximum\ demand\ load}{Total\ load\ connected} \quad (3.1)\ [50]$$

Also, the column “Hours/Year” refers to the estimated working hours around year. These values can be calculated by collect information about daily working hours for each load as individual throughout month, then multiply it by the number of working months of each load. The results of these calculations were included in table (A.3) in appendix A.

Table 3.1: The Main Loads & Energy Consumption

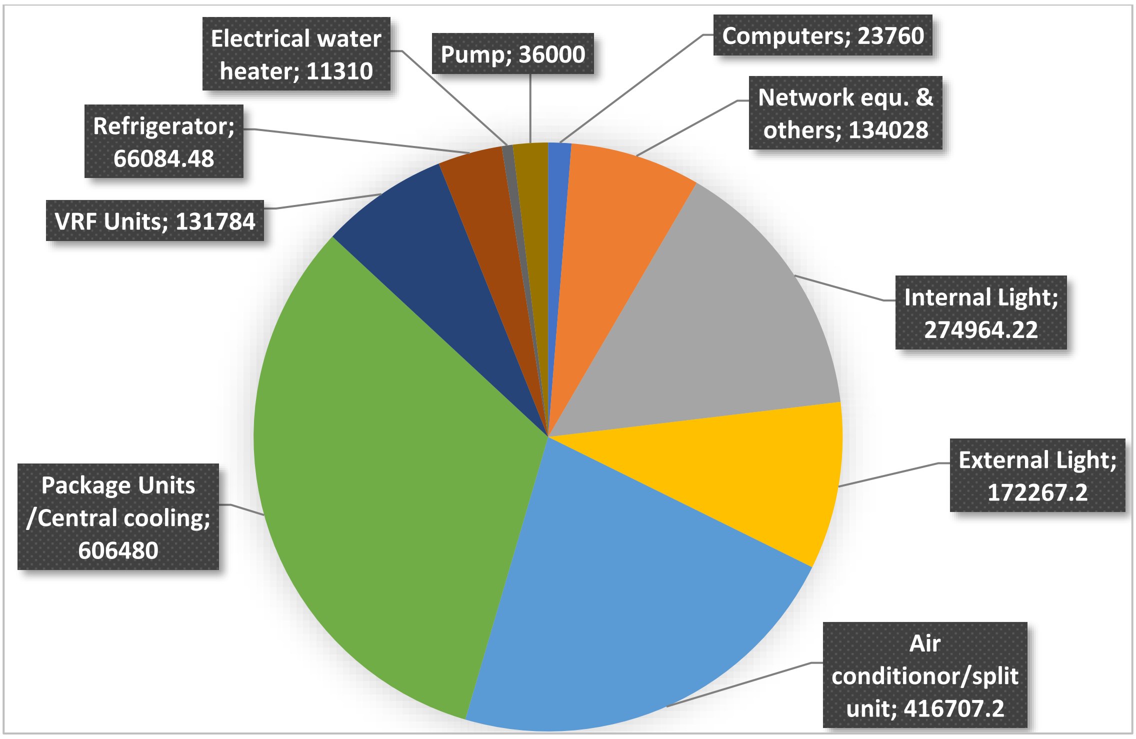
The Main Loads & Energy Consumption

Main Loads	Rated Power [W]	Demand factor	Actual Demand [W]	Hours/Year	Net Energy per year [kWh]
Computers	11000	0.75	8250	2880	23760
Network equipment & others	15300	1	15300	8760	134028
Internal Light	56577	0.75	42432.75	6480	274964.22
External Light	34180	1	34180	5040	172267.2
Air conditioner/split unit	206700	0.8	165360	2520	416707.2
Package Units /Central cooling	266000	0.95	252700	2400	606480
VRF Units	57800	0.95	54910	2400	131784
Refrigerator	11473	1	11473	5760	66084.48
Electrical water heater	14500	0.65	9425	1200	11310
Pump	20000	0.5	10000	3600	36000
Total			604030.75		1873385.1

Mainly, the consumption of energy was caused by HVAC systems and lighting systems, as shown in figure (3.2), so the study will focus on these two types of loads.

Figure 3.2Net Energy per year [kWh]

Net Energy per year [kWh]



3.2 Lighting Analysis & Suggested Measures

The total annual consumption of internal & external lighting represents about (25 %) of annual electrical needs in GACB. The investigation and measurements were conducted on the lighting system that will be shown in this section. Also, the suggested solutions, simulation results, and other calculations will be included.

The table (3.2) shows the main facilities, and illumination levels were measured inside the space and compared with standard levels. The collected data reveal the extra level of lighting, and that means there are good opportunities to reduce energy by treating these extra values to be close to standard.

Table 3.2
Current status of Lux level

Site	LUX Level By			Standard level (LUX)
	Daylight only (LUX)	Artificial light only (LUX)	Overall (LUX)	
Administrative Offices	155	271	356	500
Departure Hall/Int. light	49	200	272	200
Departure Hall/Ext. light	XXX	185	**185**	100
Arrival Hall/Int. light	110	295	**382**	200
Arrival Hall/Ext. light	XXX	65	65	100
Kitchen/ Int. light	103	1820	**1960**	300
Kitchen/ Ext. light	XXX	750	**750**	100
Service Hall & Luggage/ Int. Light	119	1900	**2000**	200
Service Hall & Luggage/Ext. light	XXX	80	80	100
Parking 1	XXX	8	8	10
Parking 2	XXX	15	15	10
Parking 3	XXX	92	**92**	10
Parking 4	XXX	85	**85**	10
Taxi Station	XXX	100	100	150
Internal Street	XXX	45	45	30
Main Lighting Pole / General purposes (8 high pressure Sodium lamp mounted on pole in which the height of pole is 25 meter and each lamp 1000 watt)	XXX	50	**50**	30
Mosque	163	200	335	300

Some analysis for data in table (3.2) above will illustrate that the lighting system in all spaces needs accurate individual auditing. But according to the methodology of this study, only halls and parking area will be focused on and simulated, then the output results will be used as benchmark.

3.2.1 Measures and opportunities for lighting

Through using DiaLux Evo software, several scenarios were simulated for the arrivals hall, which helped us to study this case and determine the suitable measures to make energy reduction without affecting on quality of services inside the hall.

The daylight effect at the arrivals hall was measured by lux meter, about (110 lux) is the daylight level inside the arrivals hall according to real measurements during a clear day, and that was included in table (3.2). So, the artificial lighting sources are required at overall working hours to match the minimum requirements of lighting level according to standard code, as Table (1.1). At present, there are (100) lighting units inside the hall to treat this gap, in which each fixture is (54 W) and (4550 lm).

On the other hand, the simulation results are obtained by DiaLux Evo and examine the effect of daylight only, in which about (149 Lux) and un-uniform distribution of light inside the area, as shown in figures and simulation report in appendix B.

By axiomatic calculations, the electrical energy needs are:

$$E = number\ of\ fixtures\ \times power \times operating\ time \tag{3.2}$$

$$E = 100\ fixtures\ \times 54\ W \times 6500\ hours$$

$$E = 35100\ KWh$$

where the estimated annual working hours are (6500),

Also, the lighting power density is:

$$power\ density = \frac{number\ of\ fixure \times power}{Area} \tag{3.3}$$

$$\frac{100\ \times 54\ W}{572\ m^2} \approx\ 9.5\ W/m^2$$

Now, some measures mentioned in Chapter One will be exploited and discussed below to reduce this amount of consumption.

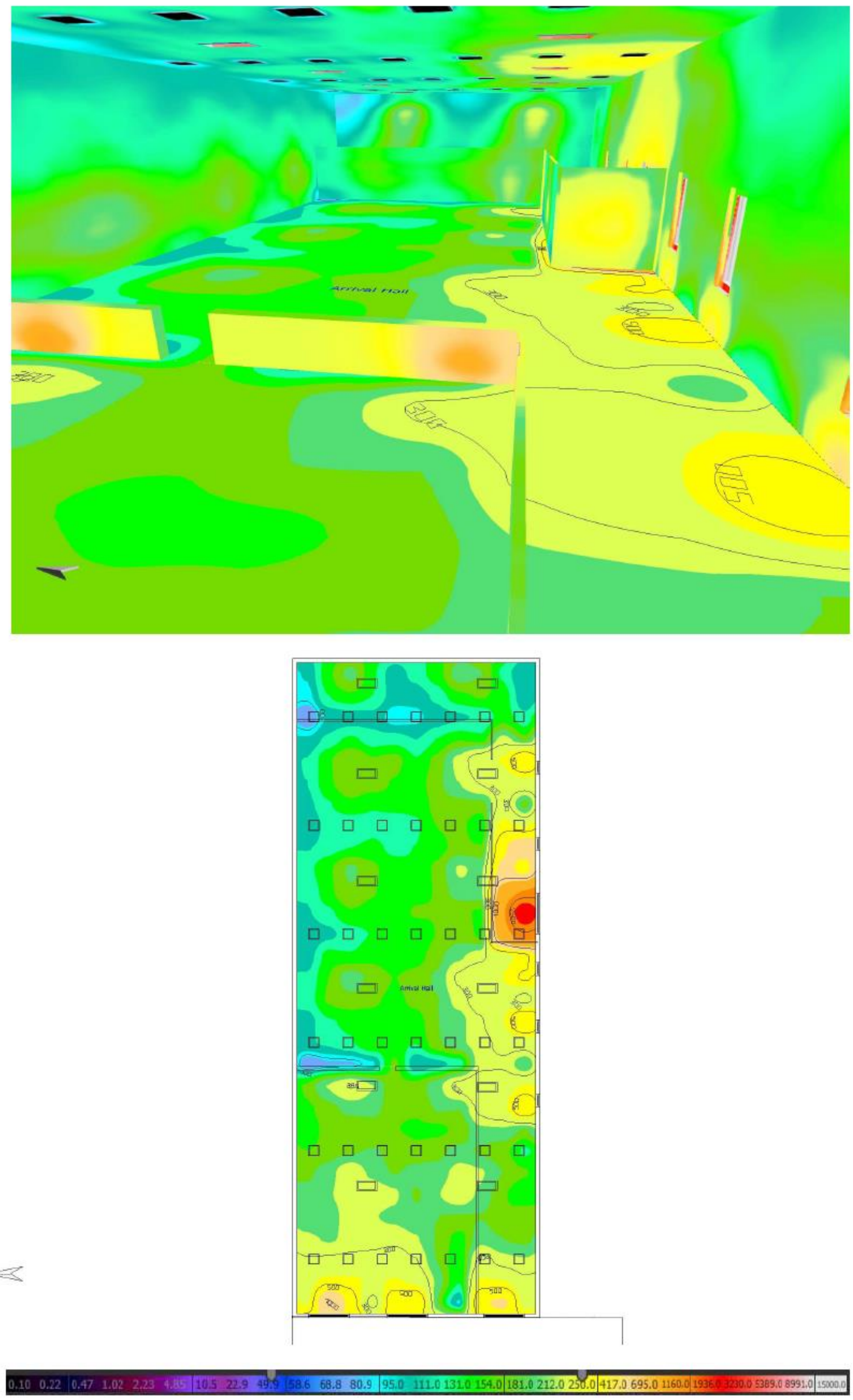
3.2.1.1 Measure-1: "Roof skylight for Arrivals Hall"

Skylight is one of the daylight method - mentioned in Chapter One - can be used to exploit the annual shining hours to light up the hall. Twelve Roof skylights with dimensions (1.2 m x 0.6 m) are suggested for this scenario and implemented virtually to simulate the overall system by Dialux evo in mid-day time of August.

The result is about (267 lux) and more uniform illumination inside the hall, without using any artificial lighting units, as shown in figure (3.3). Also, appendix C represents the simulation report.

Figure 3.3

Simulation of measure-1



3.2.1.2 Measure-2: "De-lamping & Replacement at Arrivals Hall"

In the current status, there are (100) lighting units to light up the hall. Actual measurements discover that the lux level is (295 Lux) at night, while the standard level is (200 lux), so removing lamps and redistribution fixtures are important measures. The current led lamps are (54 W) and (4550 lm), which means the efficacy is (84.2 lm/W), while the suggested lighting unit is a Philips led fixture with (31.5 W) and (4298 lm) is more efficient with (136.4 lm/W) – as shown in datasheet in Appendix D -, so the replacement current fixture by Philips one will make reduction surely.

After retrofitting the lamps inside the arrivals hall virtually and simulating it with Dialux Evo, as shown in figure (3.4) below, the result is about (222 lux), and the power of the lighting system is reduced by (4077 W), where (100) old fixtures were replaced by (42) new Philips ones according to an automatic suggestion by the simulation software to keep lighting level at least (200 lux) on average. This result was included in the simulation report in the appendix E.

Now, the lighting power density is:

$$power\ density = \frac{number\ of\ fixure \times power}{Area} \tag{3.4}$$

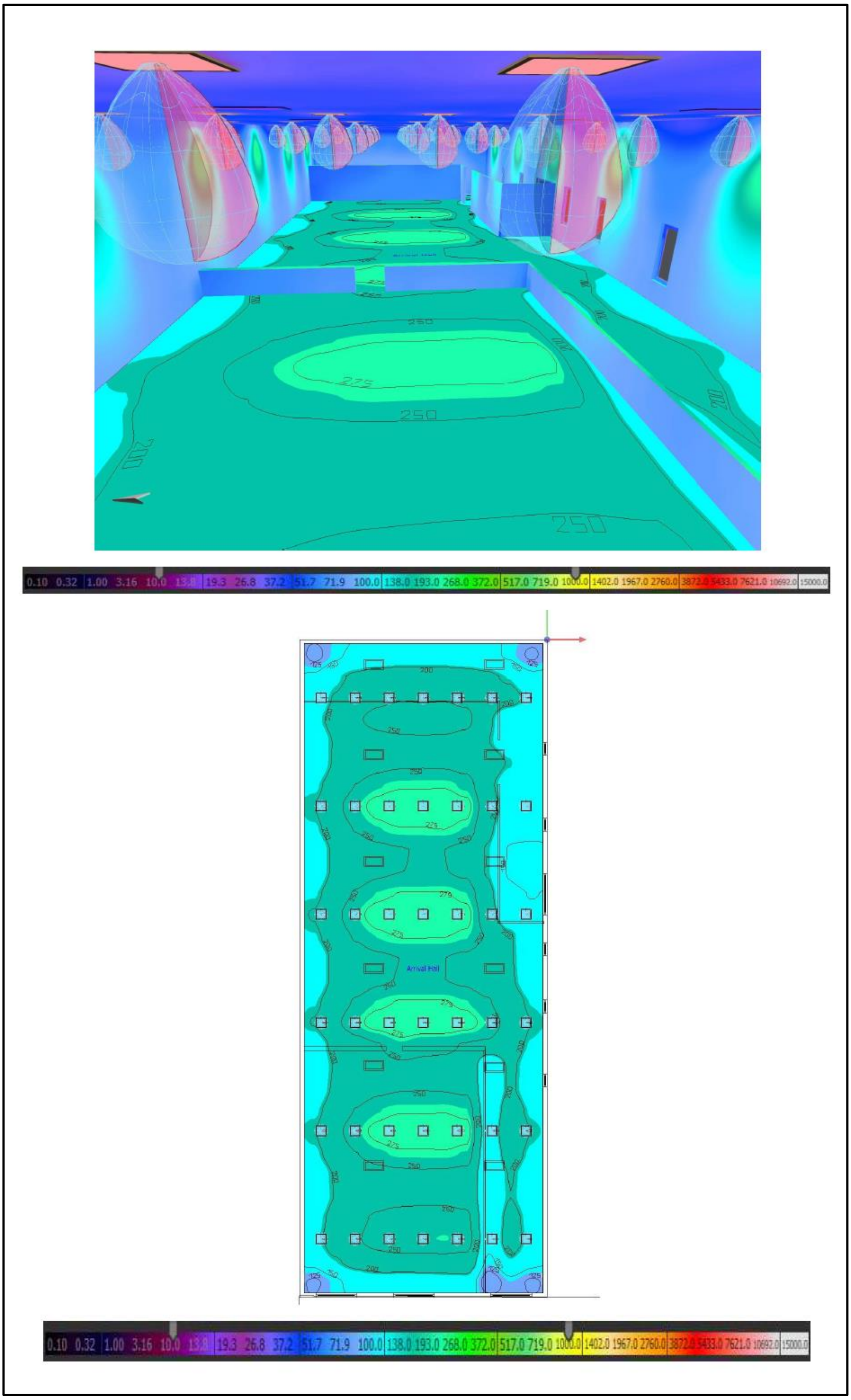
$$\frac{42\ fixture\ \times 31.5\ W}{572\ m^2} \quad \approx \quad 2.31\ \ W/m^2$$

This value represents the density inside the hall if the illumination level is (200 lux), but if illumination level is changed according to usage of space, then the equivalent value ($1.15\quad W/m^2/100\ lx$) can be used as benchmark depends on the illumination level are required inside the area.

By comparing between two results of equation (3.3) and equation (3.4), the values refer to the demand per meter square before and after using highly efficient models and make reduction of number of lighting units, moreover the importance of determine the suitable level of illumination according to the area type.

Figure 3.4

Simulation of measure-2



3.2.1.3 Measure-3: "Install Control System for Arrivals Hall"

Now, to make a combination of the advantages of measures above, control system must be integrated, to guarantee constant illumination level across the area at all times by using daylight and artificial lighting fixtures, in which the sensors inside the space will measure the lux level continuously then the special algorithms will change the level of lighting units (0 – 100 %) by using efficient dimmer device. Moreover, the selected lighting fixture is (RC332V 42S/940 PSD W62L62 MXO) from Philips brand, and that is characterized by dimmable feature according to the official web site of the manufacturer [51]. The datasheet in appendix D illustrates additional information.

In current status, the lighting units are working about (6500) hours annually. By simple estimation and according to the nature of working time, at least one-third of these hours is clear sky daytime, so if control system is installed, then natural light can light up the hall by 100% without artificial lighting for (2167) hours annually. However, DiaLux Evo can make a more accurate estimation in this case, in which it can calculate the energy needs year-round and can estimate the savings if sensors and controllers are installed. The energy evaluation report in Appendix F presents the daily simulation results for July 2022, as well as the monthly simulation for the year 2022, indicating an energy savings of (3015 kWh). Also, the simulation shows a comparison between controlled and uncontrolled systems.

