



An-Najah National University

Faculty of Graduate Studies

**ENERGY MANAGEMENT IN THE HEALTH SECTOR: A CASE
STUDY OF NABLUS SPECIALTY HOSPITAL**

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Dedication

Everyone who has supported me, from my parents to my spouse and children to my sisters to my friends, has been an incredible source of love and encouragement.

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First of all, I want to thank Allah, the Most Gracious and Merciful, for giving me the wisdom and grace to finish this task.

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Declaration

The undersigned hereby certifies that I submitted the thesis titled

ENERGY MANAGEMENT IN THE HEALTH SECTOR: A CASE STUDY OF NABLUS SPECIALTY HOSPITAL

I certify that the work included in this thesis is wholly original with no prior submissions for any other degree or academic qualification, unless otherwise noted.

Students Name:

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ENERGY MANAGEMENT IN THE HEALTH SECTOR: A CASE STUDY OF NABLUS SPECIALTY HOSPITAL

Abstract

This study is about finding ways to save energy in a big hospital, in Nablus, Palestine. The hospital uses a lot of energy every day. To see where the hospital can save energy, we did a full energy audit to understand how the hospital uses energy in day-to-day operation and to identify where the main losses and inefficiencies happen. RET Screen Expert was used as the main tool to assess the current situation and to compare improvement options.

The study suggests a number of practical measures, including the installation of a solar water-heating system, the upgrade of the lighting to more efficient technology, the enhancement of the building's insulation, the enhancement of HVAC efficiency through improved performance tuning and regular maintenance, and the installation of a photovoltaic (PV) system above the parking area to generate a portion of the hospital's electricity demand, all of which are based on the audit findings.

The environmental, financial, and energy-saving impacts of the proposed actions were examined in this study. The results showed that the implementation of the energy audit measurements could reduce energy consumption by approximately 30%, equivalent to around 379,050 kWh/year. In addition, annual cost savings of about USD 115,921 and a reduction of approximately 102 tons of CO₂ emissions per year could be achieved. The results also indicated that hospital operating costs, pollution levels, and energy consumption could be reduced simultaneously. It should be emphasized that the most effective energy-saving solutions are those that provide both environmental and financial benefits. Therefore, healthcare facility decision-makers may be encouraged to adopt such measures, as they can contribute to improving energy performance while reducing operational costs and environmental impacts.

Keywords: RET Screen analysis, Energy consumption, Energy efficiency.

Chapter one

1. Introduction

1.1 Overview

Rapid technological advancement, an increase in urban population, and a general rise in the global population have all contributed to a meteoric rise in the demand for energy in recent decades. Our homes, companies, and industries are powered by energy. In addition to facilitating our everyday activities, it enables a great deal of contemporary comforts and essential infrastructure. Conventional power infrastructures reliant on fossil fuels have been struggling under the weight of increased electrical use in recent years. This highlights the critical need of finding environmentally friendly energy sources. Many factors, including rising energy prices and emissions of greenhouse gases, are contributing to the deterioration of the climate(1).

The challenges associated with increasing power consumption can be addressed with a two-pronged approach that prioritizes energy efficiency and renewable energy sources. Renewable energy sources such as hydroelectric, solar, and wind power are preferable to fossil fuels because they employ replenishable resources and emit less carbon dioxide. Furthermore, improving energy efficiency can significantly reduce the quantity of electricity required to meet demand, making it easier on energy infrastructures. Energy audits, optimizing industrial processes, and replacing appliances are all ways to accomplish this(2).

Combining renewable energy sources with energy-saving technologies is a comprehensive strategy for fulfilling the increasing demand for electricity. This approach promotes economic growth by cutting energy costs, creating jobs in green enterprises, ensuring reliable energy supplies, and contributing to global climate goals. By focusing on efficiency and transitioning to renewable energy sources, society may assure a stable and long-term energy future while also reducing the environmental impact of energy consumption.

Energy conservation and efficiency are currently critical for meeting sustainable development goals and addressing global environmental issues. The building and industrial sectors consume a lot of energy around the world. They conduct systematic energy audits to

identify various ways to use energy more efficiently. An energy audit examines how energy is used to identify waste reduction opportunities and provide practical advice on how to reduce energy use, prices, and carbon footprint(3).

In locations like Palestine, where energy is sometimes scarce or expensive, implementing comprehensive energy auditing systems can make a significant difference. It might help protect the environment around the world, reduce the use of nonrenewable energy, and encourage people, businesses, and organizations to utilize energy more efficiently(4).

An energy audit (EA) examines how much energy a facility consumes to determine why it is wasting electricity. It entails identifying ways to save energy and advising individuals on how to use energy more efficiently while reducing pollution from electrical energy. Energy audits also consider the possibilities of employing energy-saving appliances, tools, and technology to assist people save money on their energy bills while also teaching them how to utilize energy more efficiently and logically. Energy audits benefit the environment by reducing dangerous gas and carbon emissions.

An energy audit can help a person or organization identify areas where the system can consume less energy while still performing the same amount of work. Energy audits are critical for commercial and industrial real estate because they help people find methods to reduce their energy bills and carbon footprints. An energy audit determines how much energy a home uses and then devises a strategy to make it more efficient, resulting in less energy use. Many different coefficients can be utilized to learn about and evaluate energy-saving strategies. For example, consider the cost of the primary energy supply and the annual demand(5).

An Energy Audit (EA) is a planned event that examines how a facility consumes energy in order to identify ways to make it more efficient, more comfortable, and use the least amount of energy possible. The audit identifies weaknesses in how things are done and recommends ways to save money and energy. It is critical for the long-term health of buildings since it proposes practical ways to make them more energy efficient.

An energy audit is typically performed on a regular basis to ensure that changes in factors such as how the building is used, the condition of existing equipment, and new energy-saving technology are always considered. Because of its periodic nature, building managers can ensure the facility's long-term sustainability and efficiency by adapting to new opportunities and challenges.

According to the ASHRAE 100-2006 Standard, energy audits are conducted on three levels. The level is determined by the complexity of the building, the customer's goals, the amount of time available, and the budget(6)(7):

1. Level 1: Assessment of Walk-Through

Before proceeding, ensure that there are no evident inefficiencies. This level provides a comprehensive overview of your energy consumption as well as simple energy-saving advice that will save you both time and money. It is the finest option for clients who require a quick checkup with beneficial advice.

2. Level 2: Survey and Analysis of Energy

A more in-depth study that includes a detailed look at energy consumption and suggestions for improving efficiency. This level involves investigating energy consumption, performing basic financial calculations, and learning more about how building systems operate. It is ideal for moderate to complicated buildings with specific remodeling goals.

3. Level 3: Detailed Analysis of Capital-Intensive Modifications

The audit has a detailed part that looks at all the big changes and improvements that can be made. This part of the audit includes a look at how much things will cost over time a complete model of how energy is used and specific ideas for big projects that cost a lot of money. The audit is perfect for projects with a lot of money to spend that want to make the most energy-efficient changes, to the energy-efficient projects. The energy-efficient projects will really benefit from this audit.

Energy audits are finished by following these steps. These energy audits help people who are involved see how big and detailed the energy audit should be to get what they want. This

makes sure each energy audit gives information and helps people make good choices about using energy in a way that is good, for the environment. Energy audits are important because they provide this kind of information and help with decision making about energy use(7).

1.2 Problem Statement

Hospitals and other healthcare institutions use a lot of energy. They have to keep systems running all the time. They also use medical equipment and they have to keep the temperature just right so patients are safe and comfortable.

In places like Nablus energy is very expensive and hard to come by. If hospitals do not manage energy well, it can cost them a lot of money. Put a strain on the local energy system.

This is a deal for private hospitals like the Nablus Specialized Hospital. They have to make sure they give patients care but they also have to keep their expenses low. The Nablus Specialized Hospital has to find a balance between these two things. Hospitals like the Nablus Specialized Hospital have to be careful, with energy because it affects the care they give to patients.

The reason for doing this study is to take a close look at how the Nablus Specialized Hospital uses energy. We want to see how the hospital uses energy and find ways to make it use energy better. The study checks things like how humid it's how well the hospital is insulated and how many electrical devices are being used. It also thinks about things like how many patients come to the hospital every day how many staff members are working and how many beds are available. The main goal of this study is to find out where the hospital is wasting energy or not using it well so that hospitals can use energy and still work properly.

This study shows how looking at how energy's used can help hospitals use energy in a better way. If the hospital follows the suggestions, it can reduce the things it does to the environment and also save money. It can also be an example for hospitals nearby. This project is in line with what the whole world's trying to do which is to use less energy and be more sustainable. It also helps hospitals in Palestine deal with their problems, like the Nablus Specialized Hospital. The Nablus Specialized Hospital can use this study to make changes and use energy sustainably which is good, for the hospital and the environment.

The main reason for this project is to do an energy check of the Nablus Specialized Hospital, which is a private hospital. The Nablus Specialized Hospital's energy consumption will be assessed, areas for improvement will be identified, and practical solutions will be proposed without disrupting the hospital's daily operation. The energy check will look at how the hospital uses energy in ways including:

1. check how much electricity is used by systems, like the heating and cooling system the lights, the medical equipment and the backup power systems, this will help us understand how the electrical devices are using electricity.
2. We need to check how well the building keeps the temperature right; how the building handles humidity and if the insulation in the building is doing its job. This will help us figure out ways to make the climate inside the building more comfortable. We are evaluating the building envelopes to improve the climate control, in the building.
3. check how things like the number of beds, staff schedules, patient activity levels, and working hours affecting on how energy consumption varies.

1.3 Goals of the Project

The main reason for this proposal is to do a check of the energy use, at the Nablus Specialized Hospital. We want to find out how energy the Nablus Specialized Hospital uses. We also want to identify ways to make the Nablus Specialized Hospital use energy better and give some ideas for this. All of this has to be done while making sure the Nablus Specialized Hospital keeps working well.

The specific things we want to achieve with this investigation are the following:

1. The hospital needs to figure out how to use energy. To do this we will do an energy audit of the hospital. We will then compare the hospital to hospitals around the country and, around the world. This will help us see what the hospital is doing well and what it can do better.
2. Try to use energy from the sun and other natural things. This means check if the hospital can use panels to make energy they use every day.

3. Use energy-efficient technologies to reduce the hospital's carbon footprint while also meeting global sustainability targets.

Chapter two

2. Theoretical Framework and Literature Review

2.1. Palestine Context

The energy sector situation in Palestine differs significantly from that of other Middle Eastern countries for a variety of reasons, including a lack of natural resources, unstable political conditions, a financial crisis, and a high population density. Furthermore, Palestine depends on other countries for 100% of its fossil fuel imports and for 87% of its electricity imports. Furthermore, high population growth, rising living standards, and rapid industrial growth have resulted in massive energy demand in Palestine in recent years. The total energy consumption per inhabitant in Palestine is the lowest in the region (0.79 MWh/inhabitant) and the most expensive in the Middle East. Palestine is a country with moderate wind speeds. On the other hand, Palestine has a high solar energy potential of about 3000 sunshine hours per year(8).

Global solar radiation is the sum of direct and diffuse solar radiation on a surface, where the former is radiation received from the sun before it is scattered by the atmosphere, and the latter is radiation received from the sun after its direction has been changed by atmospheric scattering. The average solar resource in Palestine ranges from 5.4 kWh/m² per day to 6 kWh/m² per day on a horizontal surface(9).

2.2. Literature Review

Hospitals are different from other businesses due to their exceptionally high energy demands, driven by 24/7 operations, have specialized medical equipment, and have strict rules for keeping the environment safe and comfortable. Important healthcare services require a constant supply of energy to function. However, such a high demand for energy complicates operations, particularly when it comes to keeping costs low and reducing environmental effect(10).

Diesel generators and grid energy provide the bulk of power for Palestinian hospitals. Both the wallet and Mother Earth take a beating from these decisions. Hospitals that use imported

gas are more likely to have problems getting the things they need. This means that the healthcare services they provide are not as good as they could be. It also affects the work that hospitals do(11).

People have been trying to fix these problems. They want to use energy and get energy from natural sources like solar energy systems that use photovoltaic panels. Using energy systems can really help cut costs and make energy more reliable when the power grid is down. This is especially important, for energy systems because they can keep working even when the grid fails and that is a big advantage of solar energy systems. Energy audits conducted in Palestinian hospitals also indicate that the electrical, heating, cooling, and lighting systems do not operate at the required efficiency(10).

Hospitals in Palestine use a lot of energy because they are always open and use systems that use a lot of energy. In 2007, the annual energy consumption of 17 main hospitals in the West Bank was reported to be approximately 15.810 GWh, with an estimated 0.93 MWh per bed per year(10).