3.2.2 Benchmark and Estimation

Now, according to the results above, other similar facilities can be estimated, where ($2.31\ W/m^2$) is the lighting power density to light up the hall with (200 Lux) on average, and then (1.15 W/m^2/100 lux) is another important value that can be concluded and used as a benchmark to retrofit the number of fixtures at other facilities. Also, about (3015 kWh) annual savings when the control system was installed, that means:

$$\frac{3015KWh}{6500\ h \times 572\ m^2} \approx 0.811\ W/m^2 \text{ saving} \tag{3.5}$$

So, the table (3.3) makes a comparison between the current status of the lighting system and the suggested measures, furthermore it shows the net energy saving of these measures, while table (A.2) – in appendix A- shows the additional energy saving if the control system will be installed.

Table 3.3
Energy saving by De-lamping & Replacement

Site	Area [m2]	operating	Current status				After retrofit				Annual Saving	
		Hours/Year	Type	Power [W]	No. of lamp	Total Power	Type	Power [W]	No. of lamp	Total Power	ΔP [KW]	ΔE [KWh]
Arrival Hall/Int. light	572	6500	LED	54	100	5400	LED	31.5	42	1323	4.077	26500.5
Departure Hall/Int. light	1200	6500	Fluresent tube T8	18	450	8100	LED	31.5	88	2772	5.328	34632
Departure Hall/Ext. light	500	3600	LED	200	6	1200	LED	56.5	16	904	0.296	1065.6
Kitchen & dining space/ Int. light	375	4380	LED	150	40	6000	LED	31.5	41	1291.5	4.7085	20623.23
Kitchen/ Ext. light	75	3600	LED	150	6	900	LED	56.5	3	169.5	0.7305	2629.8
Service Hall & Luggage/ Int. Light	270	6500	LED	150	35	5250	LED	31.5	20	630	4.62	30030
Parking 3	3000	3600	LED	150	26	3900	LED	80	14	1120	2.78	10008
Parking 4	5400	3600	LED	150	30	4500	LED	80	16	1280	3.22	11592
Internal Street	-----	3600	LED	150	20	3000	LED	80	20	1600	1.4	5040
Main Lighting Pole / General purposes (8 high pressure Sodium lamp mounted on pole in which the hight of pole is 25 meter and each lamp 1000 watt)	-----	3600	High pressure sodium	1000	8	8000	LED	150	10	1500	6.5	23400
Total						**46250**			**270**	**12590**		**165521**

3.2.3 Lighting in the parking area

The parking area is one of the facilities inside the location that consumes energy for lighting at night, Figure (J.11) -in appendix J- shows the Parking 3 & 4, where the area is (3000 m^2) & (5400 m^2) respectively. Real measurements were conducted by lux meter, which discovered extra illumination in these zones, see Table (3.2).

De-lamping and replacement measures were examined by the simulation software, then the results were summarized in Table (3.3).

3.2.4 Lighting at the Entrance of the Hall

Through a review of collected data in the table (3.2), extra illumination of external lighting at the entrance of some buildings. So, the simulation will be conducted to select suitable lighting units for the entrance of the departures hall, then the other entrance will be treated similarly, in which (6) lighting units with (200 W) were replaced by (16) units with (56.5 W), not to reduce energy only but to improve the glare and the lighting contrast too. The lighting power density can be used as an indicator or guide to estimate the other similar areas, see Table (3.3).

$$power\ density = \frac{number\ of\ fixure \times power}{Area} \tag{3.6}$$

$$\frac{16\ units\ \times 56.5\ W}{500\ m^2} \approx 1.8\ W/m^2$$

3.2.5 Additional opportunity for external lighting

Through an extended period of monitoring the external lighting system, an additional energy-saving opportunity was identified. It was observed that the external lighting units were activated approximately one hour before sunset and deactivated one hour after sunrise, on average. This inefficiency is attributed to calibration errors in the conventional timer system. Moreover, this method requires continuous human intervention for adjustments. A more effective and automated solution would be the implementation of a photocell-based control system, which would enhance operational efficiency and contribute to further energy savings.

This value of saving can be calculated by using data from table (3.1), where the total power for external lighting is (34180 watts), so the saving of electrical energy during two hours is (68.4 kWh) per day and that means the annual saving is (24966 kWh) if photocell is taken in account.

At the end of lighting section, the net of all measures above are summarized in the table (A.4) in appendix A.

3.3 HVAC Analysis & Suggested Measures

As previously mentioned, cooling is the biggest load, so several aspects of the cooling system will be treated in this section. The building envelope is one of the factors that have an influence on internal thermal comfort and efficiency of energy use, so the measure-1 below will treat the insulation and infiltration issues and examine it by HAP.

Another level of treatment for the cooling system is represented through the study the efficiency of the cooling device and the selection of a suitable energy source to feed it, therefore different cooling scenarios will be discussed in measure-2. The third measure in this section targets (116) split cooling units that are working in the location, but mostly they have low performance and old technologies. Also, this section includes the technical calculations and simulation results for suggested solutions to determine the impact of these measures.

3.3.1 Measure -1: "Retrofitting of Building Specifications"

Through analysis of the HVAC system in the Arrivals Hall and the simulation process by HAP, good opportunities were discovered to make savings in the arrivals hall and other halls that have similar specifications and operation conditions. As shown in figure (J.9 ‘a’), the final result of the simulation of HAP, where the maximum cooling load in August at current status is (359 kW) before retrofitting, while figure (J.9 ‘b’) shows the final result after implement several measures to reduce thermal leakage as shown below.

The analysis of simulation results – in appendix G- revealed huge thermal leakage from different structural component of the building, where the thermal load from the roof and infiltration are the main.

Now, some measures can be applied on the site to reduce thermal leakage, like increasing insulation and reducing the overall U-value by replacing metal roof of the hall with sandwich panel with polystyrene layer (50 mm). And heat transfer through walls can be minimized by installing internal layer of gypsum board with polystyrene board (50 mm).

On the other hand, Infiltration by doors and windows must be treated to make additional savings by using air curtains and sealing rubbers for instance. HAP software gives ability to enter the value of infiltration in unit (ACH). Even though the Palestinian Green Building Code requests (0.25 ACH) [52] as maximum value for infiltration from green buildings, the value of (0.5 ACH) as minimum target in this case may be satisfied in view of the working conditions and construction specification of the building, so this value can be recorded directly in HAP as an important measure to minimize the load.

Also, CO_2 and occupancy sensors can be integrated with a control system to create dynamic ventilation system depends on multiple parameters such as carbon dioxide concentration, then that will reduce the rate of air change inside the space and reduce the cooling load.

All mentioned measures above were examined through HAP, so the Arrivals Hall was retrofitted virtually and the simulation was repeated. The new result can be seen in appendix H, where the cooling load decreased to (148.8 kW) as shown in figure (J.9 ‘b’). However, (5%) as a safety margin was added for the cooling load, then the net result is about (155 kW). On the other hand, all costs of these measures will be discussed later in economic analysis section.

In general, after revision for working conditions and architectural specifications of halls in this case, that shows high similarity between these buildings, so the saving in thermal load of the arrivals hall can be used to estimate the savings of other similar buildings without conducting individual simulation for all spaces. So, after applying the conservation measures on similar halls, (40%) can be considered as a suitable overall saving value of the total thermal loads.

3.3.2 Measure -2: "Improvement of the performance of cooling device"

The (155 kW) cooling load can be covered through several solutions, but the suggested solution in this study focuses on a solution that depends on renewable sources. So, three solutions will be undergone for evaluation, the first option depends on a PV system to drive the current cooling device (Petra Package units), the second solution is the VRF unit with a PV system, and the third solution is a Solar absorption chiller with evacuated tube. Technical details of these scenarios will be discussed here while economic issues will be discussed later, then three scenarios can be compared and one scenario will be selected to feed the arrivals hall.

3.3.2.1 Scenario -1: "Using PV system to drive the current cooling device"

Currently, Petra package units are used to make cooling for halls, and a lot of electrical energy is consumed annually. Two cooling units serve the arrivals hall now, if suggested modifications of measure-1 are taken in account, then the cooling load will be reduced to (155 kW) only, as Figure (J.9) -in appendix J- which shows the daily cooling load in August of the arrivals hall.

Now, the daily electrical energy will be covered by PV solar panels, so some calculations below show the number of panels and inverters needed.

However, the annual electrical energy can be estimated by using the Cooling Degree-Day method:

Q_{load} = 155 kW at August in maximum point.

COP = 2 ~ 3 for package unit

$$DD_C = \sum(T_{avg.} - T_{bal.})^+ \quad (3.7)\ [53]$$

Where; $T_{avg.}$ is the summer monthly mean daily outside air temperature.

$T_{bal.}$ is the balance point temperature.

And the value of DD_C for the Dead Sea region is about 1200 [53]**,** so:

$$E_{elec.} = \frac{Q_{load} \times Time\ (hours) \times DD_C}{(T_{outside} - T_{inside}) \times COP} \quad (3.8)\ [53]$$

Where; T_{inside} is the internal design temperature (25°C), while $T_{outside}$ is the external design temperature (45°C) according to weather data from Palestinian Meteorological Authority [54].

$$E_{elec.} = \frac{155 \times 10 \times 1200}{(45-25) \times 2.5} \approx 37200\ kWh\ per\ year$$

PV system;

$$PV_{Capacity} = \frac{Annual\ Energy\ needs}{365 \times G_{avg} \times \eta_{sys.}} \quad (3.9)\ [55]$$

Where; η_{sys} is the overall system efficiency, including losses from inverter, wiring, and other system components. While G_{avg} is the value of peak sun shine hour and also it equal to yearly average of solar irradiance at the site.

Even though the solar irradiance at Jericho exceeds the average value in Palestine in summer, (5.4 kWh/m^2/day) [30] will be used here because the NZEB relies on the net metering principle. Bidirectional meter is used to calculate the net consumption, whenever the PV system delivers more power than the facility needs, then the excess energy is exported to the grid and the excess spins the electric meter backward, but at other times, when demand exceeds the supplied energy by the PVs, then the grid provides supplementary power [55]. Thereby the additional production in summer will be consumed again in winter to achieve net zero annually.

$$PV_{Capacity} = \frac{37200}{365\ \times 5.4\ \times 0.93} \approx 20\ kW_p$$

This system needs (50) PV panels and one inverter (20 kW ac), and can be implemented over (140-meter sq.).

3.3.2.2 Scenario-2: "VRF unit with PV system"

This solution suggests replacing the package units with a VRF system and installing PV panels to provide electricity for VRF. The COP of these package units - on average – is (2.5). While the COP of VRF is about (4), so the replacement with VRF can make saving by (37.5 %).

Q_{load} is (155 kW) at August in maximum load. And the COP for VRF is (4), so:

$$E_{elec.} = \frac{Q_{load} \times Time\ (hours) \times DD_c}{(T_{outside} - T_{inside}) \times COP} \quad (3.10)\ [53]$$

$$E_{elec.} = \frac{155 \times 10 \times 1200}{(45-25) \times 4} \approx 23250\ kWh\ \ per\ season$$

PV system;

$$PV_{Capacity} = \frac{Annual\ Energy\ needs}{365 \times G_{avg} \times \eta_{sys.}} \quad (3.11)$$

$$PV_{Capacity} = \frac{23250}{365\ \times 5.4\ \times 0.93} \approx 13\ kW_p$$

This system needs (32) PV panels and one inverter (13 kW ac), and can be implemented over (91-meter sq.).

3.3.2.3 Scenario -3: "Solar absorption chiller with evacuated tube"

Figure (J.10) – in Appendix J- represents the configuration of suggested solar absorption cooling system. According calculated thermal load through HAP, additional calculation must be conducted to determine the size of evacuated tube, so:

Q_{load} = 155 kW at August / maximum load.

Mostly, the COP of absorption chiller is (0.5 ~ 0.6), so the heat gain is needed from collector at maximum load:

$$Heat\ gain = \frac{Qload}{COP} \quad (3.12)$$

$$Heat\ gain = \frac{155}{0.55} = 282\ kW$$

$$\text{Collector Area} = \frac{Max.power\ (w)}{Irradiation\ (w/m^2) \times efficiency\ of\ collector} \quad (3.13)$$

$$Collector\ Area = \frac{282000}{800\ w/m^2\ \times\ 0.7}$$

$$Collector\ Area\ = 503\ m^2 \quad \text{of evacuated tube collector}$$

Where the efficiency of evacuated tube according ASHRAE guidelines [56].

The total implemented area (includes the spaces between collectors) is:

$$503 \times 1.5 = 754.5\ m^2 \tag{3.14}$$

$$\therefore\ 754.5/155 = 4.87\ m^2/kw \tag{3.15}$$

3.3.2.4 Scenario - 4: "Do-Nothing"

After reducing the cooling load to 155 kW by measure-1, the "Do-Nothing" scenario will be considered as reference scenario. This scenario means "Make No Change" in the current HVAC devices that depends on cooling devices from PETRA brand and consume electricity from the traditional grid;

Q_{load} = 155 kW, is maximum load in August.

COP = 2 ~ 3 for package unit

Annual electrical energy can be estimated by using the Cooling Degree-Day method:

$$E_{elec.} = \frac{Q_{load} \times Time\ (hours) \times DD_c}{(T_{outside} - T_{inside}) \times COP} \qquad (3.16)\ [53]$$

$$E_{elec.} = \frac{155 \times 10 \times 1200}{(45-25) \times 2.5} \approx 37200\ KWh\ \ per\ year$$

After the technical comparison between the four different types of cooling systems, the exciting question now is: Which of these scenarios are more feasible and more suitable for this case study? This question will be discussed later in the economic section (3.6).

3.3.3 Measure -3: "Replace Split Unit with VRF"

The average COP for split units that existed in this case is about (3). While, in general, the COP for the VRF system is (4). So, the replacement process will reduce the energy to (0.75) of the current needs; in other words, a (25%) saving can be achieved if VRF systems are used instead of the old split units. The table (3.1) shows the current annual energy needs for split units are (416707.2 kWh), therefore the annual saving is (104176.8 kWh).

3.4 Solar Water Heater System

SWH is one of popular systems in Palestine where (68%) of residential buildings use the flat plate collector or evacuated tube collector on the rooftop, and that makes saving of carbon footprint by (395,000) tons annually [57].

A small amount of energy is needed -in this case- to cover hot water needs in the winter season, as included in table (3.1), so outlet hot water with (45°C) will be satisfied, and these needs can be achieved easily in a warm climate such as Jericho, so the amount of hot water can be covered completely by SWH.

The calculation below shows the sizing of SWH, in which the electrical needs for water heater - according to Table (3.1) – is (11310 kWh) through about (150) days annually, so the daily needs is:

$$11310/150 = 75.4 \text{ kWh per day} \qquad (3.17)$$

And the area of flat plate collectors is:

$$\text{Total area} = \text{Energy} / (\text{daily radiation x efficiency of collector}) \qquad (3.18)$$

$$Total\ area \ = \ 75.4 \ / \ (5.4\ x\ 0.35) \quad \approx \ 40\ m^2$$

Where the efficiency of flat plate is about 35% [58].

That means, the number of collectors is:

$$\therefore\ No.\#\ coll. = \ 40\ /\ 2\ =\ 20\ coll. \qquad (3.19)$$

And the capacity of storage tank is:

$$Q = m\ \times\ C_p \times\ \Delta T \qquad (3.20)\ [59]$$

This equation represents the amount of heat that required to increase the temperature of the amount of water m in (kg) by ΔT, where C_p is the specific heat of water and ΔT is the difference of outlet temperature and inlet temperature of water.

$$m = \frac{Q}{C_p \times\ \Delta T}$$

$$m = \frac{75.4\,KWh \times 3600}{4.18 \times (45 - 15)}$$

Where; the outlet desired temperature is (45 °C) and the assumption of inlet design temperature is (15 °C) as minimum value, where according to historical data of ambient air temperature is about (10 °C) during winter days [60], and Ashrae code refer to (+ 5 degree) as difference value of water temperature and ambient air temperature in winter.

$$\therefore\ m = 2171.5\ Kg\ per\ day$$

Storage tank capacity ≈ 2200 Liter

3.5 PV system of NZEB

NZEB's idea must include a renewable system to cover the annual needs of energy. PV system is one of popular renewable systems in Palestine where the yearly average of solar radiation is (5.4 kWh/$\boldsymbol{m^2}$/day), available technology and easier to integrated with public buildings, so the PV system will be discussed in this section.

The first step is to calculate the net electrical needs after applying the mentioned measures above, and the final results of saving will be shown in economic section. Anyway, the annual energy -before applying measures- is (1,873,385.10 kWh), while the annual saving is (613,376.00 kWh) as a result of applying the all-mentioned measures, so the annual electrical needs is (1,260,009.1 kWh).

Now, make additional calculations to size the ON-Grid PV system:

$$PV_{Capacity} = \frac{Annual\ Energy\ needs}{365 \times G_{avg} \times \eta_{sys.}} \qquad (3.21)$$

$$PV_{Capacity} = \frac{1{,}260{,}009.10}{365 \times 5.4 \times 0.93} \approx 687\ kWp$$

However, the productivity degradation of PV panels must be taken in account, so (15%) additional capacity must be added as a safety margin and to satisfy the additional needs in the site that may come up through the next two years.

$$\boxed{System\ Capacity \approx 800\ kWp}$$

PVSYST was used to determine the number of PV panels and Inverter devices and to simulate the suggested system to examine productivity and overall efficiency. Table (A.5) -in appendix A- shows the summary of the results, while appendix I shows the results of the PVSYST simulation in detail.

According to general assessment for some projects of PV system in Palestine, each kilowatt peak (kWp) of installed capacity typically requires approximately 6 to 8 square meters of space as rule of thumb, that depends on the efficiency of PV panel and available irradiance. Therefore, an (800 kWp) would require an estimated area of around (6,000) square meters, which could be accommodated within a parking area.

3.6 Economic Analysis of NZEB

A feasibility study for all measures above will contribute to differentiating and comparing the options, furthermore this will reveal the economic benefits of these measures. Multiple partitions in this section will treat lighting, HVAC, and the overall solution through economic indicators according to local prices from several companies for the components and retrofitting works.

3.6.1 Lighting

According to the results of Table (A.4) -in appendix A-, the annual saving of lighting measures is (202583.6 kWh) and then the equivalent annual savings cost is about (39938 $), where the electrical energy cost from traditional grid is (0.20 $/kWh).

Table (A.7) -in appendix A- represents the cost of all modifications in the lighting system, where the total cost of required measures is (58,200 $), so the simple payback period is about (18) months.