According to the Palestinian Central Bureau of Statistics (PCBS), by 2021 the number of hospitals in Palestine had reached 89—54 in the West Bank and 35 in the Gaza Strip—with a total of 7,296 beds (4,270 in the West Bank and 3,026 in Gaza(12). Hospitals are projected to represent approximately 6% of the overall energy demand within the service buildings sector. The HVAC (heating, ventilation, and air conditioning) system is the most energy-intensive component in hospitals, accounting for around 70% of electricity usage. Electric motors account for around 19%, while lighting systems represent about 21%(13). These findings highlight the urgency with which the healthcare sector must improve the energy efficiency of its facilities in order to reduce expenses and emissions of greenhouse gases. The energy requirements of hospitals are high, distinguishing them from other types of companies. Reasons for this include their round-the-clock availability, the technology they use, and the stringent regulations imposed on patient safety and comfort. To deliver essential healthcare services and keep the people they serve safe, healthy, and happy, they must constantly expend a great deal of energy. This high demand, on the other hand, makes it difficult to run a firm, particularly in terms of controlling expenses and reducing environmental harm(10).

Most Palestinian hospitals rely on the electricity grid and diesel generators as their primary energy sources. In addition to being expensive, these solutions are harmful to the environment. Additionally, healthcare services are more vulnerable to supply chain disruptions when gasoline is imported from other nations(11).

Renewable energy sources like solar photovoltaic (PV) systems, have been getting a lot of attention lately. People are also trying to use energy efficiently. These efforts are helping to lower costs and make energy more reliable when the grid goes down. Renewable energy sources are showing a lot of promise. They help reduce costs. Energy reliability also gets a boost during outages. Energy audits conducted in Palestinian hospitals reveal inefficiencies in electrical systems, heating, cooling, and lighting, highlighting the importance of retrofitting and implementing smarter energy management systems(10).

The hospitals in Palestine, specifically in the West Bank, where the electrical energy consumption in the hospitals can be reduced from 4057.7 MWh/year to 2888.6 MWh/year. Also, there is the reduction of the production of one of the most greenhouse gases that are responsible for global warming in the world. Research shows CO₂ production has been reduced by 1,292,134 kg of CO₂/year (14).

There is great potential for energy savings in the Palestinian hospitals' sector by implementing energy conservation measures of no and low-cost investment. Energy consumption in hospitals is huge due to non-awareness and lack of experience of energy management procedures; in addition to continuous negligence of energy employment, the hospitals are likewise old, thus inappropriate to implement energy conservation or management in their present conditions(10).

Energy audit (EA) is a process to detect operating problems, improve occupants' comfort, and optimize energy use of existing buildings. In addition, it identifies the opportunities for energy conservation. The process is periodic in nature, and it assesses changes in building use, the condition of existing equipment, and the applicability of new energy-efficient technologies. EA can be conducted at 3 different levels depending on the time, budget constraints, the building complexity, and client requirements. The energy audits have 3 levels defined by the ASHRAE 100-2006 standard as the following: level 1, "walk-through

assessment”; level 2, “energy survey and analysis”; and level 3, “detailed analysis of capital-intensive modifications.” (15).

In Palestine, solar water heater is modest and simple, and they must be created, regulated, and supervised, much like their upkeep. Whatever heating technique is utilized, the water temperature must be kept at or above a level appropriate for proper hygiene and disease prevention (about 60°C). Increasing the use of renewable energy (RE) is one of the most successful ways to promote sustainability. Solar water heating (SWH) is one of several commercially mature technologies that are highly appealing, since it reduces the hospital’s whole reliance on diesel fuel; it was considered to construct the SWH system on the available roof of the hospital (14).

The study “Enhancing Energy Efficiency in Palestinian Dairy Factory Utilizing RET Screen Expert” analyzes how a dairy factory in Palestine can minimize its energy use through a detailed energy audit and the implementation of RET Screen Expert. The researchers explored several practical options, such as upgrading lighting, improving insulation, maintaining steam traps, reducing steam losses, installing heat-recovery systems, and adding a solar water-heating unit. Their findings show that the plant may save a lot of money and lower its energy use and CO₂ emissions by a large amount. The study shows that well-planned energy-saving strategies can make industrial operations more sustainable overall(16).

An energy audit for Rafidia Hospital identified saving opportunities, which were heat recovery, which is achieved by rerouting and utilizing the wasted heat from the oxygen production compressors. This opportunity can save 25,351 NIS and 11.4 tons of CO₂ annually, with a very short payback period of 8 months. The second identified opportunity was applying overall boiler maintenance to the steam boiler, which will result in savings of 95,922 NIS and 41.4 tons of CO₂ annually, with a payback period less than 6 months. The third identified opportunity was adjusting and increasing the load factor of the washing machines(17).

The results revealed that through an appropriate energy management of healthcare buildings, it is possible to save up to 8.60 kWh/m² per year for buildings of less than 5000 m² (with no beds), which represents an expense of 1.55/m². In healthcare buildings larger than 5000 m²

(with beds), it was possible to save up to 6.88 kWh/m² per year, which represents an expense of 1.25/m²(18).

The study of energy consumption and cost in a large acute hospital in the subtropical city of Taipei, Taiwan. The result showed that air-conditioning is the major electricity end use, accounting for more than 50% of the total building energy consumed. Studies performed by Natural Resources Canada pointed out that the highest energy consumption was generated by the use of heating, lighting, and ventilation (19).

User occupancy is one of the key factors of an energy-efficient lighting control system. In conventional occupancy-based batch lighting control systems, when the presence of any user is detected in an area, a controller switches all or several corresponding lights on, and when the absence is detected for a given delay period, it switches off the lights. An experimental study shows that in such a system 20-26% energy can be saved compared with manual switching(20).

Inside a business building, each building service system's energy consumption is recorded in order to identify the system's weak points, unlock latent potential, and deliver a thorough energy audit analysis. The energy audit concentrates on equipment consumption, particularly air conditioning systems, electronic equipment, lighting systems, elevators, etc., by examining energy consumption. Wintertime field measurements of the indoor environment were conducted as part of the energy audit study. Measurements of the CO₂ concentration, relative humidity, and inside temperature were made during the field measurement. Office occupancy rate and the external climate are two major determinants of changes in overall energy consumption. Approximately 45% of the energy used is consumed by the air conditioning system. placing it in first place. The energy consumption of the lighting system is just less than 10%. Some measures are put forward to increase energy efficiency(20).

The use of solar panels to produce electric power and reduce electricity consumption: the electrical energy produced by photovoltaic systems produces 43% of the electricity used for the cooling and heating load for a six-story hospital with an area of 5000 square meters, and also from the indirect use of PV panels, 18% of the cooling load is saved. This amount alone is equal to 51% of the electrical energy produced by photovoltaic systems in the building(21).

Deepalakishmi studied the energy consumption in Ruby Hall Clinic in Pune, the result revealed that there is a reduction in the consumption by over 27% by installing of solar heating panels and a water treatment plant, utilizing waste heat recovery from air conditioning systems, optimizing indoor and street lighting, checking the air conditioning system, and implementing effective automation and control(19).

Energy efficiency in cooling systems is critical for maintaining safe and comfortable environments in hospitals. According to studies, using high-efficiency chillers, variable refrigerant flow (VRF) systems, and free-cooling techniques can dramatically reduce energy demand. Increasing insulation and incorporating renewable options like solar-powered cooling can make cooling systems more efficient. Reducing energy waste from overcooling is made easier with regular maintenance and modern control systems(11).

Although they use a lot of power, boiler systems are vital in hospitals as they produce steam and hot water. You may greatly improve overall efficiency by using modern condensing boilers and waste heat recovery equipment. The system's efficiency and the amount of heat lost can be enhanced by properly insulating and maintaining the storage tanks and pipelines. In addition to helping the planet, renewable fuels like biomass can help keep energy costs stable in the long run(22).

In an effort to help the Palestinian healthcare industry save energy, Da'as surveyed Palestinian hospitals and offered concrete recommendations. Total energy costs were reduced by 17% on average for hospitals. Among these, 14% went toward HVAC, 43% toward oxygen production equipment, 17% toward power factor correction, and 5% toward lighting systems(18) . After installing an energy management system, Jenin Governmental Hospital drastically cut down on power use and carbon monoxide emissions. Both the environment and the bottom line benefited from the use of solar power and the modernization of the HVAC and lighting systems. Recovering heat from oxygen compressors, maintaining a functional steam boiler, and enhancing laundry operations were three significant potentials for energy consumption reduction that an ASHRAE Type 2 energy audit at Rafidia Hospital uncovered. Focusing on steps that improve the performance of current equipment and implementing a systematic technique to track energy usage were mentioned as ways to promote efficiency and sustainability in the study.

With an emphasis on the HVAC system, this study will conduct an exhaustive energy audit of Nablus Specialty Hospital. Research has demonstrated that HVAC systems are among the most significant energy consumers in healthcare buildings, so this is where the attention is concentrated. Various fan coil units (FCUs) will have their air-movement capabilities evaluated using an Extech AN320 anemometer. All of the LED lights at the hospital will be examined to find out whether there is a way to reduce their energy use.

Both the solar water heater and the diesel boiler that the hospital now uses to heat water are inefficient. That is why the inquiry will lead to improved and novel approaches to replacing the water heater. To further assess the thermal efficiency of the building's doors and windows, a thermal camera will be utilized. The heat will stay in and the inside will be more comfortable as a result. Finally, in order to reduce energy use and partially fulfill its annual electricity needs, the hospital will construct a photovoltaic (PV) solar system.

Chapter Three

3. Methodology

3.1. Methodology

Discovering the actual energy consumption of Nablus Specialty Hospital and developing strategies to improve efficiency are the primary objectives of this study. Examining the electrical and energy systems of the hospital is the initial stage of the study process. Then, it consults the RET Screen Expert app to investigate renewable energy options and potential energy savings.

Several realistic approaches are followed in the research:

1. Pre-Audit Assessment

The following details were gathered by the researcher regarding the hospital:

- A synopsis of the hospital's annual fuel, water, and electrical expenses.
- An overview of the hospital's annual power, water, and fuel bills.
- Specifications and operating conditions for important energy-consuming equipment, including HVAC systems, pumps, boilers, lighting, and refrigeration.
- Detailed architectural drawings including construction information for the building's walls, windows, and doors.
- When it's open, how many people work there, and how various departments typically use the area.

2. Site Visit and Field Data Collection

To learn more, we visited the hospital:

- There were assessments of critical systems and locations.
- High-energy spots and possible trouble spots were located.

- Operational practices, and user behaviors that influence energy use were observed.

3. Analysis of Usage Data

We analyzed past utility data and field measurements to:

- Find systems that consume more energy than usual.
- Understand seasonal patterns and peak demand periods.
- Highlight the main areas with potential for energy savings.

4. Identification of Saving Opportunities

Based on our findings, we produced a set of Energy Efficiency Measures (EEMs).

Examples of technical work include modernizing equipment, improving control systems, and reinforcing the building. Among the operational stages are training staff and raising their awareness of energy consumption.

5. Economic and Environmental Evaluation

Each EEM was evaluated in terms of:

- Investment cost.
- Expected annual energy and cost savings.
- Simple payback period.
- Reduction in greenhouse gas (GHG) emissions.

6. Development of an Energy Efficiency Plan

We looked at the results. Made a plan to help Nablus Specialty Hospital use energy better. The plan had some goals that Nablus Specialty Hospital wanted to achieve. It also had some ideas for how Nablus Specialty Hospital could achieve those goals. It had some suggestions, for how Nablus Specialty Hospital could keep getting better at using energy.

3.2. Data Collection

The energy audit and the RET Screen modeling needed a lot of information to work properly. This is what we found out:

- **Historical Utility Data:** includes things like power bills, fuel expenses, and tariffs.
- **Facility Survey:** This is a check of the hospital. We look at the heat the ventilation and the air conditioning. We also check the lighting and the medical equipment. The hot water and the building structure are part of the check too. The hospital people thought about ways to save energy. They looked at the windows and the insulation. They also looked at things that are similar, to these. The hospital wants to make sure the heat, ventilation and air conditioning are working well. They want to save energy with the lighting and the medical equipment. The hospital building structure and the hot water are parts of the check.
- **Captured critical systems:** and control panels using thermal imaging and photographs to identify heat loss regions
- **Continuous Monitoring:** is when we use meters that are only attached for a short time to certain things that use electricity. These meters help us see things, like how much electricity's being used the voltage and the power factor. We can see all of this information as it happens. This way we can get an idea of how these things use electricity over time. The process involves measuring airflows, lighting levels.
- **Operational Data:** The typical daily and weekly operation cycles, the number of beds, and the occupancy rates.