3.6.2 Feasibility study for scenarios of HVAC devices

To perform a realistic study for selecting a suitable option for the HVAC component, these scenarios must be compared with do-nothing or don't make a change on the current system that depends on traditional grid of electricity, so "do-nothing" will be considered as reference scenario. Now, according to the result of section (3.3.2.4), the cost of the annual cooling load for the arrivals hall in scenario-4 is (7440 $), so this cost will represent the saving for other scenarios.

Economic analysis -in this phase- will depend on two indicators: simple payback period and present worth. Anyway, some assumptions must be defined to conduct this analysis, in which the first assumption is the lifetime of all solutions is (20) years at the minimum and the second assumption is (10%) as the minimum attractive rate of return (MARR). At the end of this phase, the result of these indicators can refer to a more feasible solution for our case.

Table (3.4) shows the cost of each scenario, while Table (3.5) shows the result of the comparison between the suggested scenarios, and this information refers to the scenario-1 is more feasible for our case study. Table (A.6) -in appendix A- shows the details of the analysis for these scenarios. AC scenarios

Table 3.4
Component Cost of HVAC scenarios

Scenario-1			
Item	Quantity	Cost/unit	Total cost ($)
PV panels 400 W	50	130	6500
20 kW inverter	1	4000	4000
Steel structure and other components	20	250	5000
Installation work	20	100	2000
Total			17500
Scenario-2			
Item	Quantity	Cost/unit	Total cost ($)
155 KW VRF unit	155	200	31000
13 kW inverter	1	2600	2600
PV panels 400 W with installation	32	130	4160
Steel structure and other components	13	250	3250
Installation work	13	100	1300
Total			42310
Scenario-3			
Item	Quantity	Cost/unit	Total cost ($)
155 KW Low Temp. Absorption chiller	155	200	31000
Evacuated Tube with structure	503	200	100600
Installation work	1	10000	10000
Total			141600

Table 3.5
The result of economic analysis of HVAC Scenarios

Scenario	1	2	3	4
Investment cost ($)	17,500	42,310	141,600	0
Life time		20		
Annual saving ($)	7440	7440	7440	-7440
Space (m^2)	140	91	755	0
SPP	3	6	20	-
PW	45,840.91	21,030.91	- 78,259.09	- 63,340.91
MARR		10%		

3.6.3 Feasibility study for overall NZEB case:

Table (3.6) shows the summary of all savings that may be achieved if all mentioned measures are applied. Economic indicators -like simple payback period (SPP) and present worth (PW) - will be examined in this phase to determine the feasibility of applying the NZEB idea on this case study.

Table 3.6: Summary of total annual Energy saving

Summary of total annual Energy saving

Loads	Net Energy per year [kWh]	Total save [kWh]	Saving annual cost ($)	Saving [%]
Lighting section (Int. + Ext.)	447,231.42	202,583.6	39,937.91	45.5
Air conditioner/split unit	416,707.2	104,176.8	20,537.71	25
Cooling Load & HVAC device of halls	738,264	295,305.6	58,217.39	40
Electrical water heater	11,310	11,310	2,229.69	100
Total Remaining loads	259,872.48	0	0	0
Total	1,873,385.1	613,376	120,922.7	32.7

Table (3.7) contains the summary of retrofitting cost - for each system as individual - that are needed to conduct the overall economic study.

Table 3.7
Summary of retrofitting Cost

For lighting			
Item	Quantity	Cost $ /Unit	Total cost ($)
New light units	270	100	27,000
control system with sensors	1	3000	3,000
Skylight windows	70	400	28,000
Photocell for external light	1	200	200
Total			**58,200**
HVAC & Building retrofit			
Item	Quantity	Cost $ /Unit	Total cost ($)
Replacement Roof with sandwich panel (with 50mm polystyrene board)	3000 m^2	45	135,000
Add insulation layer of 50mm polystyrene for walls with installation work	2200	60	132,000
Install control system for HVAC with sensors	1	12000	12,000
HVAC Recovery system	4	15000	60,000
			339,000
Replace split units with VRF			
Item	Quantity	Cost $ /Unit	Total cost ($)
62 KW VRF	8	12000	96,000
Installation	8	4000	32,000
Total			**128,000**
SWH			
Item	Quantity	Cost $ /Unit	Total cost ($)
Solar collector / Flat plate	20	150	3,000
350-liter Storage Tank	6	500	3,000
Steel Structure and Installation Work	1	5500	5,500
Total			**11,500**
PV system			
Item	Quantity	Cost $ /Unit	total cost ($)
PV module 410 Watt	1944	130	252,720
Inverter 66 kWac	9	13500	121,500
Steel structure for 3000 m2 PV and 6 m above the ground	3000	50	150,000
Installation work (for 800 KW)	800	100	80,000
Total			**604,220**
Net Total Cost			**1,140,920**

Table (3.8) shows the summary of accumulative investment cost and saving cost for all systems and applied measures of the NZEB case. In addition, this table shows the annual saving cost for the PV system, if the PV system is installed then the annual consumption (1,260,009.10 kWh) will be covered as free-from PV instead of the traditional grid and will eliminate about (250,000 $) as annual electricity cost.

Table 3.8: Summary of economic data
Summary of economic data

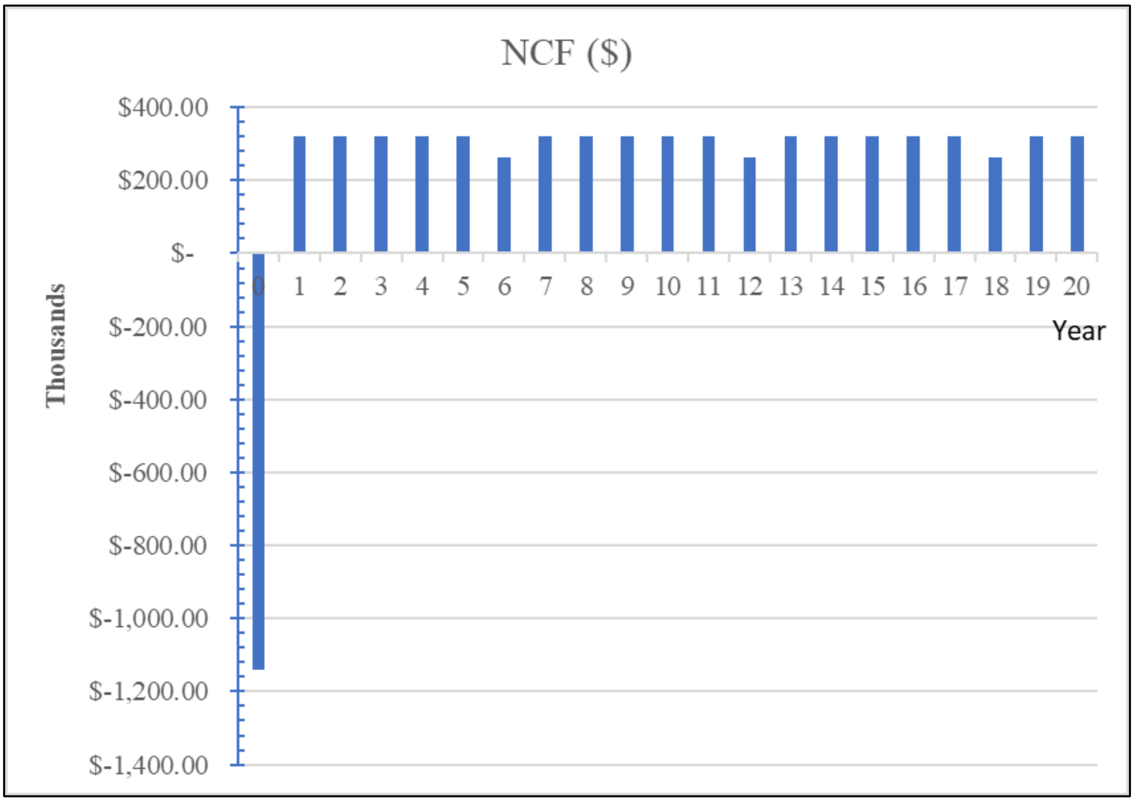
System	Investment cost ($)	Saving Annual Cost ($)	Life Time	Annual O&M ($)
Lighting	58,200	39,937.91	6	-
HVAC & Building Retrofit	339,000	58,217.39	20	-
Replace Split unit with VRF	128,000	20,537.71	20	8,000
Solar absorption chiller	-	-	0	-
SWH	11,500	2,229.69	20	-
PV	604,220	248,401.79	20	42,000
Total	1,140,920	369,324.49		50,000

According to the information in table (3.8), an analysis table (A.8) -in Appendix A- was built, in order to show economic analysis in detail. While the table (3.9) shows the economic indicators value as SPP is less than (4) years and PW is positive value. Also, the net cash flow -figure (3.5)- was drawn according to the data of the analysis table (A.8) in appendix A.

Table 3.9 Economic analysis result
Economic analysis result

Indicator	Value
PW	1,515,804.92
SPP	3.5 Years
Rate of Return (ROR)	27%
Saving To Investment Ratio (S/I)	28%
Profitability Index	126%
LCOE	0.06 $/kWh

Figure 3.5: Net cash flow
Net cash flow



The net cash flow above illustrates the value of initial investment of NZEB vision in GACB, and also it shows the achieved annual saving – about (350,000 $) – that will cause return of the invested capital within four years.

All previous tables above represent collected data and the results of calculation and simulation are carried out step by step according to the methodology of this study, in order to get decisive answer about economical parameters and amount of energy savings that can prove the feasibility of applying the concept of NZEB.

3.7 Environmental Analysis of NZEB

One kilowatt hour of traditional electricity from a gas station will produce (0.7) Kg of CO2. According to data in Table (3.8), the current annual consumption of electrical energy is (1,873,385.1 kWh), so the CO2 pollution is (1,311,369.57) Kg annually as a result of the generation of electrical needs from gas stations.

When the mentioned measures are applied, then the annual saving of electrical needs is (613,376.00) kWh, so the reduction of CO_2 is (429,363.20 Kg/year). While an additional reduction of the net annual production of CO_2, if the concept of NZEB is applied. For a more accurate calculation of CO_2 emission, the Appendix I is an overall simulation by PVSYST, where the life cycle emission (LCE) is taken into account then the green carbon reduction is (16759.5) Tons over 20 years. That refers to the applying of NZEB concept at GACB can eliminate the annual amount of carbon emissions that are produced currently by traditional grid.

Chapter Four
Discussion and Conclusions

This chapter will refer to some points about NZEB, that represent the limitations and challenges may deviate or restrict results if they are not taken into account, in which the challenges toward NZEB can be divided mainly into: Technical aspects, economic aspects and social aspects [5].

On the other hand, an action plan will be shown here to give attention to the implementation ideas of NZEB. Also, another section to discuss and comment on the results, and then talk about conclusions, recommendations, and future development of this research.

4.1 Limitations & Challenges

- Initial cost of efficient construction and materials is one of the important limitations that make misgivings about the feasibility of NZEB and form resistance to transition attempts.
- The small altering of the perimeter or physical boundary of the buildings may cause different outcomes even within the same case.
- The challenges of global warming and climate fluctuations throughout the years of the life cycle of NZEB projects can deviate the predicted outcomes.
- In some cases, complex energy modeling software is required to make analysis and guarantee the annual outcomes.
- Free spaces, Location & orientation of the facility can be considered one of the limitations for energy production from renewable resources, especially solar and wind technology.
- Lack of incentive programs and encouragement regulations in this field.
- Lack of awareness towards efficient practices of energy production and energy use.
- Throughout this study, the critical challenge is: How can perform realistic modifications inside the GACB site to perform NZEB without reduction in the quality of services?

4.2 Action plan for Implementation

NZEB idea can be carried out over multiple stages during a time frame of five years or more. Also, the work can be categorized according to the cost: No-cost measures, low-cost measures, and costly measures, as table (A-9) in appendix A. While the figure (J.12) -in appendix J- represents the timeline for five years to complete the transition of GACB toward NZEB.

4.3 Discussion

1) Summary: Chapter one refers to several methods of conservation measures and some renewable systems can be employed to perform the net zero energy in public buildings in Palestine. And chapter two shows the targeted case and the procedure for conducting the study by using some software. Chapter three focuses on applying different measures and examining them through numerical values, calculations, and simulation results.
2) The methodology of this research depends on performing analysis for some buildings and spaces, and then the results were generalized to other facilities by using some indicators like energy consumption per unit area (Energy intensity) and lighting power density. However, several opportunities can be discovered if detailed analyses are conducted for each part as an individual.
3) Maybe the consumption of individual lighting devices is small relatively, but this study proves the total consumption of these lighting units in public buildings represents the 2^{nd} load, where the huge number of fixtures or lighting units caused huge demand for a long time during working day. In addition, the arbitrary selection of these devices will cause huge deviations in power demand at large-scale buildings, so it is necessary to focus on the specifications of lighting units and select suitable devices according to space usage.
4) Appendix F shows the importance of exploiting the daylight and intelligent control system to light up the spaces, in which the numerical values of consumption and charts - at controlled and uncontrolled cases – are shown in this report, and refer to saving in cost and CO_2 emission during only one day at July.
5) By review of the case study, the thermal load is the main burden not just because of the effect of high infiltration and bad insulation only, but also because the facilities inside the location were built as separated objects that caused increasing of the

exposed areas and then increase the heat exchange with ambient air. So, good architectural design and innovative practices during construction work will contribute additional savings and reduce the cost of insulation work.

6) The results of the comparison between multiple options of HVAC, emphasize the positive effect of using high-performance cooling device, which reduction of energy consumption and also minimizes the size of the solar system and the space needed for installation.
7) An absorption chiller with an evacuated tube is not a perfect choice for cooling in this case, which the cost of the system component is very expensive now, but mostly the absorption chiller will be more efficient if it is used as part of the cogeneration system to exploit the waste heat of industrial buildings for instance.
8) Exploit solar energy to generate electrical needs is one of the sustainable practices, especially since these technologies are available and easy to implement, and in view of the efficiency of PV panels is continuously improving. Furthermore, the large area is available in GACB and it is used as parking, so the installation PV system will make multiple utilizations of spaces and create mutual benefits, in which PV module will work as an umbrella for vehicles in the parking.
9) The overall PV system performance is (79.2%), the loss diagram of the PVSYST report (Appendix I) refers to the temperature caused about (16 %) reduction of productivity, so the temperature in Jericho is considered the main challenge for the PV system, and it is necessary to give attention for cooling techniques of PV panel.
10) The NZEB creates a multiple distributed generation points and reduces the dependency on centralized traditional resources like gas stations, furthermore the economic and environmental aspects that can lead to more sustainability. Also, NZEB mitigates the related threats of traditional power stations by military activities and wars, so it can promote the concept of energy security.
11) Finally, the findings of such as this study can be exploited to make forecasting and future planning for the energy field in the commercial sector in Jericho district, where about (30 %) saved through applying conservation strategies, while the remaining (70 %) of current needs must be covered from renewable resources by adopting a national plan for renewable energies to be implemented during the next twenty years. Then that will return several benefits for Jericho district, which will reduce the imported amount of electricity from neighboring countries like Jordan. Furthermore, that will

allow to other sectors - such as the industrial sector and residential sector in Jericho - to expand and become more prosperous without negative impacts from the commercial sector.

4.4 Conclusions

1) NZEB support mitigating negative environmental impacts, and improving energy security parameters. Furthermore, it promotes the decentralization concept of energy generation.
2) NZEB is divided into two prominent parts: Energy auditing to reduce squandering of energy, and Generation on-site through renewable systems to cover annual needs.
3) Energy reduction in public buildings requires a combination of several actions, like architectural aspects, thermal insulation, high-efficient windows and skylights, smart control systems, high-efficient lighting & cooling systems, and good practices during operation time.
4) The applying of conservation strategies in GACB make reduction of electrical needs by (32.7%). This result emphasizes the importance of conducting energy auditing and applying suitable conservation strategies for public buildings.
5) More than (1800 MWh) annual needs of electricity will be covered by applying NZEB concept in GACB.
6) Additional benefit of applying NZEB in GACB, where more than (1250) Ton reduction of carbon footprint annually.
7) HVAC systems represent the main load in hot regions, so it is necessary to invest with highly efficient systems and develop a new green HVAC package.
8) This study can be considered as a guideline and general framework toward the transition to net zero energy, in which it gives the main lines & strategies to achieve that in public buildings.
9) Recommendations: It’s necessary to force all public buildings to conduct energy auditing and apply conservation strategies. Also, regulations and policies of related fields must take place in Palestine, and monitoring committees must be activated to guarantee applying the regulations. On the other hand, the raising public consciousness in related fields will support NZEB.

4.5 Future work

The future vision for this research, conduct more detailed auditing for each part of GACB as an individual, through using a power analyzer device to investigate power factor and 3-phase balance. Furthermore, make a feasibility study to exploit another innovative idea to generate additional green energy by using CSP technology, for instance. Also, study the potential of hydraulic energy from the high traffic inside the location to produce electricity through Artificial bumps. On the other hand, additional studies can be performed to build a charging station for electrical vehicles inside the parking area to promote green practices.

List of Abbreviations

Abbreviation	Meaning
ACH	Air Change per Hour
AHU	Air Handling Unit
BMS	Building Management System
COP	Coefficient of Performance
CSP	Concentrated Solar Power
GACB	General Administration of Crossings & Borders
HAP	Hourly Analysis Program
HVAC	Heating, ventilation, and air conditioning
IBI	Intelligent Building Institute
JDECo	Jerusalem District Electricity Company
LCE	Life Cycle Emission
LCOE	Levelized Cost of Energy
LENI	Lighting Energy Numeric Indicator
MARR	Minimum Attractive Rate of Return
NGO	Non-Governmental Organization
NZEB	Net Zero Energy Building
PGBC	Palestinian Green Building Council
PLC	Programmable Logic Controller
PV	Photovoltaic
PW	Present Worth
ROR	Rate of Return
SAH	Solar Air Heater
SCADA	Supervisory Control and Data Acquisition
SPP	Simple Payback Period
SWH	Solar Water Heater
VRF	Variable Refrigerant Flow
VVVF	Variable Voltage Variable Frequency

References

[1] Palestinian Central Bureau of Statistics, "https://www.pcbs.gov.ps/Portals/_Rainbow/Documents/Energy-consum-2011-2020_A.html," Palestinian Central Bureau of Statistics.

[2] T. A. Hamed and K. Peric, "The role of renewable energy resources in alleviating energy poverty in Palestine," Dec. 01, 2020, *Elsevier Ltd*. doi: 10.1016/j.ref.2020.09.006.

[3] A. Juaidi, F. G. Montoya, I. H. Ibrik, and F. Manzano-Agugliaro, "An overview of renewable energy potential in Palestine," Nov. 01, 2016, *Elsevier Ltd*. doi: 10.1016/j.rser.2016.07.052.

[4] N. Said, "An Overview of Green Buildings Potential in Palestine," *International Journal of Sustainable and Green Energy*, vol. 8, no. 2, p. 20, 2019, doi: 10.11648/j.ijrse.20190802.11.

[5] B. Alatawneh and R. Corrao, "Near Zero Energy House in Palestine: Identification of the Future Challenges," 2015.

[6] I. Khatib, A. Qasrawi, and T. Yasin, "A Case Study of Energy Auditing-A Tool for Energy Conservation in Industry," 2011.

[7] N. Bozkurt and M. T. Baydaş, "A General Overview of Turkey's Zero-Energy Building History in the World Context," 2023, doi: 10.5281/zenodo.8200942.

[8] R. K. Jaysawal, S. Chakraborty, D. Elangovan, and S. Padmanaban, "Concept of net zero energy buildings (NZEB) - A literature review," *Clean Eng Technol*, vol. 11, p. 100582, Dec. 2022, doi: 10.1016/J.CLET.2022.100582.

[9] M. T. Iqbal, "A feasibility study of a zero energy home in Newfoundland," *Renew Energy*, vol. 29, no. 2, pp. 277–289, Feb. 2004, doi: 10.1016/S0960-1481(03)00192-7.

[10] V. Corrado, G. Murano, S. Paduos, and G. Riva, "On the Refurbishment of the Public Building Stock Toward the Nearly Zero-energy Target: Two Italian case studies," *Energy Procedia*, vol. 101, pp. 105–112, Nov. 2016, doi: 10.1016/J.EGYPRO.2016.11.014.

[11] V. Corrado, I. Ballarini, S. Paduos, and L. Tulipano, "A new procedure of energy audit and cost analysis for the transformation of a school into a nearly zero-energy building," in *Energy Procedia*, Elsevier Ltd, 2017, pp. 325–338. doi: 10.1016/j.egypro.2017.11.146.

[12] T. Huo *et al.*, "China's energy consumption in the building sector: A Statistical Yearbook-Energy Balance Sheet based splitting method," *J Clean Prod*, vol. 185, pp. 665–679, Jun. 2018, doi: 10.1016/j.jclepro.2018.02.283.

[13] L. Tronchin, M. Manfren, and B. Nastasi, "Energy efficiency, demand side management and energy storage technologies – A critical analysis of possible paths of integration in the built environment," *Renewable and Sustainable Energy Reviews*, vol. 95, pp. 341–353, Nov. 2018, doi: 10.1016/J.RSER.2018.06.060.

[14] F. Bandeiras, M. Gomes, P. Coelho, and J. Fernandes, "Towards net zero energy in industrial and commercial buildings in Portugal," *Renewable and Sustainable Energy Reviews*, vol. 119, p. 109580, Mar. 2020, doi: 10.1016/J.RSER.2019.109580.

[15] A. Magrini, L. Gobbi, and F. R. D'Ambrosio, "Energy Audit of Public Buildings: The Energy Consumption of a University with Modern and Historical Buildings. Some Results," in *Energy Procedia*, Elsevier Ltd, Nov. 2016, pp. 169–175. doi: 10.1016/j.egypro.2016.11.022.

[16] J. King Saud Univ and ! Vo, "Energy Audit and Potential Energy Saving in an Office Building in Riyadh, Saudi Arabia," 2009.

[17] M. T. I. Khan, Q. Ali, and M. Ashfaq, "The nexus between greenhouse gas emission, electricity production, renewable energy and agriculture in Pakistan," *Renew Energy*, vol. 118, pp. 437–451, Apr. 2018, doi: 10.1016/J.RENENE.2017.11.043.

[18] J. Iwaro and A. Mwasha, “A review of building energy regulation and policy for energy conservation in developing countries,” *Energy Policy*, vol. 38, no. 12, pp. 7744–7755, Dec. 2010, doi: 10.1016/J.ENPOL.2010.08.027.

[19] I. A. Rahardjo *et al.*, “Analysis of Energy Consumption and Energy Efficiency in Government Office Buildings of Bengkulu, Indonesia,” in *Journal of Physics: Conference Series*, IOP Publishing Ltd, Dec. 2021. doi: 10.1088/1742-6596/2111/1/012052.

[20] S. N. J. Al-Saadi, M. Ramaswamy, H. Al-Rashdi, M. Al-Mamari, and M. Al-Abri, “Energy Management Strategies for a Governmental Building in Oman,” in *Energy Procedia*, Elsevier Ltd, 2017, pp. 206–210. doi: 10.1016/j.egypro.2017.11.039.

[21] A. Alajmi, “Energy audit of an educational building in a hot summer climate,” *Energy Build*, vol. 47, pp. 122–130, Apr. 2012, doi: 10.1016/J.ENBUILD.2011.11.033.

[22] A. S. H. Abdallah, A. Makram, and M. Abdel-Azim Nayel, “Energy audit and evaluation of indoor environment condition inside Assiut International Airport terminal building, Egypt,” *Ain Shams Engineering Journal*, vol. 12, no. 3, pp. 3241–3253, Sep. 2021, doi: 10.1016/j.asej.2021.03.003.

[23] M. Elnaggar, “Useful energy, economic and reduction of greenhouse gas emissions assessment of solar water heater and solar air heater for heating purposes in Gaza, Palestine,” *Heliyon*, vol. 9, no. 6, p. e16803, Jun. 2023, doi: 10.1016/J.HELIYON.2023.E16803.

[24] H. H. Sait, “Auditing and analysis of energy consumption of an educational building in hot and humid area,” *Energy Convers Manag*, vol. 66, pp. 143–152, 2013, doi: 10.1016/j.enconman.2012.10.005.

[25] I. H. Ibrik and M. M. Mahmoud, “Energy efficiency improvement procedures and audit results of electrical, thermal and solar applications in Palestine,” *Energy Policy*, vol. 33, no. 5, pp. 651–658, Mar. 2005, doi: 10.1016/j.enpol.2003.09.008.

[26] S. Monna, A. Juaidi, R. Abdallah, and T. Salameh, "Sustainable energy retrofitting for residential buildings in Palestine, a simulation based approach," in *2021 12th International Renewable Engineering Conference, IREC 2021*, Institute of Electrical and Electronics Engineers Inc., Apr. 2021. doi: 10.1109/IREC51415.2021.9427862.

[27] D. Brounen, N. Kok, and J. M. Quigley, "Energy literacy, awareness, and conservation behavior of residential households," *Energy Econ*, vol. 38, pp. 42–50, Jul. 2013, doi: 10.1016/J.ENECO.2013.02.008.

[28] E. Kocak, E. E. Ulug, and B. Oralhan, "The impact of electricity from renewable and non-renewable sources on energy poverty and greenhouse gas emissions (GHGs): Empirical evidence and policy implications," *Energy*, vol. 272, p. 127125, Jun. 2023, doi: 10.1016/J.ENERGY.2023.127125.

[29] A. Mavrigiannaki *et al.*, "Zero energy concept at neighborhood level: A case study analysis," *Solar Energy Advances*, vol. 1, p. 100002, Jan. 2021, doi: 10.1016/J.SEJA.2021.100002.

[30] W. A. Salah, M. Abuhelwa, and M. J. Bashir, "The key role of sustainable renewable energy technologies in facing shortage of energy supplies in Palestine: Current practice and future potential," Apr. 15, 2021, *Elsevier Ltd*. doi: 10.1016/j.jclepro.2020.125348.

[31] A. G. Gaglia, S. Lykoudis, A. A. Argiriou, C. A. Balaras, and E. Dialynas, "Energy efficiency of PV panels under real outdoor conditions–An experimental assessment in Athens, Greece," *Renew Energy*, vol. 101, pp. 236–243, Feb. 2017, doi: 10.1016/J.RENENE.2016.08.051.

[32] E. J. Gago, T. Muneer, M. Knez, and H. Köster, "Natural light controls and guides in buildings. Energy saving for electrical lighting, reduction of cooling load," *Renewable and Sustainable Energy Reviews*, vol. 41, pp. 1–13, Jan. 2015, doi: 10.1016/J.RSER.2014.08.002.

[33] M. F. M. A. Halim, M. F. Yaakub, M. H. Harun, K. A. M. Annuar, F. H. M. Basar, and M. N. Omar, "An analysis of energy saving through delamping method," *International Journal of Electrical and Computer Engineering*, vol. 9, no. 3, pp. 1569–1575, Jun. 2019, doi: 10.11591/ijece.v9i3.pp1569-1575.

[34] SAS Abdul-Hameed and YMM M Saleem, "Employing natural lighting systems technology in raising environmental efficiency in educational buildings," *Iraqi Journal of Architecture and Planning*, 2017.

[35] H. J. Han *et al.*, "An advanced lighting system combining solar and an artificial light source for constant illumination and energy saving in buildings," *Energy Build*, vol. 203, p. 109404, Nov. 2019, doi: 10.1016/J.ENBUILD.2019.109404.

[36] W. Paul, "ELECTRICAL ENERGY SAVING THROUGH LAMPS REPLACEMENT AND COMPONENTS INCOMPATIBILITY ON LIGHTING SYSTEM ECONOMICS." [Online]. Available: www.ijert.org

[37] A. Abd El-Khalek, K. Youssef, and I. Yassin, "Opportunities of energy saving in lighting systems for public buildings," *Renewable Energy and Sustainable Development (RESD)*, vol. 3, 2017, doi: 10.21622/RESD.2017.03.1.095.

[38] Y. Aussat, A. Rosmanis, and S. Keshav, "A power-efficient self-calibrating smart lighting system," *Energy Build*, vol. 259, p. 111874, Mar. 2022, doi: 10.1016/J.ENBUILD.2022.111874.

[39] G. N. Spyropoulos and C. A. Balaras, "Energy consumption and the potential of energy savings in Hellenic office buildings used as bank branches—A case study," *Energy Build*, vol. 43, no. 4, pp. 770–778, Apr. 2011, doi: 10.1016/J.ENBUILD.2010.12.015.

[40] D. Bienvenido-Huertas, D. Sánchez-García, A. Pérez-Fargallo, and C. Rubio-Bellido, "Optimization of energy saving with adaptive setpoint temperatures by calculating the prevailing mean outdoor air temperature," *Build Environ*, vol. 170, p. 106612, Mar. 2020, doi: 10.1016/J.BUILDENV.2019.106612.

[41] H. Zhang, Y. Tao, and L. Shi, "Solar Chimney Applications in Buildings," *Encyclopedia*, vol. 1, no. 2, pp. 409–422, May 2021, doi: 10.3390/encyclopedia1020034.

[42] A. Al-Falahi, F. Alobaid, and B. Epple, "A new design of an integrated solar absorption cooling system driven by an evacuated tube collector: A case study for Baghdad, Iraq," *Applied Sciences (Switzerland)*, vol. 10, no. 10, May 2020, doi: 10.3390/app10103622.

[43] M. H. Jahangir, A. Kargarzadeh, and F. Javanshir, "Energy investigation in buildings applying a solar adsorption chiller coupled with biofuel heaters and solar heating/cooling systems in different climates," *Energy Reports*, vol. 8, pp. 15493–15510, Nov. 2022, doi: 10.1016/J.EGYR.2022.10.428.

[44] "https://www.araner.com/blog/how-do-absorption-chillers-work."

[45] I. A. Gondal, "Prospects of shallow geothermal systems in HVAC for NZEB," *Energy and Built Environment*, vol. 2, no. 4, pp. 425–435, Oct. 2021, doi: 10.1016/J.ENBENV.2020.09.007.

[46] W. Lyu, X. Li, B. Wang, and W. Shi, "Energy saving potential of fresh air pre-handling system using shallow geothermal energy," *Energy Build*, vol. 185, pp. 39–48, Feb. 2019, doi: 10.1016/J.ENBUILD.2018.12.037.

[47] T. Wilberforce, A. G. Olabi, E. T. Sayed, K. Elsaid, H. M. Maghrabie, and M. A. Abdelkareem, "A review on zero energy buildings – Pros and cons," *Energy and Built Environment*, vol. 4, no. 1, pp. 25–38, Feb. 2023, doi: 10.1016/J.ENBENV.2021.06.002.

[48] D. O. Nduka, A. N. Ede, K. D. Oyeyemi, and O. M. Olofinnade, "Awareness, benefits and drawbacks of net zero energy building practices: Construction industry professional's perceptions," in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Nov. 2019. doi: 10.1088/1757-899X/640/1/012026.

[49] W. Salah Alaloul and M. Ali Musarat, “Impact of Zero Energy Building: Sustainability Perspective.” [Online]. Available: www.intechopen.com

[50] J. P. Guyer, “Introduction to Electrical Power Requirements for Buildings Credit: 2 PDH.”

[51] PHILIPS Company, “https://www.lighting.philips.com/prof/indoor-luminaires/recessed/slimblend-gen2/910505102458_EU/product.”

[52] State of Palestine, “Second Edition 2024 Green Building Guidline-State Palestine,” 2024.

[53] M. A. Alsaad and M. A. Hammad, “HEATING AND Air CONDITIONING FOR RESIDENTIAL BUILDININGS FIFTH EDITION,” 1994.

[54] Palestinian Meteorological Authority, “Climate Bulletin (2018) [Online]. ”. Available: www.pmd.ps

[55] GILBERT M. MASTERS, “RENEWABLE AND EFFICIENT ELECTRIC POWER SYSTEMS,” 2013.

[56] ASHRAE, “ASHRAE 93-2010: Methods of Testing to Determine the Thermal Performance of Solar Collectors,” 2010.

[57] A. Yasin, “Technical and Financial Assessment of Glazed and Evacuated Tubes Solar Collectors for Domestic Water Heating Application in Palestine .2017 ”،

[58] L. M. Ayompe, A. Duffy, M. Mc Keever, M. Conlon, and S. J. McCormack, “Comparative field performance study of flat plate and heat pipe evacuated tube collectors (ETCs) for domestic water heating systems in a temperate climate,” *Energy*, vol. 36, no. 5, pp. 3370–3378, May 2011, doi: 10.1016/J.ENERGY.2011.03.034.

[59] M. A. B. M.-H. Yunus A. Cengel, “Thermodynamics: An Engineering Approach Seventh Editionin SI Units,” 2011.

[60] “https://weatherspark.com/y/98833/Average-Weather-in-Jericho-Palestinian-Territories-Year-Round#Figures-Temperature.”

[61] EUROPEAN STANDARD CODE, "EN_12464-1 (illumination level code)," 2002.

[62] A. De Almeida, B. Santos, P. Bertoldi, and M. Quicheron, "Solid state lighting review – Potential and challenges in Europe," *Renewable and Sustainable Energy Reviews*, vol. 34, pp. 30–48, Jun. 2014, doi: 10.1016/J.RSER.2014.02.029.

[63] Y. Lv, L. Xia, M. Li, L. Wang, Y. Su, and J. Yan, "Techno-economic evaluation of an optical fiber based hybrid solar lighting system," *Energy Convers Manag*, vol. 225, Dec. 2020, doi: 10.1016/j.enconman.2020.113399.

[64] "https://weatherspark.com/y/98833/Average-Weather-in-Jericho-Palestinian-Territories-Year-Round#Figures-ColorTemperature."

Appendices

Appendix A

Tables

Table A.1

Luminous efficacy of different lamp

NO.#	*Type of Lamp*	*Efficacy (lm/W)*
1	Incandescent	5-15
2	Halogen	12-35
3	Mercury	40-60
4	Compact Fluorescent Lamp (CFL)	40-65
5	Fluorescent	50-100
6	Metal Halide	50-100
7	High-pressure sodium (Standard)	80-100
8	High-pressure sodium (color improved)	40-60
9	Light-emitting Diode (LED)	20-120

[62]

Table A.2

Saving by control system

Site	Area $[m^2]$	Hours/Year	Saving $[W/m^2]$	Annual Saving [kWh]
Arrival Hall/Int. light	572	6500	0.811	3015.30
Departure Hall/Int. light	1200	6500		6325.80
Kitchen & dining space/ Int. light	375	4380		1332.07
Service Hall & Luggage/ Int. Light	270	6500		1423.31
Total				12096.47

Table A.3

Working hours of different loads throughout year

Main Loads	Daily hours	Hours/ month	mon./year	Hours/Year
Computers	8	240	12	2880
Network equipment & others	All time	-	-	8760
Internal Light	18	540	12	6480
External Light	14	420	12	5040
Air conditioner/split unit	14	420	6	2520
Package Units /Central cooling	16	480	5	2400
VRF Units	16	480	5	2400
Refrigerator	16	480	12	5760
Electrical water heater	8	240	5	1200
Pump	10	300	12	3600

Table A.4

The Net annual saving of measures of lighting

Measures	Annual saving [kWh]
De-lamping/Replacement/Skylight	165521.13
Control system for Internal lighting	12096.47

Photocell for External lighting	24966
Total	202583.6

Table A.5
Information of PV system

Item	Result
Capacity	800 kWp
PV panel Model	JKM410M-72H-V
No# PV modules	1944
Inverter Model	CSI-125KTL-GS-E
No# Inverter	9
Productivity	1429 MWh/year
Efficiency	79.20%