To verify the accuracy of the data, we utilized measuring equipment provided by the Palestinian Energy and Natural Resources Authority. The data was entered into RET Screen Expert for analysis after collection. Here are a few examples of the tools:

- Energy analyzer and harmonics Meters.
- Lux Meter.
- Ammeter and Voltmeter.
- Thermal Imaging Camera
- Airflow Meter.

3.3. Technical and Economic Analysis

In the analysis step, both the capabilities of RET Screen Expert and more conventional engineering calculations are used.

- **Basis modelling:** Nablus Specialty Hospital built their baseline energy model using RET Screen. Energy usage history, equipment specifications, and local weather reports were all part of it.
- **Evaluation of Energy Efficiency Measures (EEMs):** We simulated each suggested EEM in RET Screen to estimate annual energy, cost, and greenhouse gas emissions savings.
- **Economic Indicators:** Simple payback period and Net present value (NPV). were calculated in RET Screen.

Chapter Four

4. General Description and Data Collection

4.1. General Hospital Description

Nablus Specialized Hospital is a private hospital in the city of Nablus. The hospital is made up of one six-story building that is 4,200 square meters in size. It has 54 patient beds and about 250 staff members. The hospital is open 24 hours a day, seven days a week. The Northern Electricity Distribution Company (NEDCO) is the only company that provides electricity to the facility, which runs 24 hours a day, 7 days a week. To ensure uninterrupted power during outages, the hospital relies on a 550 kVA generator to support critical loads. In 2024, its electricity consumption reached 1,026,225 kWh, costing 811,673 shekels annually.

4.2. Facility Layout

Figure 1 is the schematic diagram of Nablus Specialized Hospital, shows the general shape and area of the hospital. And the table 1 shows more details about the hospital layout description.

Figure 1

schematic diagram of Nablus Specialized Hospital

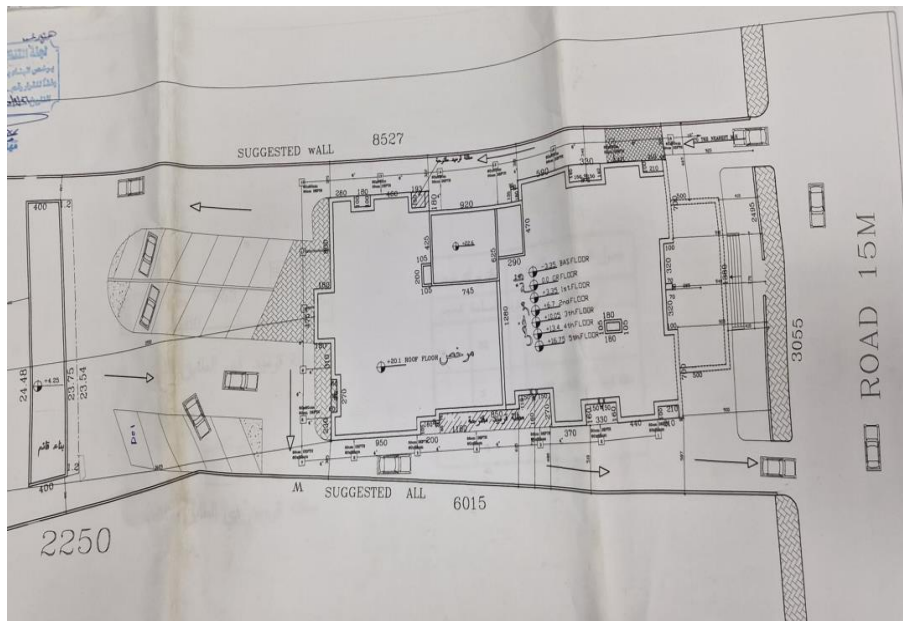


Table 1*Structural description of the hospital*

floor	Total area (m²)	content
Basement floor	700	Kitchen, laboratory, laundry, warehouse, CT scan
Ground floor	700	First aid and emergency, registration and accounting, pharmacy, cafeteria, outpatient clinics, 3 employee offices
First floor	700	Administration offices, operations and daily surgery, doctors' rooms
Second floor	700	Department of Obstetrics and Gynecology, Premature Babies
Third floor	700	ICU, Internal Medicine and Surgery, Patient Sleeping Rooms
Fourth floor	700	Ophthalmology Department, CCU Catheterization, Private Wing

4.3. Energy consumption in the hospital

The hospital uses the electricity from the grid (NEDCO) to operate different types of systems and appliances. And use diesel to operate the hot water boiler and to operate the standby generator when the electricity from the grid is cut off.

Table 2*Energy information of the hospital*

Energy source	<ul style="list-style-type: none"> ● NEDCO company ● Stand by diesel generator ● Diesel boiler for hot water
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Energy consumption in 2024	<ul style="list-style-type: none"> • Electrical energy: 1,026,225 kWh/year • Thermal energy: 7500 L/year
----------------------------	--

4.4. Bill Analysis

An essential part of any audit process is analyzing energy bills since it gives information about past energy usage, cost patterns, and times of peak demand. It is possible to find usage trends by looking at monthly electricity and diesel bills over a 12- to 24-month period.

4.4.1. Electricity Consumption

The average electricity consumption of the hospital is 85,519 kWh/month in 2024; Table 3 shows the electricity consumption in 2024. And it’s also showing the cost in shekels, and KVR.

Table 3

Electricity consumption of the hospital in 2024

Month	consumption (kWh)	cost (NIS)	KVR
Jan	80,948	64,028	14,615
Feb	77,363	61,191	12,458
Mar	76,202	60,274	15,770
Apr	67,903	53,710	14,296
May	74,510	58,934	11,418
Jun	108,263	85,626	9,002
Jul	96,486	76,309	8,285

Aug	106,455	84,192	10,840
Sep	103,664	81,987	9,408
Oct	83,004	65,651	8,702
Nov	68,047	53,825	16,253
Dec	83,380	65,952	15,573

Figure 2 illustrates how much electricity use each month of the year. People typically consume more electricity during the summer because air conditioning devices work for long time. This is especially true in inpatient rooms, intensive care units, and operating rooms, where maintaining the proper temperature is critical. However, there may be a slight increase during the winter, particularly if electric heating or ventilation systems are employed. The hospital under consideration consumed the most electricity in August, accounting for around 106,455 kWh. In April, it consumed the least amount of electricity, approximately 67,903 kWh. This modification occurred as the necessity for cooling altered. Figure 3 depicts how much electricity the hospital consumed each year from 2022 to 2025. Over the years, consumption has increased little.