Table A.6
Details of Analysis for HVAC scenarios

Scenario-1						
# Year	Investment	Saving	NCF	Present Value	Cum SPP	SPP
0	-17,500.00		-17,500.00	-17,500.00	-17,500.00	
1		7440.00	7,440.00	6,763.64	-10,060.00	-
2		7440.00	7,440.00	6,148.76	- 2,620.00	-
3		7440.00	7,440.00	5,589.78	4,820.00	3
4		7440.00	7,440.00	5,081.62	12,260.00	-
5		7440.00	7,440.00	4,619.65	19,700.00	-
6		7440.00	7,440.00	4,199.69	27,140.00	-
7		7440.00	7,440.00	3,817.90	34,580.00	-
8		7440.00	7,440.00	3,470.81	42,020.00	-
9		7440.00	7,440.00	3,155.29	49,460.00	-
10		7440.00	7,440.00	2,868.44	56,900.00	-
11		7440.00	7,440.00	2,607.67	64,340.00	-
12		7440.00	7,440.00	2,370.61	71,780.00	-
13		7440.00	7,440.00	2,155.10	79,220.00	-
14		7440.00	7,440.00	1,959.18	86,660.00	-
15		7440.00	7,440.00	1,781.08	94,100.00	-
16		7440.00	7,440.00	1,619.16	101,540.00	-
17		7440.00	7,440.00	1,471.96	108,980.00	-
18		7440.00	7,440.00	1,338.15	116,420.00	-
19		7440.00	7,440.00	1,216.50	123,860.00	-
20		7440.00	7,440.00	1,105.91	131,300.00	-
				45,840.91		
Scenario-2						
# Year	Investment	Saving	NCF	Present Value	Cum SPP	SPP
0	- 42,310.00		- 42,310.00	- 42,310.00	- 42,310.00	
1		7440.00	7,440.00	6,763.64	-34,870.00	-
2		7440.00	7,440.00	6,148.76	- 27,430.00	-
3		7440.00	7,440.00	5,589.78	-19,990.00	-
4		7440.00	7,440.00	5,081.62	-12,550.00	-
5		7440.00	7,440.00	4,619.65	- 5,110.00	-
6		7440.00	7,440.00	4,199.69	2,330.00	6
7		7440.00	7,440.00	3,817.90	9,770.00	-
8		7440.00	7,440.00	3,470.81	17,210.00	-
9		7440.00	7,440.00	3,155.29	24,650.00	-
10		7440.00	7,440.00	2,868.44	32,090.00	-

11		7440.00	7,440.00	2,607.67	39,530.00	-
12		7440.00	7,440.00	2,370.61	46,970.00	-
13		7440.00	7,440.00	2,155.10	54,410.00	-
14		7440.00	7,440.00	1,959.18	61,850.00	-
15		7440.00	7,440.00	1,781.08	69,290.00	-
16		7440.00	7,440.00	1,619.16	76,730.00	-
17		7440.00	7,440.00	1,471.96	84,170.00	-
18		7440.00	7,440.00	1,338.15	91,610.00	-
19		7440.00	7,440.00	1,216.50	99,050.00	-
20		7440.00	7,440.00	1,105.91	106,490.00	-
				21,030.91		

Scenario-3

# Year	Investment	Saving	NCF	Present Value	Cum SPP	SPP
0	- 141,600.00		- 141,600.00	-141,600.00	- 141,600.00	
1		7440.00	7,440.00	6,763.64	- 134,160.00	-
2		7440.00	7,440.00	6,148.76	- 126,720.00	-
3		7440.00	7,440.00	5,589.78	- 119,280.00	-
4		7440.00	7,440.00	5,081.62	- 111,840.00	-
5		7440.00	7,440.00	4,619.65	- 104,400.00	-
6		7440.00	7,440.00	4,199.69	- 96,960.00	-
7		7440.00	7,440.00	3,817.90	- 89,520.00	-
8		7440.00	7,440.00	3,470.81	- 82,080.00	-
9		7440.00	7,440.00	3,155.29	- 74,640.00	-
10		7440.00	7,440.00	2,868.44	- 67,200.00	-
11		7440.00	7,440.00	2,607.67	- 59,760.00	-
12		7440.00	7,440.00	2,370.61	- 52,320.00	-
13		7440.00	7,440.00	2,155.10	- 44,880.00	-
14		7440.00	7,440.00	1,959.18	- 37,440.00	-
15		7440.00	7,440.00	1,781.08	-30,000.00	-
16		7440.00	7,440.00	1,619.16	- 22,560.00	-
17		7440.00	7,440.00	1,471.96	-15,120.00	-
18		7440.00	7,440.00	1,338.15	- 7,680.00	-
19		7440.00	7,440.00	1,216.50	- 240.00	-
20		7440.00	7,440.00	1,105.91	7,200.00	20
				- 78,259.09		

Scenario-4

# Year	Investment	Saving	NCF	Present Value	Cum SPP	SPP
0	-		-	-	-	
1		-7440.00	- 7,440.00	- 6,763.64	- 7,440.00	-
2		-7440.00	- 7,440.00	- 6,148.76	- 14,880.00	-
3		-7440.00	- 7,440.00	- 5,589.78	- 22,320.00	-
4		-7440.00	- 7,440.00	- 5,081.62	- 29,760.00	-
5		-7440.00	- 7,440.00	- 4,619.65	- 37,200.00	-
6		-7440.00	- 7,440.00	- 4,199.69	- 44,640.00	-
7		-7440.00	- 7,440.00	- 3,817.90	- 52,080.00	-
8		-7440.00	- 7,440.00	- 3,470.81	- 59,520.00	-
9		-7440.00	- 7,440.00	- 3,155.29	- 66,960.00	-
10		-7440.00	- 7,440.00	- 2,868.44	- 74,400.00	-
11		-7440.00	- 7,440.00	- 2,607.67	- 81,840.00	-
12		-7440.00	- 7,440.00	- 2,370.61	- 89,280.00	-
13		-7440.00	- 7,440.00	- 2,155.10	- 96,720.00	-
14		-7440.00	- 7,440.00	- 1,959.18	- 104,160.00	-
15		-7440.00	- 7,440.00	- 1,781.08	- 111,600.00	-
16		-7440.00	- 7,440.00	- 1,619.16	- 119,040.00	-

17	-7440.00	-	7,440.00	-	1,471.96	-	126,480.00	-
18	-7440.00	-	7,440.00	-	1,338.15	-	133,920.00	-
19	-7440.00	-	7,440.00	-	1,216.50	-	141,360.00	-
20	-7440.00	-	7,440.00	-	1,105.91	-	148,800.00	-
				-	**63,340.91**			

Table A.7

Retrofitting Cost of lighting system

Item	Quantity	Cost/Unit	Total cost ($)
New light units	270	100	27,000
control system with sensors	1	3000	3,000
Skylight windows	70	400	28,000
Photocell for external light	1	200	200
Total			58,200

Table A.8

Details of economic analysis of NZEB

Year	Investment	Saving	O&M	NCF	Present Value	Cum SPP	SPP
0	- 1,140,920.00			- 1,140,920.00	- 1,140,920.00	- 1,140,920.00	
1		369,324.49	- 50,000.00	319,324.49	290,294.99	- 821,595.51	-
2		369,324.49	-50,000.00	319,324.49	263,904.54	-502,271.02	-
3		369,324.49	- 50,000.00	319,324.49	239,913.22	- 182,946.53	-
4		369,324.49	- 50,000.00	319,324.49	218,102.92	136,377.96	4
5		369,324.49	-50,000.00	319,324.49	198,275.39	455,702.46	-
6	- 58,200.00	369,324.49	- 50,000.00	261,124.49	147,397.97	716,826.95	-
7		369,324.49	-50,000.00	319,324.49	163,863.95	1,036,151.44	-
8		369,324.49	-50,000.00	319,324.49	148,967.23	1,355,475.93	-
9		369,324.49	- 50,000.00	319,324.49	135,424.76	1,674,800.42	-
10		369,324.49	- 50,000.00	319,324.49	123,113.41	1,994,124.91	-
11		369,324.49	- 50,000.00	319,324.49	111,921.29	2,313,449.40	-
12	- 58,200.00	369,324.49	-50,000.00	261,124.49	83,202.31	2,574,573.89	-
13		369,324.49	- 50,000.00	319,324.49	92,496.93	2,893,898.38	-
14		369,324.49	- 50,000.00	319,324.49	84,088.12	3,213,222.88	-
15		369,324.49	-50,000.00	319,324.49	76,443.74	3,532,547.37	-
16		369,324.49	- 50,000.00	319,324.49	69,494.31	3,851,871.86	-
17		369,324.49	- 50,000.00	319,324.49	63,176.65	4,171,196.35	-
18	- 58,200.00	369,324.49	- 50,000.00	261,124.49	46,965.53	4,432,320.84	-
19		369,324.49	- 50,000.00	319,324.49	52,212.11	4,751,645.33	-
20		369,324.49	- 50,000.00	319,324.49	47,465.55	5,070,969.82	-
	- 1,315,520.00				**1,515,804.92**		

Table A.9

Tasks Categorization

NO Cost & Low-Cost Measures	Costly Measures
Awareness	Improve Insulation of the building by using Polystyrene Board or any other insulation materials
Turn off lamps after work time and unplug computers, printers, etc.	Replacement of lighting system with efficient lamps
Calibrate the setpoint of HVAC on 25 Celsius	Replace the Split units with VRF
Install Photocell	Install an integrated recovery system

Continuous monitoring, Reports & Feedback	Install BMS to make intelligent control for site
Reduce Infiltration by sealing the leakage of windows and doors	
Reduce Infiltration of internal air by installing a revolving door in hall entrance	
De-lamping	

Appendix B

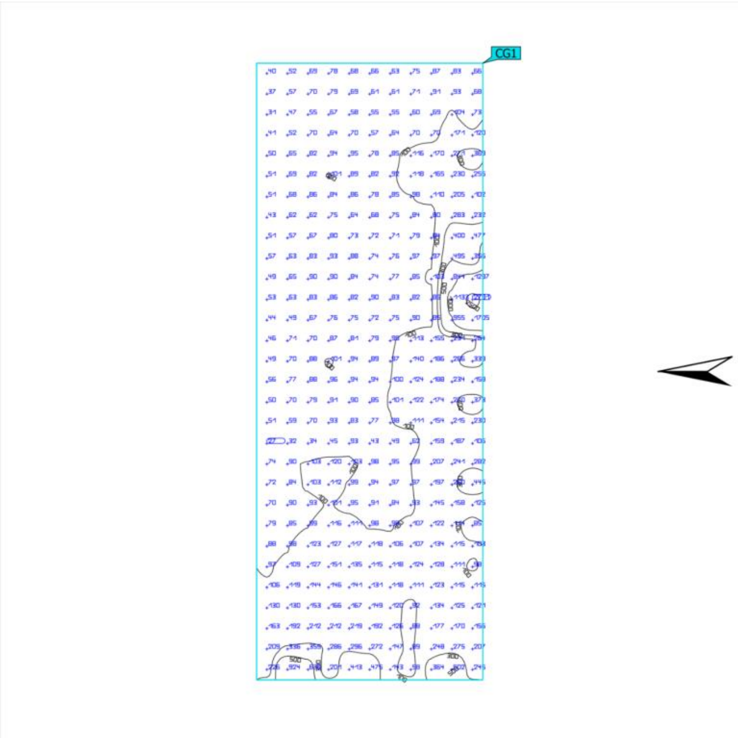
Lighting simulation of Arrival Hall -Without modification- Report

2 pages

DIALux

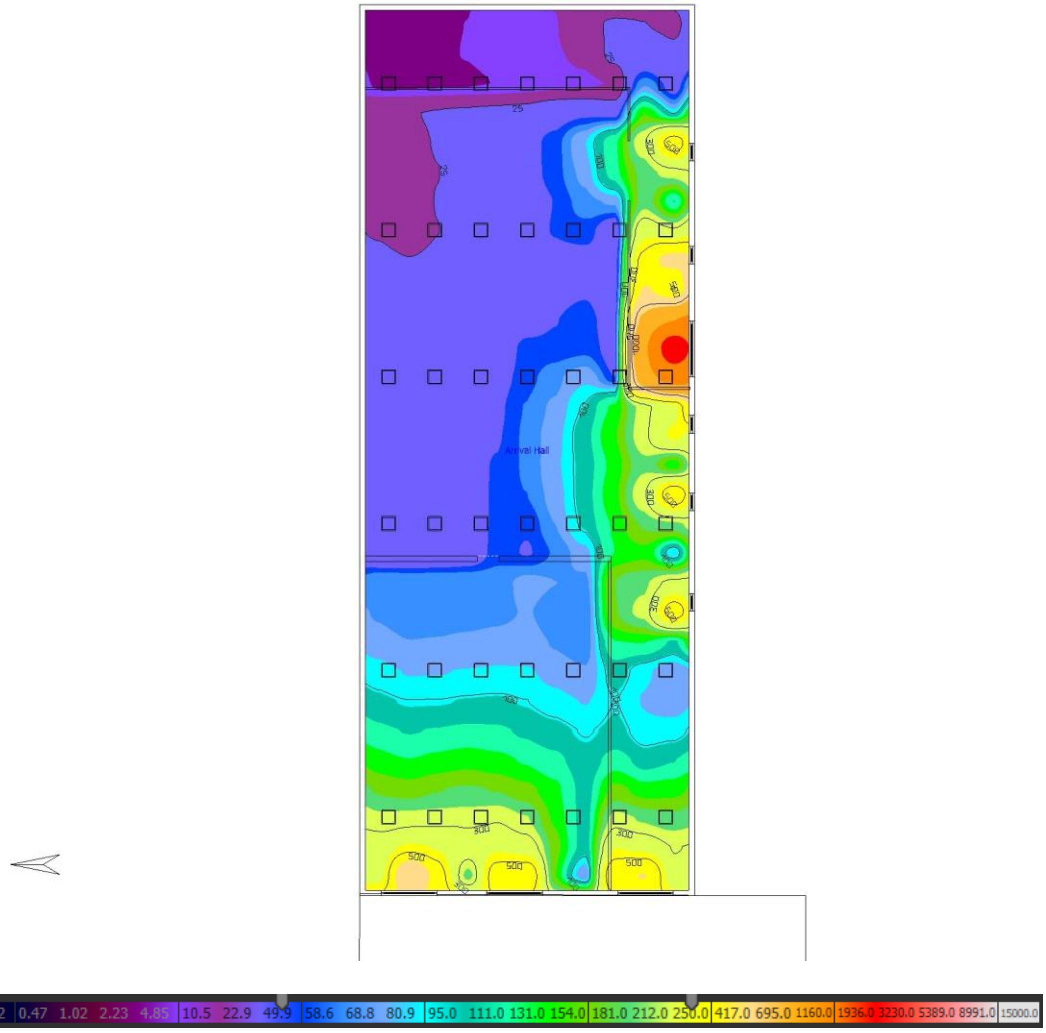
Project

Building 1 · Arrival Hall · Arrival Hall (Daylight scene without modification)



Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface 5 Perpendicular illuminance Height: 0.100 m	149 lx	27.4 lx	2791 lx	0.18	0.010	CG1

Utilisation profile: Transportational areas - Airports (5.52.1 Arrival and departure halls, baggage claim areas)


Arrival Hall
0.10 0.22 0.47 1.02 2.23 4.85 10.5 22.9 49.9 58.6 68.8 80.9 95.0 111.0 131.0 154.0 181.0 212.0 250.0 417.0 695.0 1160.0 1936.0 3230.0 5389.0 8991.0 15000.0

Appendix C

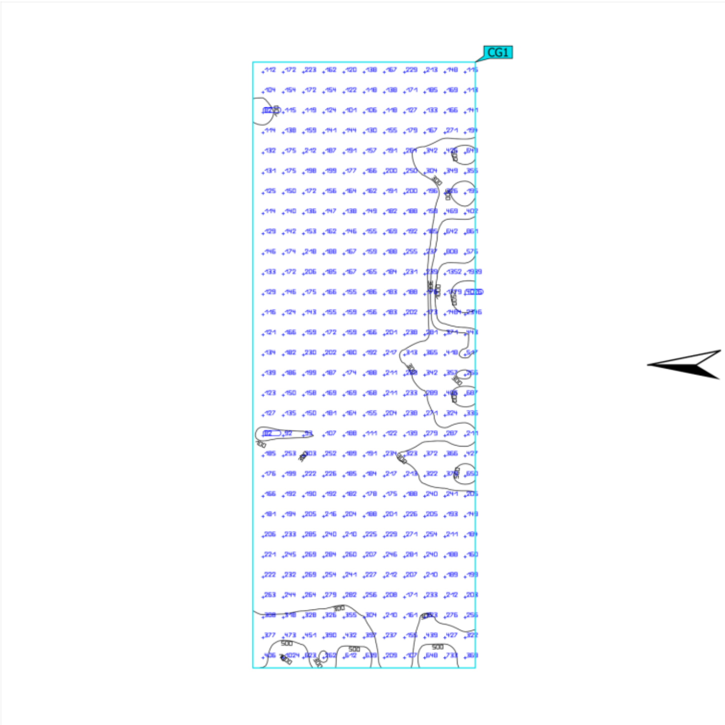
Lighting simulation of Arrival Hall - with skylight - Report

One pages

DIALux

Project

Building 1 · Arrival Hall · Arrival Hall (Daylight scene with skylight)



Properties	$\bar{E}$	Emin	Emax	Uo (g1)	g2	Index
Calculation surface 5 Perpendicular illuminance Height: 0.100 m	267 lx	82.0 lx	4026 lx	0.31	0.020	CG1

Utilisation profile: Transportational areas - Airports (5.52.1 Arrival and departure halls, baggage claim areas)

1

Appendix D

Philips datasheet

2 pages

PHILIPS Lighting

SlimBlend Gen2

RC332V 42S/940 PSD W62L62 MXO

RC332V | SlimBlend Gen2, 31.5 W, Power supply unit with DALI interface, 90°

Offices are looking for high-performance lighting that enhances performance, comfort, well-being, and sustainability. That's why 'surface of light' solutions that deliver excellent quality of light with great functionality and connectivity are in such demand. Like Philips SlimBlend Gen2 – a complete family of slim luminaires designed for enhanced well-being and circularity. SlimBlend Gen2 luminaires offer state-of-the-art efficacy and excellent light quality (CRI>90) with upgradability features and repairability that promise a long lifetime. They are also designed for recyclability, making them a truly circular, green choice. But it's the high-quality light that makes SlimBlend Gen2 luminaires really stand out. The special Micro Hexagonal Optics (MXO) provides glare-free comfort & also infuses the homogeneous light with sparkles, creating a lively surface of light that enhances interiors and offers full Office compliance. SlimBlend Gen 2 is a minimalist solution with superior lighting specifications combined with a best-in-class connectivity using Interact Pro - all with a sustainable approach to high-performance office lighting.