Figure 2

Hospital Electricity Monthly consumption kWh in 2024

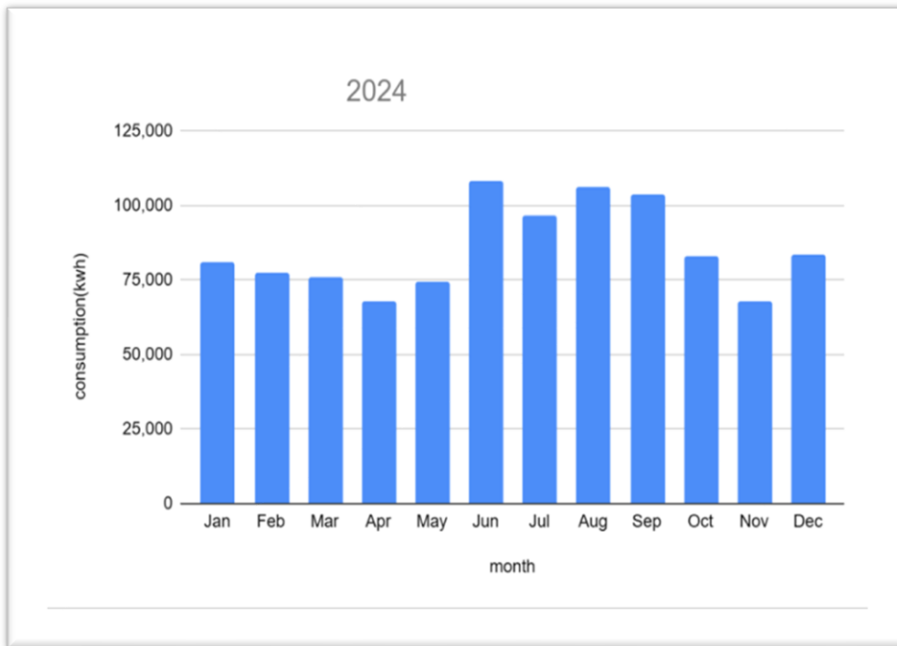
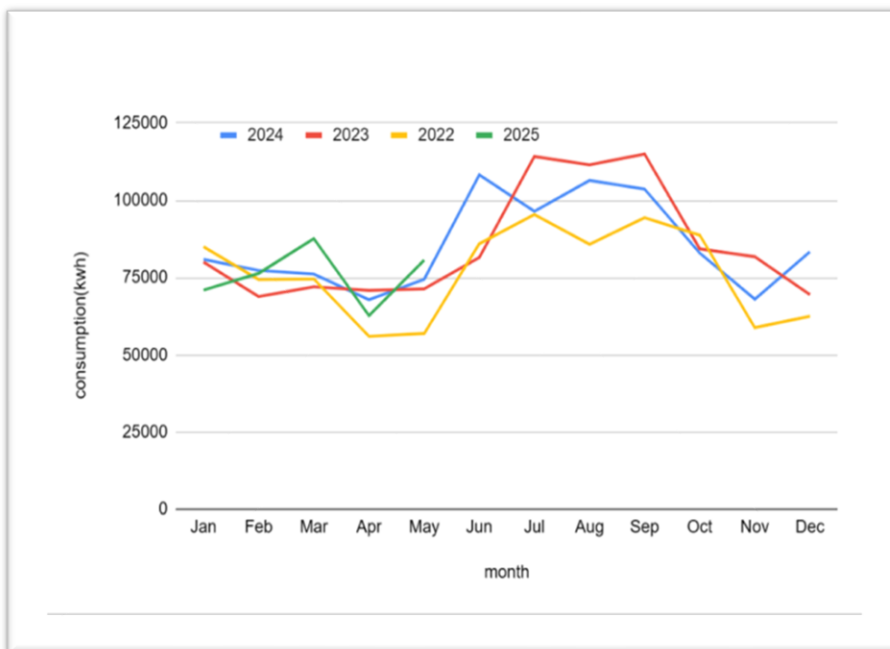


Figure 3

Hospital electricity consumption 2022-2025



4.4.2. Diesel and LPG consumption

The hospital uses diesel for a couple of things: it runs the boiler to make hot water and it powers the backup generator when the power goes out. The hospital uses diesel mostly for these two things. The boiler, at the hospital uses 450 liters of diesel each month on average to give the hospital hot water. The hospital uses diesel to provide the hospital with water. The table below shows how diesel fuel the hospital used in 2024.

Table 4

Diesel, LPG, and water consumption in 2024.

Description	Consumption	Cost (NIS)
Diesel consumption: 7500 L/year	<ul style="list-style-type: none">● 5400 L/year: Hot water boiler● 2100 L/year: Standby generator	35,100
LPG consumption	<ul style="list-style-type: none">● 156 Kg LPG: for cooking	9,073
Water consumption	<ul style="list-style-type: none">● 5,308 m³	69,011