Product data

General Information	
Light source replaceable	No
Number of gear units	1 unit
Driver included	Yes
Product family code	RC332V [SlimBlend Gen2]
Lighting Technology	LED
Value ladder	Specification
Light Technical	
Luminous Flux	4,300 lm

Luminous Efficacy (rated) (Nom)	137 lm/W
Saturated Red (R9)	>50
Correlated Color Temperature (Nom)	4000 K
Color rendering index (CRI)	>90
Beam angle of light source	120 degree(s)
Light source color	940 neutral white
Optic type	-
Luminaire light beam spread	90°
Unified glare rating CEN	19

Datasheet, 2024, September 2 data subject to change

SlimBlend Gen2

Operating and Electrical	
Input Voltage	220 to 240 V
Line Frequency	50 to 60 Hz
Inrush current	5.5 A
Inrush time	0.055 ms
Power Consumption	31.5 W
Power Factor (Fraction)	0.9
Connection	Push-in connector 5-pole
Cable	-
Number of products on MCB of 16 A type B	32

Temperature	
Ambient temperature range	+10 to +35 °C

Controls and Dimming	
Dimmable	Yes
Driver/power unit/transformer	Power supply unit with DALI interface
Control interface	DALI
Constant light output	No

Mechanical and Housing	
Housing Material	Steel
Reflector material	-
Optic material	-
Optical cover material	Polystyrene
Fixation material	-
Housing Color	White
Optical cover finish	Textured
Overall length	620 mm
Overall width	620 mm
Overall height	43 mm
Dimensions (Height x Width x Depth)	43 x 620 x 620 mm

Approval and Application	
Ingress protection code	IP20/44 [Finger-protected, wire-protected, splash-proof]
Mech. impact protection code	IK03 [0.3 J]
Sustainability rating	Lighting for circularity
Protection class IEC	Safety class II
Glow-wire test	Temperature 650 °C, duration 30 s
Flammability mark	For mounting on normally flammable surfaces
CE mark	Yes
ENEC mark	ENEC mark
Warranty period	5 years
Photobiological risk	Photobiological risk group 0 @ 200mm to EN62471
EU RoHS compliant	Yes

Initial Performance (IEC Compliant)	
Luminous flux tolerance	+/-10%
Initial chromaticity	(0.43, 0.40) SDCM<3
Power consumption tolerance	+/-10%
Standard Deviation of Colour Matching (McAdam ellipse)	SDCM≤3

Over Time Performance (IEC Compliant)	
Control gear failure rate at median useful life 50000 h	2.5 %
Control gear failure rate at median useful life 100000 h	5 %
Lumen maintenance at median useful life* 50000 h	L90
Lumen maintenance at median useful life* 100000 h	L80

Application Conditions	
Performance ambient temperature Tq	25 °C
Maximum dim level	10%
Suitable for random switching	No

Product Data	
Order product name	RC332V 42S/940 PSD W62L62 MXO
Full product name	RC332V 42S/940 PSD W62L62 MXO
Full product code	872016901477000
Order code	910505102458
Material Nr. (12NC)	910505102458
Numerator - Quantity Per Pack	1
Net Weight (Piece)	3.500 kg
EAN/UPC - Product/Case	8720169014770
Numerator - Packs per outer box	1
EAN/UPC - Case	8720169014770

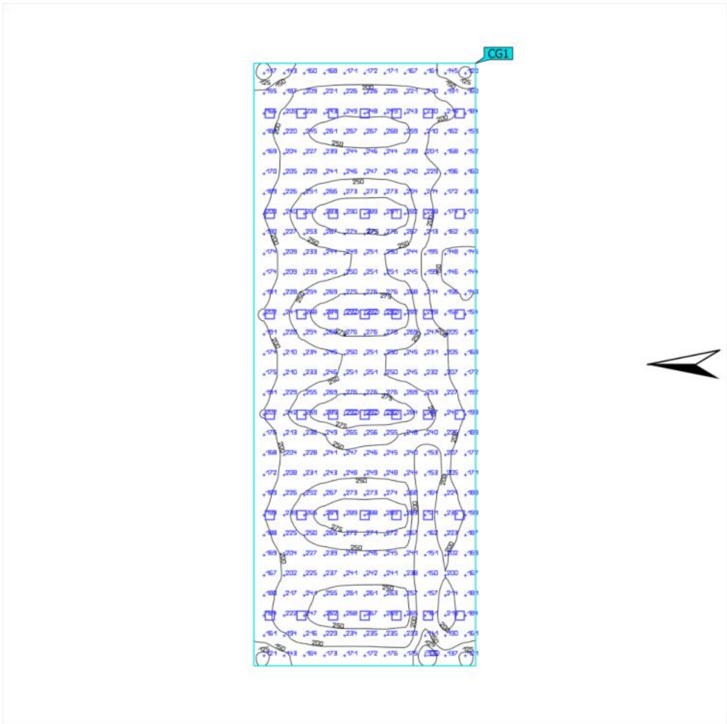
Appendix E

Lighting simulation of Arrival Hall - Lamp only- Report

2 Pages

Project

Building 1 · Arrival Hall · Arrival Hall (Lamps Only)



Properties	Ē	Emin	Emax	Uo (g1)	g2	Index
Calculation surface 5 Perpendicular illuminance Height: 0.100 m	222 lx	106 lx	292 lx	0.48	0.36	CG1

Utilisation profile: Transportational areas - Airports (5.52.1 Arrival and departure halls, baggage claim areas)

Project

Building 1 · Arrival Hall (Lamps Only)

Room list

Arrival Hall

P_{total}	A_{Room}	Lighting power density
1323.0 W	572.75 m²	2.31 W/m² (Room)

pcs.	Manufacturer	Article No.	Article name	P	$\Phi_{Luminaire}$
42	Philips	RC330VI-db47fde9-905e-438e-832a-ab48eaca06da	RC332V 42S/940 PSD MXO W62L62 ELP3	31.5 W	4298 lm

Appendix F

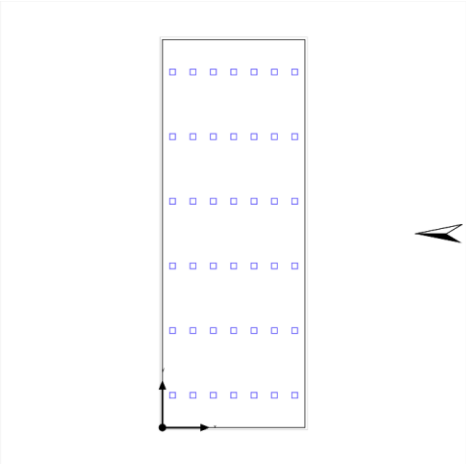
Energy evaluation Report of lighting in Arrival Hall

3 Pages

Project

Building 1 · Arrival Hall · Arrival Hall

Energy evaluation year



Annual energy consumption

	Uncontrolled	Controlled	Saving
Energy consumption (kWh/a)	8692	5677	3015
LENI (kWh/(m² * a))	15.2	9.91	5.26
Costs ($/a)	1738.42	1135.39	603.03
CO_2 (kg/a)	6084	3974	2111

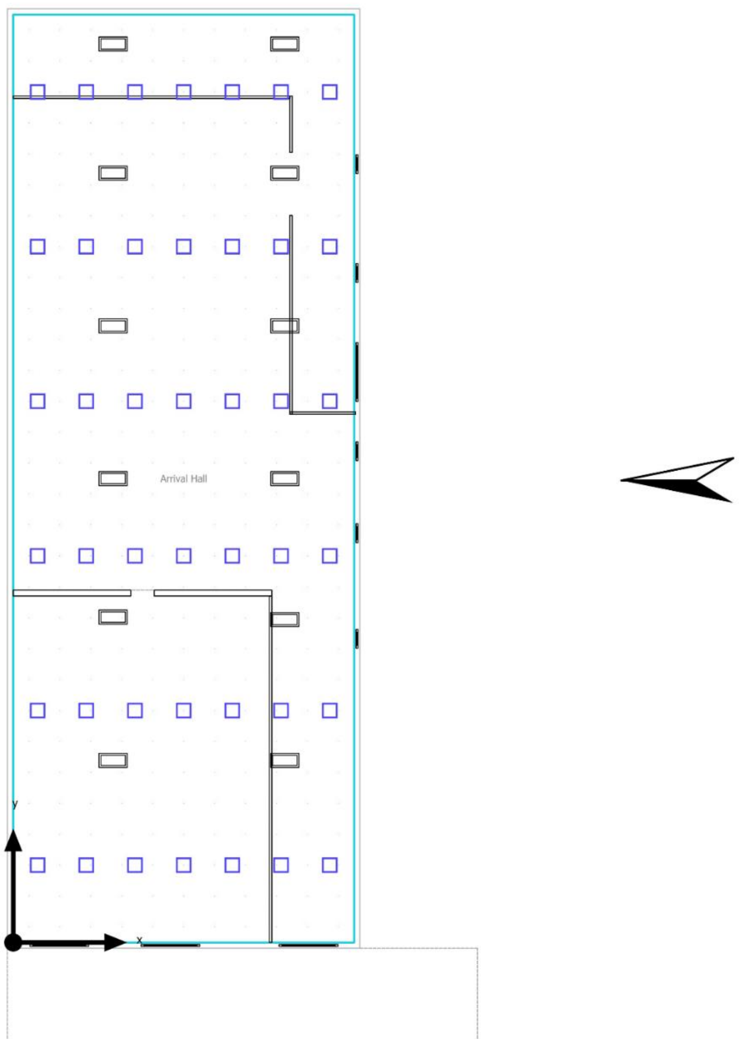
Planning data

Utilisation profile	Transportational areas - Airports (5.52.1 Arrival and departure halls, baggage claim areas)
Target illuminance	200 lx
Utilisation times	6:00 - 24:00 o'clock
Days per Week	7 (Mon - Sun)

Project

Building 1 · Arrival Hall · Arrival Hall

Energy evaluation day (7/1/2022 12:00)

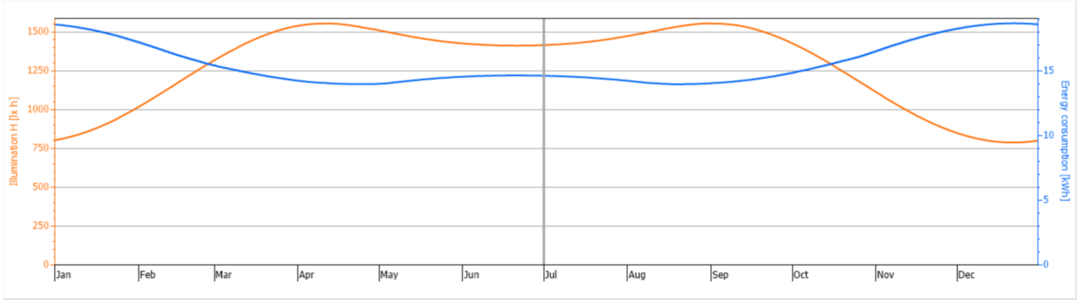


2

Project

Building 1 · Arrival Hall · Arrival Hall

Energy evaluation day (7/1/2022 12:00)

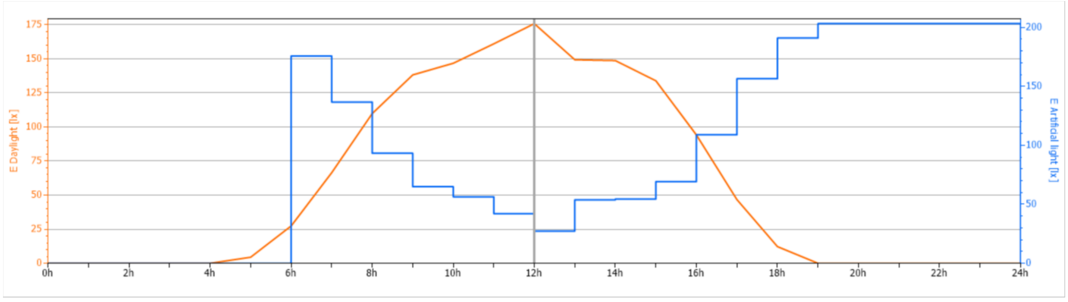


Annual energy consumption

Daily viewing: 7/1/2022

Energy consumption	
Uncontrolled	23.8 kWh
Controlled	14.6 kWh

Saving	
Energy	9.19 kWh
Costs	1.84 $
CO_2	6.43 kg



Daily schedule

Point in time viewing: 12:00

Illuminance / Power consumption	
E Artificial light	27.3 lx
E Daylight	176 lx
P	178 W

Saving	
P	1145 W
Shading	Open/None

Appendix G

Summary of Simulation for Arrival Hall by HAP in Current Situation

2 pages

Air System Sizing Summary for 002 - Arrival Hall

Project Name: GACB 05/09/2024
Prepared by: GACB 05:31PM

Air System Information

Air System Name	002 - Arrival Hall		Number of zones	1	
Equipment Class	UNDEF		Floor Area	570.0	m²
Air System Type	SZCAV		Location	Jericho, Palestine	

Sizing Calculation Information

Calculation Months	Aug to Aug	Zone L/s Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space L/s Sizing	Individual peak space loads

Central Cooling Coil Sizing Data

Total coil load	359.3	kW	Load occurs at	Aug 1500	
Sensible coil load	213.0	kW	OA DB / WB	47.5 / 35.3	°C
Coil L/s at Aug 1500	14199	L/s	Entering DB / WB	25.5 / 20.2	°C
Max block L/s	15881	L/s	Leaving DB / WB	13.4 / 13.0	°C
Sum of peak zone L/s	15881	L/s	Coil ADP	12.1	°C
Sensible heat ratio	0.593		Bypass Factor	0.100	
L/(s kW)	39.5		Resulting RH	61	%
m²/kW	1.6		Design supply temp.	14.4	°C
W/m²	630.4		Zone T-stat Check	1 of 1	OK
Water flow @ 5.6 K rise	15.48	L/s	Max zone temperature deviation	0.0	K

Supply Fan Sizing Data

Actual max L/s	15881	L/s	Fan motor BHP	9.45	BHP
Standard L/s	16319	L/s	Fan motor kW	7.50	kW
Actual max L/(s·m²)	27.86	L/(s·m²)			

Outdoor Ventilation Air Data

Design airflow L/s	671	L/s	L/s/person	3.36	L/s/person
L/(s·m²)	1.18	L/(s·m²)			

Air System Design Load Summary for 002 - Arrival Hall

Project Name: GACB | 05/09/2024
Prepared by: GACB | 05:31PM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Aug 1500 COOLING OA DB / WB 47.5 °C / 35.3 °C			HEATING DATA AT DES HTG HEATING OA DB / WB 19.7 °C / 14.0 °C		
ZONE LOADS	Details	Sensible (W)	Latent (W)	Details	Sensible (W)	Latent (W)
Window & Skylight Solar Loads	9 m²	973	-	9 m²	-	-
Wall Transmission	466 m²	15875	-	466 m²	1502	-
Roof Transmission	600 m²	81320	-	600 m²	3614	-
Window Transmission	9 m²	568	-	9 m²	41	-
Skylight Transmission	0 m²	0	-	0 m²	0	-
Door Loads	15 m²	3992	-	15 m²	85	-
Floor Transmission	0 m²	0	-	0 m²	0	-
Partitions	0 m²	0	-	0 m²	0	-
Ceiling	570 m²	16962	-	570 m²	0	-
Overhead Lighting	6772 W	6476	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	2000 W	1930	-	0	0	-
People	140	10229	18662	0	0	0
Infiltration	-	46156	92337	-	2772	-35133
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	184482	111000	-	8013	-35133
Zone Conditioning	-	177679	111000	-	0	-35133
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	14199 L/s	0	-	0 L/s	0	-
Ventilation Load	600 L/s	17102	35072	0 L/s	0	0
Supply Fan Load	14199 L/s	6705	-	0 L/s	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	7%	11546	-	7%	0	-
>> Total System Loads	-	213032	146071	-	0	-35133
Central Cooling Coil	-	213032	146305	-	0	0
>> Total Conditioning	-	213032	146305	-	0	0
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

Appendix H

Summary of Simulation for Arrival Hall by HAP After Retrofitting

2 pages

Air System Sizing Summary for 002 - Arrival Hall

Project Name: GACB (After Retrofit) 05/09/2024
Prepared by: GACB 03:59PM

Air System Information

Air System Name	002 - Arrival Hall		Number of zones	1	
Equipment Class	UNDEF		Floor Area	570.0	m²
Air System Type	SZCAV		Location	Jericho, Palestine	

Sizing Calculation Information

Calculation Months	Aug to Aug	Zone L/s Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space L/s Sizing	Individual peak space loads

Central Cooling Coil Sizing Data

Total coil load	148.8	kW	Load occurs at	Aug 1500	
Sensible coil load	73.3	kW	OA DB / WB	47.5 / 35.3	°C
Coil L/s at Aug 1500	3376	L/s	Entering DB / WB	29.6 / 23.8	°C
Max block L/s	3656	L/s	Leaving DB / WB	12.1 / 11.8	°C
Sum of peak zone L/s	3656	L/s	Coil ADP	10.1	°C
Sensible heat ratio	0.492		Bypass Factor	0.100	
L/(s kW)	22.7		Resulting RH	61	%
m²/kW	3.8		Design supply temp.	14.4	°C
W/m²	261.0		Zone T-stat Check	1 of 1	OK
Water flow @ 5.6 K rise	6.41	L/s	Max zone temperature deviation	0.0	K

Supply Fan Sizing Data

Actual max L/s	3656	L/s	Fan motor BHP	9.45	BHP
Standard L/s	3757	L/s	Fan motor kW	7.50	kW
Actual max L/(s·m²)	6.41	L/(s·m²)			

Outdoor Ventilation Air Data

Design airflow L/s	671	L/s	L/s/person	3.36	L/s/person
L/(s·m²)	1.18	L/(s·m²)			

Air System Design Load Summary for 002 - Arrival Hall

Project Name: GACB (After Retrofit) 05/09/2024
Prepared by: GACB 03:59PM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Aug 1500 COOLING OA DB / WB 47.5 °C / 35.3 °C			HEATING DATA AT DES HTG HEATING OA DB / WB 19.7 °C / 14.0 °C		
ZONE LOADS	Details	Sensible (W)	Latent (W)	Details	Sensible (W)	Latent (W)
Window & Skylight Solar Loads	9 m²	973	-	9 m²	-	-
Wall Transmission	466 m²	2890	-	466 m²	323	-
Roof Transmission	600 m²	3807	-	600 m²	476	-
Window Transmission	9 m²	323	-	9 m²	24	-
Skylight Transmission	0 m²	0	-	0 m²	0	-
Door Loads	15 m²	3371	-	15 m²	42	-
Floor Transmission	0 m²	0	-	0 m²	0	-
Partitions	0 m²	0	-	0 m²	0	-
Ceiling	570 m²	5084	-	570 m²	0	-
Overhead Lighting	6772 W	6476	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	2000 W	1930	-	0	0	-
People	140	10229	18662	0	0	0
Infiltration	-	11048	22081	-	693	-8783
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	46131	40743	-	1558	-8783
Zone Conditioning	-	46462	40743	-	0	-8783
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	3376 L/s	0	-	0 L/s	0	-
Ventilation Load	620 L/s	16892	34707	0 L/s	0	0
Supply Fan Load	3376 L/s	6926	-	0 L/s	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	7%	2982	-	7%	0	-
>> Total System Loads	-	73262	75449	-	0	-8783
Central Cooling Coil	-	73262	75511	-	0	0
>> Total Conditioning	-	73262	75511	-	0	0
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