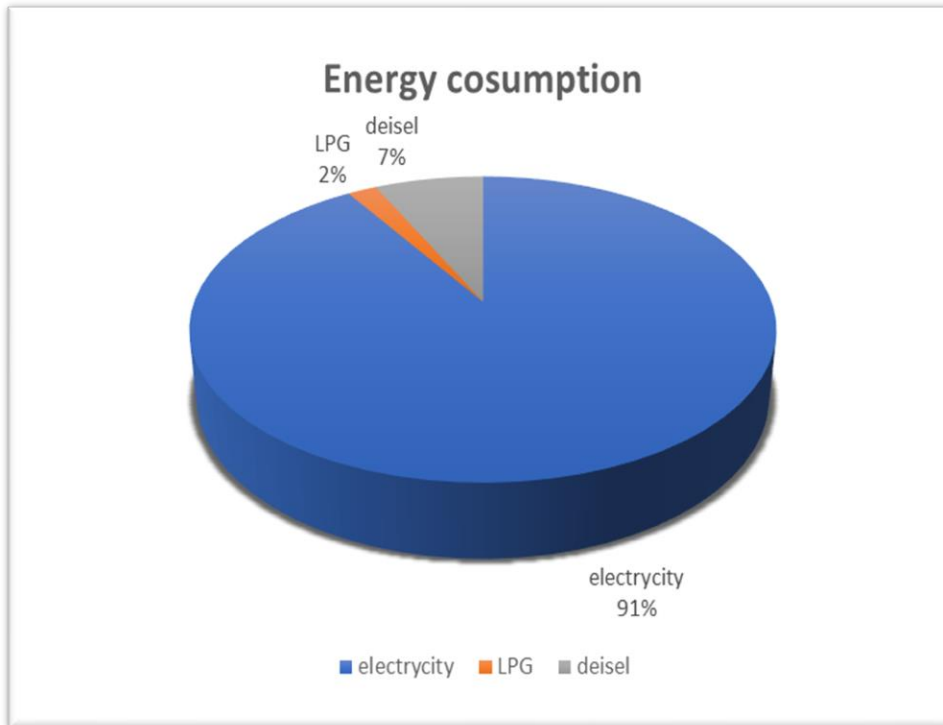
4.4.3. Total Energy consumption

Figure 4 shows that electricity is what the hospital uses the most for energy it is 91 percent of the total energy that the hospital uses. This is because the hospital is open all the time, twenty-four hours a day seven days a week. Electricity is the source of energy, for the hospital. Diesel is used a bit it is about 7 percent of the energy that the hospital uses and it is mostly used for backup systems. The hospital also uses LPG but it is a small part of the

energy mix it is only about 2 percent. Electricity and diesel and LPG are the types of energy that the hospital uses.

Figure 4

Energy consumption percentage in 2024



4.4.4. Total of energy utilization index (EUI)

1. Energy utilization index (EUI)

The Energy utilization index (EUI): is the total amount of energy consumption of a building—from all energy sources—divided by the building’s gross floor area, typically expressed in units like Btu /ft²/year or kWh/m²/year. It’s a recommended benchmark metric for all buildings(23).

$$EUI = \frac{\text{Total Energy Consumption (kWh)}}{\text{Building Area (m}^2\text{)}} \quad (1)$$

The Nablus hospital annual energy use is 1,128,088 kWh. {1,026,255 kWh (electricity) + 21,583 kWh (LPG) + 80,250 kWh (diesel)} = 1,128,088 kWh. With building area = 4,200 m²

$$EUI = \frac{1,128,088}{4,200} = 268.6 \text{ kWh/m}^2$$

The benchmark for atypical hospital is 200-400 kWh/m²/year, and less 200 kWh/m²/year for an efficient hospital. The Nablus hospital's EUI of 268.6 kWh/m²·year is more than the 200 kWh/m²·year limit for an efficient hospital, which means that the building is not energy efficient. This means that now is an excellent time to do an energy audit to lower the EUI and help the hospital run more efficiently.

Operational EUI (Per Bed or Patient Day)

$$EUI = Total\ Energy \frac{Consumption(kWh)}{Number\ of\ Beds \times Operating\ Days} \quad (2)$$

The Nablus hospital has 54 beds for 365 days that's equal to 19,710 bed-days.

$$EUI = \frac{1,128,088}{19,710} = 57.2 \text{ kWh/bed_day}$$

The calculated EUI of 57.2 kWh/bed-day for Nablus Hospital is in the usual range of 50–100 kWh/bed-day. This means that the hospital's energy use is reasonable and quite efficient on a per-bed basis.

4.5. Energy Balance

The first step in setting efficiency goals is to analyze how energy is being used across the hospital. By finding departments or systems with high or low energy consumption, the audit can focus on the areas that offer the greatest potential for savings. This way we can make sure that we are doing things that will give us the results. We want to focus on the things that will really pay off for our operations.

4.5.1. Energy Analyzer Data for Main Distribution Board

An energy analyzer was installed on the hospital’s distribution board for three days. Power consumption patterns, peak demand periods, and the power factor were monitored during this period. The obtained results are presented in Figures 5 and 6, while the complete data are provided in Appendix E.

$$\text{True Power Factor} = \text{Displacement PF} \times \text{Distortion PF}$$

$$\text{Displacement Power Factor} = \cos(\varphi)$$

$$\text{Distortion Power Factor} = \frac{1}{\sqrt{1 + (\text{THD})^2}}$$

Based on the analysis of the power analyzer data, the true power factor was found to be directly available in the recorded measurements. Therefore, no additional calculation was required. The obtained true power factor profile is shown in Figure 6.

Figure 5

The load curve for main distribution (KW) for selected period from 6 July to 8 July.