Appendix I

The results of PVSYST simulation in details

8 Pages

Version 7.1.3

PVsyst - Simulation report

Grid-Connected System

Project: GACB project

System power: 797 kWp

Jericho - Palestine, State Of

Eng. Alaa Qatrawi

Signature

PVsyst V7.1.3
VC0, Simulation date:
13/05/24 22:04
with v7.1.3

Project: GACB project

Variant: New simulation variant

Project summary

Geographical Site
Jericho
Palestine, State Of

Situation

Latitude	31.86 °N
Longitude	35.46 °E
Altitude	0 m
Time zone	UTC+2

Project settings
Albedo 0.20

Meteo data
Jericho
Meteonorm 7.3 (1990-2004), Sat=100% (Modified by user) - Synthetic

System summary

Grid-Connected System

PV Field Orientation
Fixed plane
Tilt/Azimuth 30 / 0 °

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

System information

PV Array		Inverters	
Nb. of modules	1944 units	Nb. of units	9 units
Pnom total	797 kWp	Pnom total	594 kWac
		Pnom ratio	1.342

Results summary

Produced Energy	1429 MWh/year	Specific production	1793 kWh/kWp/year	Perf. Ratio PR	79.18 %

Table of contents

General parameters

Grid-Connected System

PV Field Orientation

Orientation

Fixed plane	
Tilt/Azimuth	30 / 0 °

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	separate

Horizon
Free Horizon

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Jinkosolar
Model	JKM410M-72H-V
(Original PVsyst database)	
Unit Nom. Power	410 Wp
Number of PV modules	1944 units
Nominal (STC)	797 kWp
Modules	108 Strings x 18 In series
At operating cond. (50°C)	
Pmpp	729 kWp
U mpp	672 V
I mpp	1085 A

Inverter

Manufacturer	Canadian Solar Inc.
Model	CSI-66KTL-GS
(Original PVsyst database)	
Unit Nom. Power	66.0 kWac
Number of inverters	36 * MPPT 25% 9 units
Total power	594 kWac
Operating voltage	200-850 V
Pnom ratio (DC:AC)	1.34

Total PV power

Nominal (STC)	797 kWp
Total	1944 modules
Module area	3911 m²
Cell area	3471 m²

Total inverter power

Total power	594 kWac
Nb. of inverters	9 units
Pnom ratio	1.34

Array losses

Thermal Loss factor
Module temperature according to irradiance

Uc (const)	20.0 W/m²K
Uv (wind)	0.0 W/m²K/m/s

DC wiring losses

Global array res.	10 mΩ
Loss Fraction	1.5 % at STC

Module Quality Loss

Loss Fraction	-0.8 %

Module mismatch losses

Loss Fraction	2.0 % at MPP

Strings Mismatch loss

Loss Fraction	0.1 %

IAM loss factor
Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

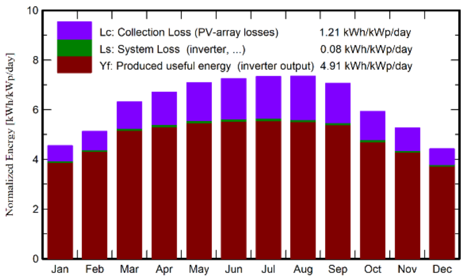
Main results

System Production

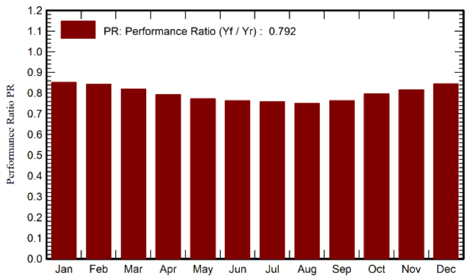
Produced Energy 1429 MWh/year

Specific production 1793 kWh/kWp/year
Performance Ratio PR 79.18 %

Normalized productions (per installed kWp)



Performance Ratio PR



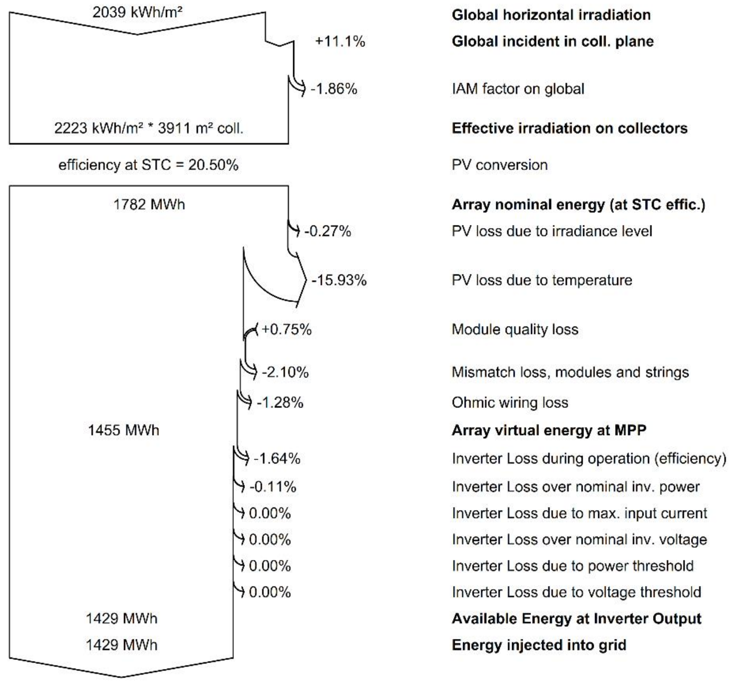
Balances and main results

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	ratio
January	95.5	38.10	26.20	141.2	138.9	97.5	96.0	0.852
February	109.7	49.80	28.80	143.6	141.4	98.1	96.6	0.843
March	165.6	63.60	30.70	195.7	192.5	129.9	127.8	0.819
April	191.8	75.50	36.60	201.1	197.2	129.2	127.0	0.793
May	232.2	73.60	41.90	219.8	215.1	137.6	135.3	0.772
June	242.3	59.50	43.60	217.7	212.6	134.7	132.5	0.763
July	248.0	57.20	44.30	227.3	221.8	139.8	137.4	0.758
August	226.2	57.50	46.50	228.0	223.4	138.7	136.4	0.750
September	185.9	50.60	43.50	211.8	208.1	131.2	129.0	0.764
October	143.5	54.50	39.00	183.7	180.8	118.5	116.6	0.796
November	108.2	37.10	35.10	157.8	155.8	104.4	102.7	0.816
December	90.1	37.10	30.19	137.2	135.3	93.8	92.3	0.845
Year	2039.0	654.10	37.24	2265.0	2222.8	1453.3	1429.4	0.792

Legends

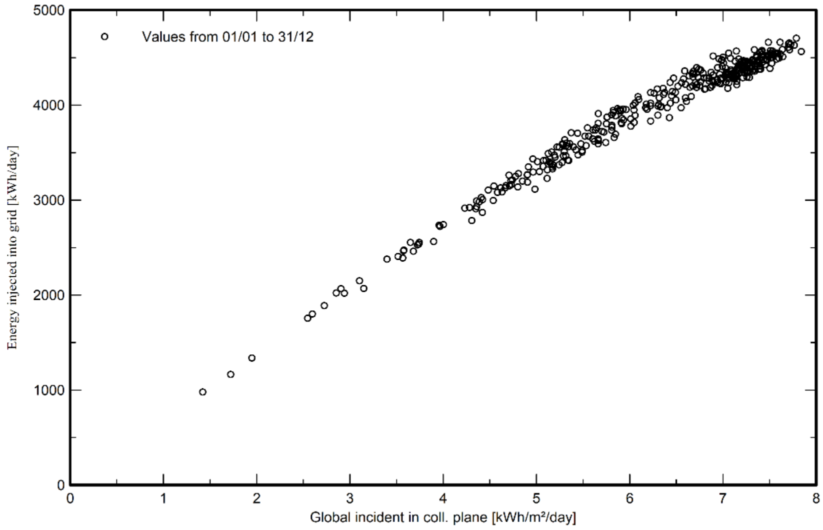
GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

Loss diagram

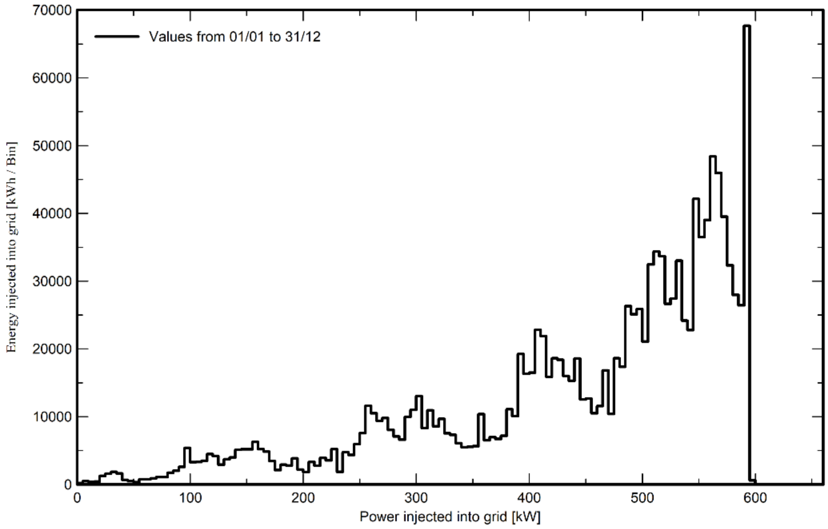


Special graphs

Daily Input/Output diagram



System Output Power Distribution



Cost of the system

Installation costs

Item	Quantity units	Cost USD	Total USD
Total			0.00
Depreciable asset			0.00

Operating costs

Item	Total USD/year
Total (OPEX)	0.00

System summary

Total installation cost	0.00 USD
Operating costs	0.00 USD/year
Produced Energy	1429 MWh/year
Cost of produced energy (LCOE)	0.000 USD/kWh

CO_2 Emission Balance

Total: 16759.5 tCO_2

Generated emissions

Total: 1460.58 tCO_2

Source: Detailed calculation from table below:

Replaced Emissions

Total: 20011.8 tCO_2

System production: 1429.41 MWh/yr

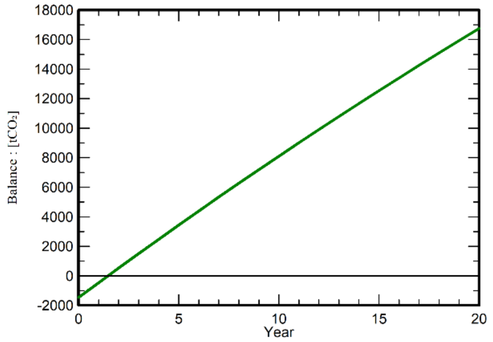
Grid Lifecycle Emissions: 700 gCO_2/kWh

Source: Custom value supplied by user

Lifetime: 20 years

Annual degradation: 1.0 %

Saved CO_2 Emission vs. Time



System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal [$kgCO_2$]
Modules	1713 kgCO2/kWp	800 kWp	1370724
Supports	4.40 kgCO2/kg	19520 kg	85931
Inverters	436 kgCO2/units	9.00 units	3925

Appendix J

Figures

Figure J.1

Solar Tube /Light Duct

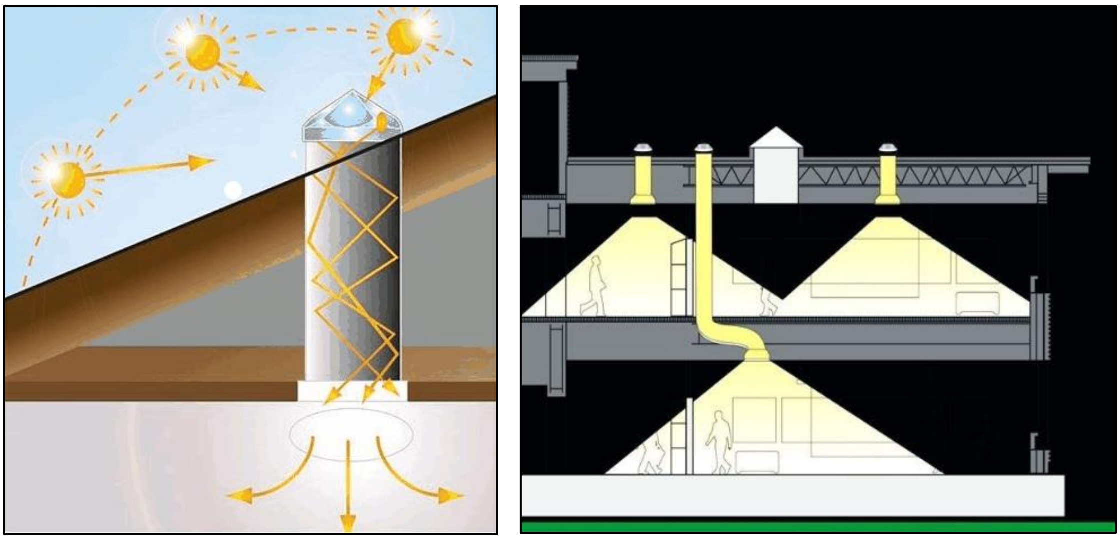
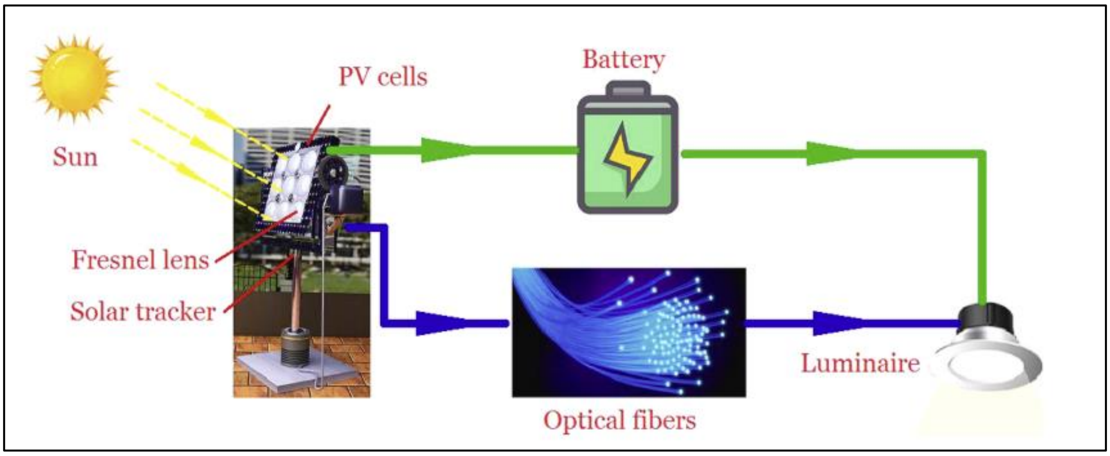


Figure J.2

Hybrid solar lighting system



source: Y. Lv, L. Xia, M. Li, L. Wang, Y. Su, and J. Yan, "Techno-economic evaluation of an optical fiber based hybrid solar lighting system," Energy Convers Manag, vol. 225, Dec. 2020, doi: 10.1016/j.enconman.2020.113399

Figure J.3

Configuration of lighting control system

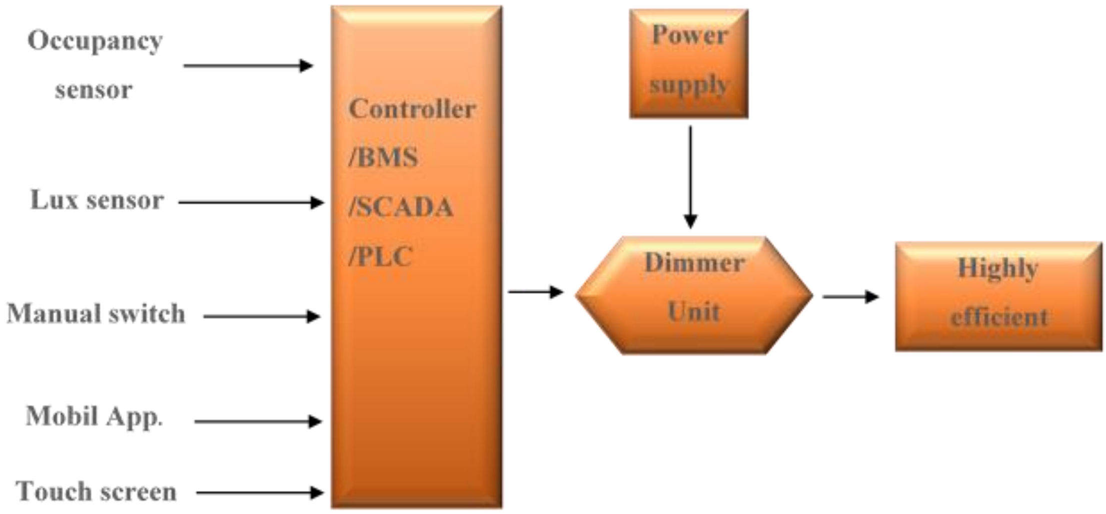
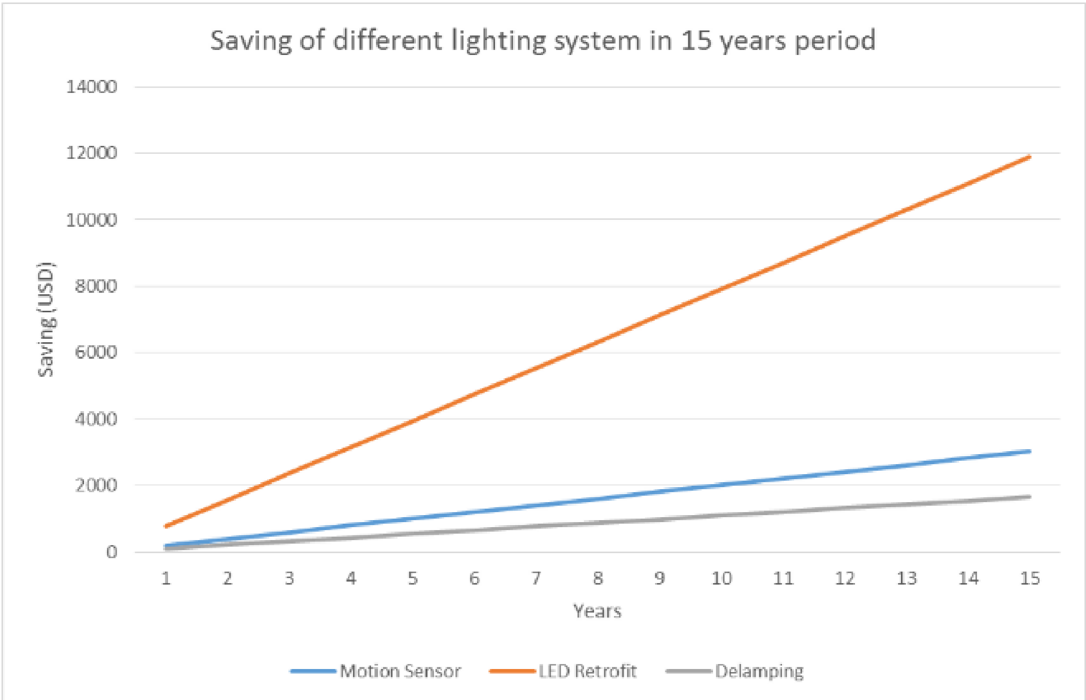


Figure J.4

Economic comparison of lighting conservation strategies



source: M. F. M. A. Halim, M. F. Yaakub, M. H. Harun, K. A. M. Annuar, F. H. M. Basar, and M. N. Omar, "An analysis of energy saving through delamping method," *International Journal of Electrical and Computer Engineering*, vol. 9, no. 3, pp. 1569–1575, Jun. 2019, doi: 10.11591/ijece.v9i3.pp1569-1575

Figure J.5
Principle of solar chimney

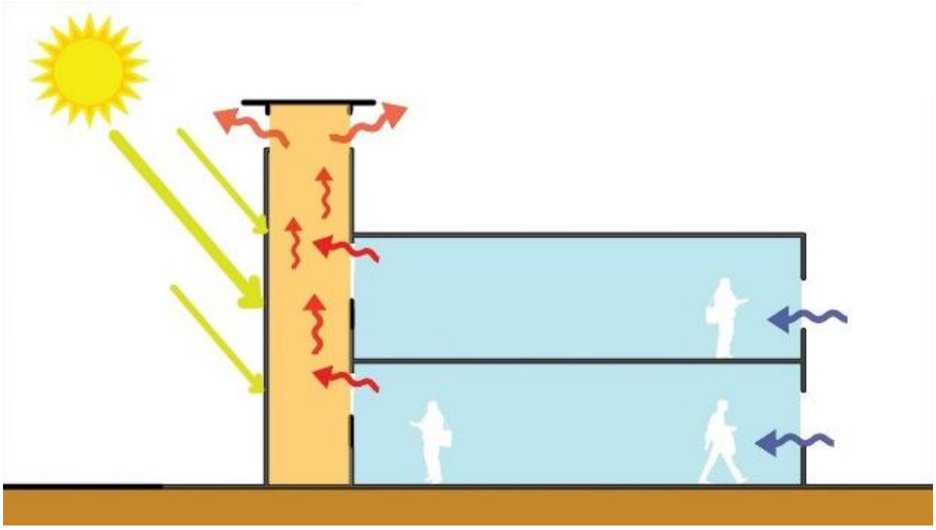
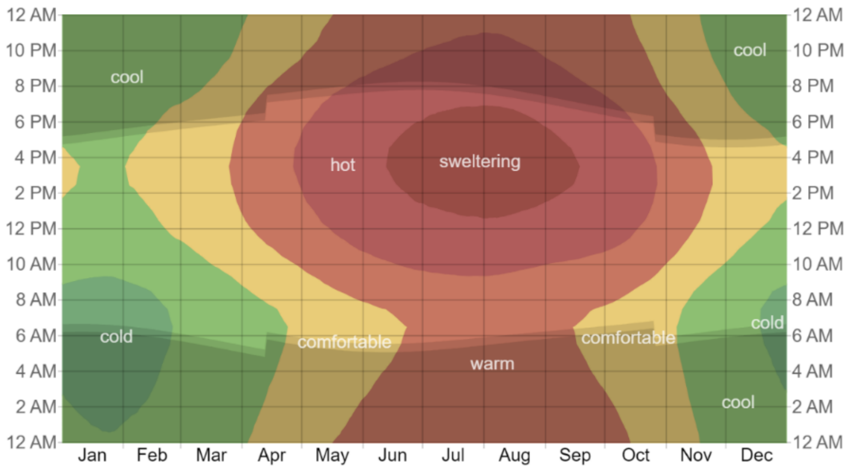


Figure J.6
Jericho weather



*source:*https://weatherspark.com/y/98833/Average-Weather-in-Jericho-Palestinian-Territories-Year-Round#Figures-ColorTemperature

Figure J.7
Aerial photograph

Figure J.8
Single line diagram of main electrical board

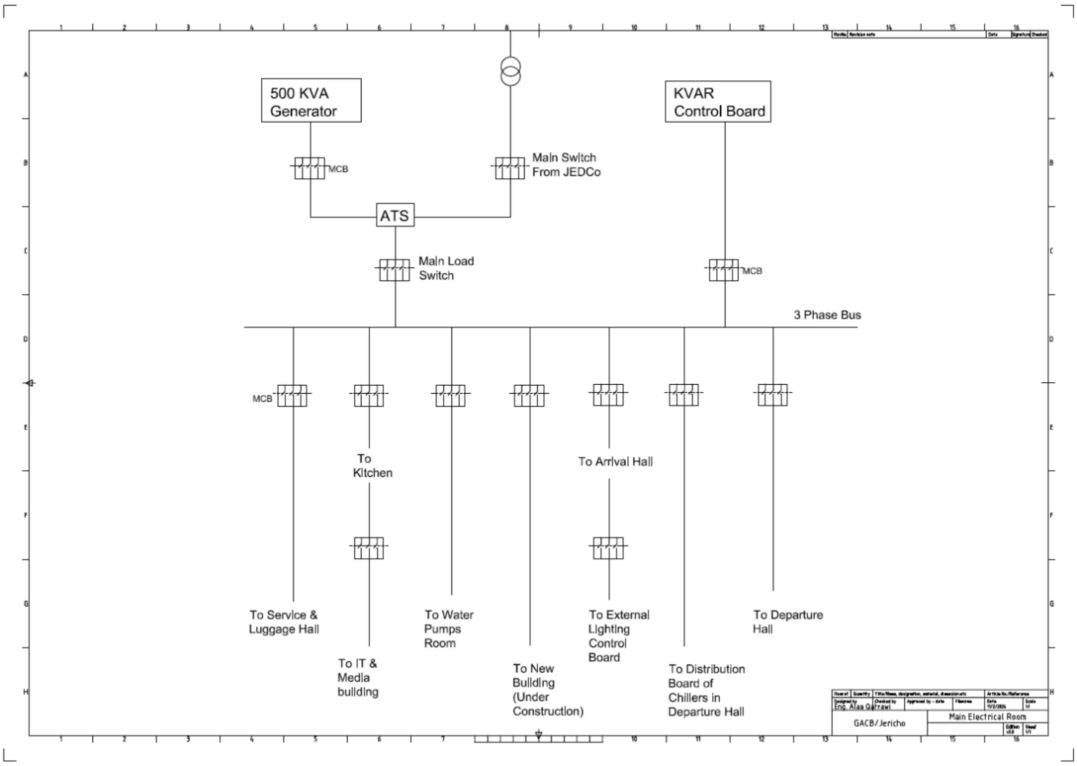
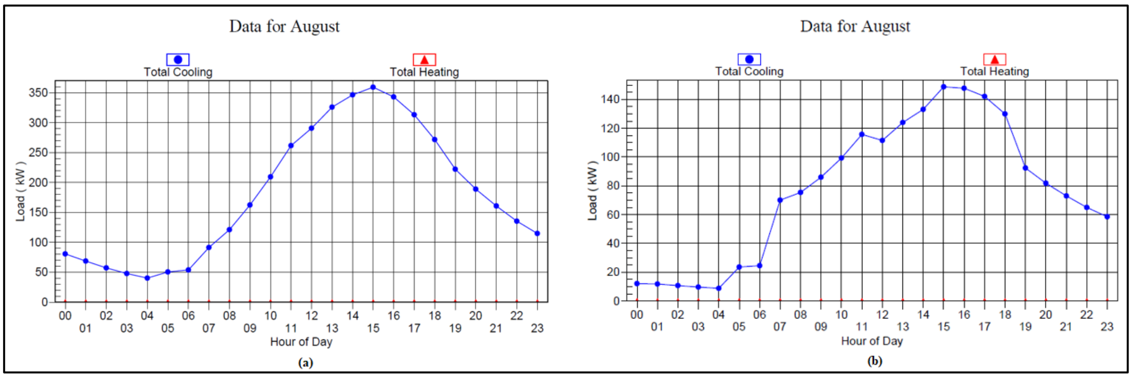


Figure J.9

Cooling load at max. day of Aug. (simulation by HAP)



(a): Before applying measure-1 (b): After applying measure-1

Figure J.10

The suggested solar absorption HVAC system

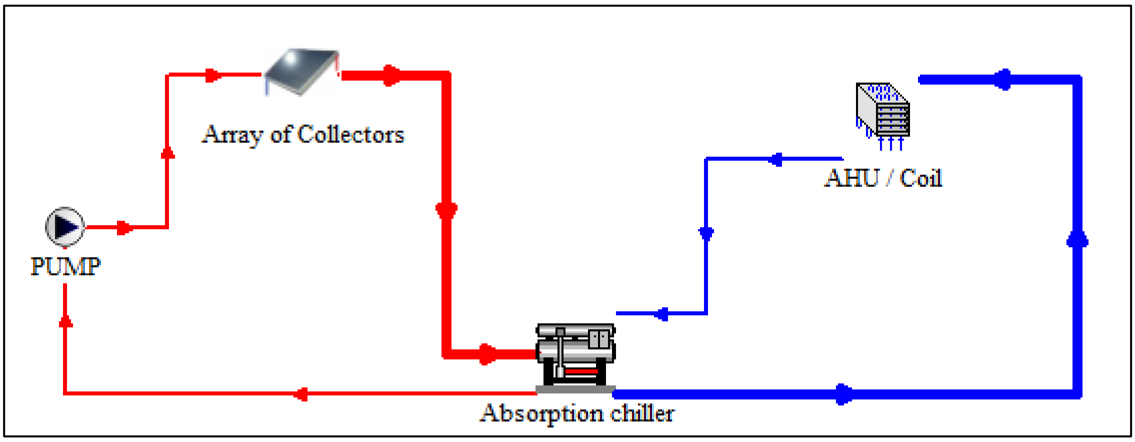


Figure J.11

Simulation result of lighting for parking 3 & 4

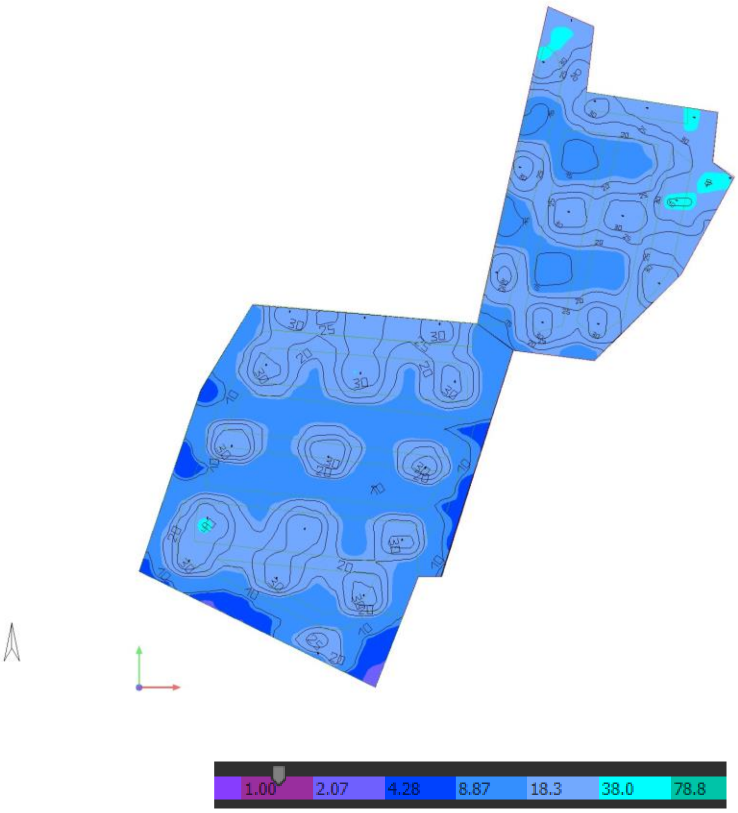
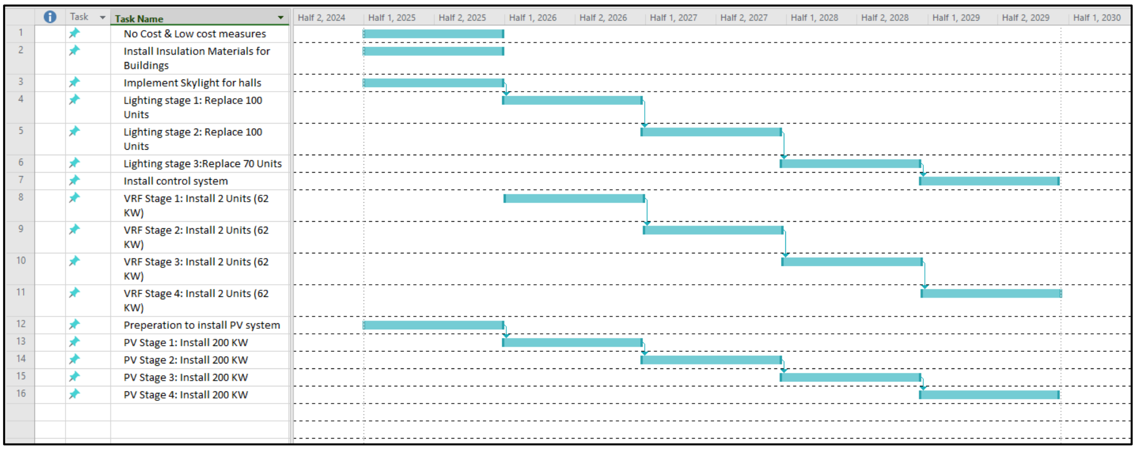


Figure J.12

General time frame of GACB transition



جامعة النجاح الوطنية

كلية الدراسات العليا

الأبنية العامة صفرية الطاقة في فلسطين
دراسة حالة: الادارة العامة للمعابر والحدود – أريحا

إعداد

علاء ابكار حيدر قطراوي

إشراف

د. عماد بريك

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس –فلسطين.

2024

الأبنيـة العامـة صفريـة الطاقـة في فلسطين
دراسة حالة: الإدارة العامة للمعابر والحدود – أريحا

إعداد
علاء ابكار حيدر قطراوي
إشراف
د. عماد بريك

الـملخص

يتزايد الاحتياج للطاقة الكهربائية في مدينة أريحا سنويا خاصة في ظل الأجواء الحارة التي تتسم بها المدينة، ونظراً الى مشكلة الاحتباس الحراري العالمي والتي تسبب الحاجة المستمرة لتهيئة الأجواء الداخلية للمباني العامة باستخدام أنظمة التبريد المختلفة. تختبر هذه الدراسة تطبيق مفهوم الأبنية الصفرية الطاقة في الأبنية العامة، والتي تسعى الى تحقيق الاتزان بين كمية الاستهلاك السنوي من الطاقة الكهربائية اللازمة داخل المبنى من جهة وكمية الطاقة المنتجة محليا باستخدام التقنيات المتجددة من ناحية أخرى. ان النظرة المهنية لتطبيق مفهوم الأبنية الصفرية يتطلب دراسة شاملة لكل حالة على حدة، من أجل ضمان رفع كفاءة الأداء الطاقي للمبنى من خلال تطبيق مبادئ التدقيق الطاقي واستراتيجيات الحفاظ على الطاقة كخطوة أولية قبل الانتقال الى استغلال الموارد المتجددة لتوليد الطاقة الكهربائية. يتمثل الهدف الأساسي من هذه الدراسة في لفت الانتباه الى العديد من الفرص والوسائل التقنية المتجددة في مجال الطاقة، والتي يمكن استخدامها في المباني العامة من أجل تقليل التكاليف السنوية. تعتمد طريقة الدراسة والبحث في هذا العمل بشكل أساسي على استخدام برامج المحاكاه الحاسوبية، من أجل اختبار العديد من الوسائل والمفاضلة بينها من منظور تقني واقتصادي. وبالنظر الى النتائج النهائية من دراسة هذه الحالة – مبنى الادارة العامة للمعابر والحدود / أريحا – فان النتائج تشير الى توفير في الطاقة المستخدمة بنسبة (32.7 %) نتيجة تطبيق وسائل الحفاظ على الطاقة التي تم الاشارة اليها في هذه الدراسة، كما تبين الدراسة امكانية خفض الانبعاثات السنوية من غاز ثاني اكسيد الكربون بمقدار (1250 طن) نتيجة استخدام ألواح الطاقة الكهروضوئية كمصدر للطاقة

بديلاً عن المصادر التقليدية. علاوة على ذلك، فان المؤشرات الاقتصادية قد جاءت ايجابية، والتي كان أبرزها مؤشر مدة استرجاع رأس المال (SPP) وهي أقل من أربع سنوات، اضافة الى مؤشر تكلفة وحدة الطاقة المتولدة (LCOE) والتي كانت نتيجتها (0.06$/kWh)، أي ما يعادل تقريبا الثلث من التكلفة الحالية للكيلو واط – ساعة من الشبكة التقليدية. هذه النتائج وغيرها في هذه الدراسة تدفع نحو تبني استراتيجية فاعلة خلال العشرين سنة القادمة، من أجل الانتقال الى تطبيق مفهوم المباني الصفرية في المنشأت العامة، من خلال توظيف التقنيات المستدامة في المباني العامة وزيادة الاهتمام بوسائل الترشيد الطاقي لا سيما في أنظمة الانارة وأنظمة التكييف.

الكلمات المفتاحية: الأبنية العامة الصفرية، تدقيق الطاقة، مبادئ ترشيد الاستهلاك.