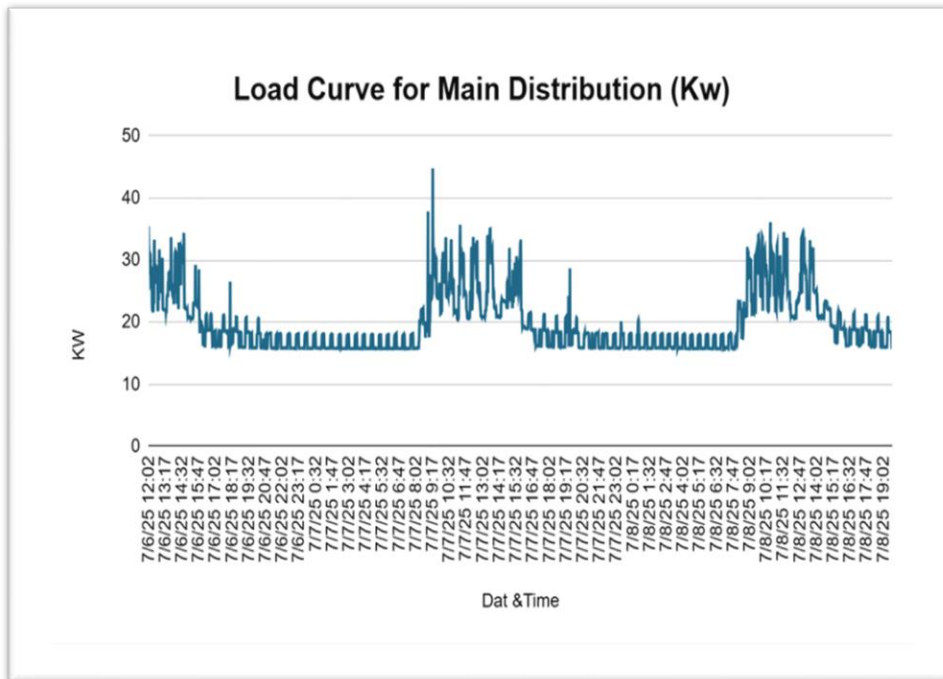
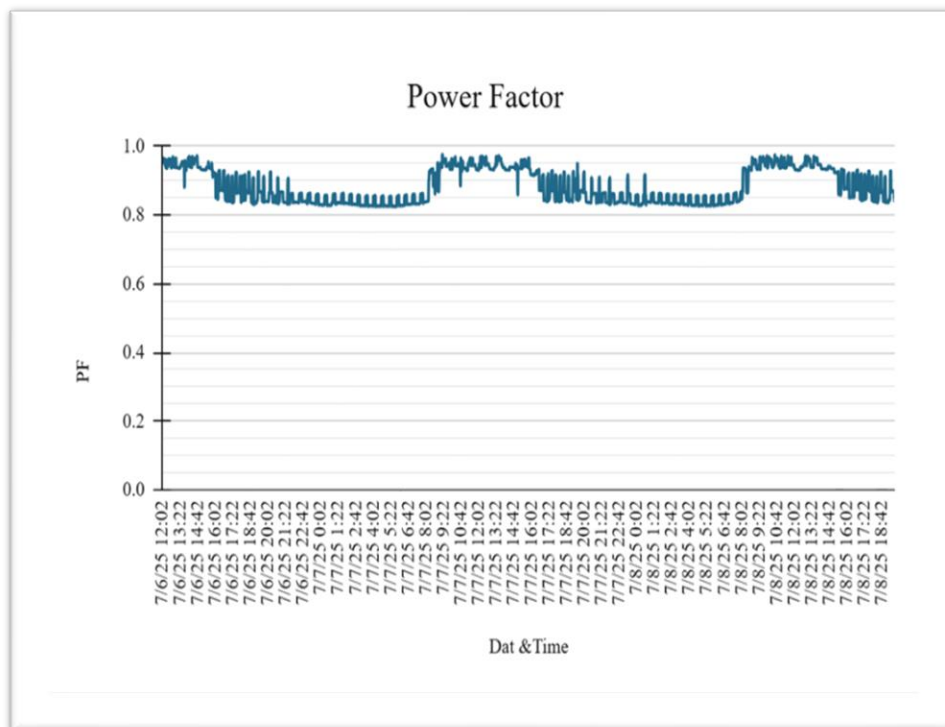


Figure 6 shows that the power factor changed between 0.82 and 0.98 during the measurement period. If we look at the graph, we can see that the power factor drops after around 15:00 every day. This happens because the hospitals power usage changes when the office staff and outpatient clinics finish work. At this time the real power, which is measured in kilowatts goes down. This is because things like lights and office equipment are turned off or used less. However, the big machines like cooling systems, pumps and ventilation equipment keep running but they use a little less power.

The capacitor bank that is being used helps to balance out the power factor. It does not change when the power usage goes down. So, the power factor is lower because the big machines are still using a lot of power even when the real power is lower. The power factor is lower in the graph because of this. The power factor is what we are looking at. It is affected by the power usage of the hospital and the power factor is an important thing to consider when looking at the hospitals power usage and the power factor changes, during the day.

Figure 6

True PF for main distribution Board



The hospital should look at the measured data to make sure the power factor stays steady all day. This is important when the load levels change. If the hospital uses a multi-step capacitor system instead of the fixed capacitor bank the reactive power will change when the load changes. This will help keep the power factor the same. Reduce the losses and penalties that happen when the power factor is low. The hospital should also check the machines, like chillers and pumps. These machines can add a lot of power when it is not needed. The hospital should check the hospitals power requirements regularly to make sure everything is working properly. The hospitals power factor is important. The hospital should make sure it stays steady.

4.5.2. Chiller and Air conditioning system

The hospital uses a York air-cooled chiller, which's like a heat pump to keep itself cool. This chiller is the way the hospital controls its temperature. The hospital also has units, called decentralized split units that help with cooling in specific areas.

The details about the chiller are in Appendix B. It shows all chiller Calculations and the Chiller nameplate. A chiller was identified from the nameplate as a YORK YMPA0230PE50 Air-Cooled Chiller / Heat Pump operating on R410A refrigerant with an electrical supply of 400V / 3Ph / 50Hz. The nominal operating current was indicated as 139 A at 400V, while the maximum current was indicated as 166.4 A at 400V. The chiller's total yearly energy usage is 352,000 kWh/year.

Based on the nameplate data, the nominal electrical input was estimated using the three-phase power equation

$$P=\sqrt{3}\times V\times I\times PF$$

Where a supply voltage of 400 V, a nominal current of 139 A, and an assumed power factor of 0.85 were used

$$P=1.73\times 400\times 139\times 0.85/1000$$

$$P=81.9\approx 82 \text{ KWH}$$

The nominal electrical input was estimated at approximately 82 KW. The operating hours of the chiller were estimated based on the conducted site visits and field measurements. These measurements were reviewed and compared with the required indoor temperature conditions necessary to maintain patient comfort, in addition to the actual operating schedules of the clinics and office areas. Based on this assessment, the chiller operating hours were estimated at 2,800 hours during the summer season and 1,500 hours during the winter season, resulting in a total annual operating duration of approximately 4,300 hours/year. The annual energy consumption was calculated at approximately 229,600 kWh/year for summer operation and 123,000 kWh/year for winter operation. Therefore, the total annual energy consumption was estimated to 352,600 kWh/year.

The split units were also used to cool different zones within the hospital, and their annual energy consumption was estimated at approximately 95,971 kWh/year all calculation in appendix B.

4.5.3. lighting system

Most of the hospital's lights are 45-watt LEDs, and 18-watt LED lights in stairwells. Additionally, neon LED lights are installed in the bathrooms. The total amount of energy used by lighting system was estimated based on the total number of lamps throughout the hospital and their respective operating hours; the total amount of energy used by lights is about 136,537 kWh/year (all in Appendix B).

4.5.4. Laundry and Sterilization

This area has three washing machines, each with a 20 kg load and 3KW power rating, and one 6KW dryer, each running for around 12 hours a day. There is also a sterilization unit that runs for about 10 hours a day. The entire amount of energy used for laundry and sterilization is 75,000 kWh per year (All in Appendix B).

4.5.5. Medical Devices

Medical equipment are important for hospitals to run, and depending on the type, hours of operation, and technology, they can use a lot of energy. A clamp meter is used to find out

how much power a device uses and how long it runs; the total energy use is 194,760 kWh/year (All in Appendix B).

4.5.6. kitchen

The hospital kitchen is another department that uses a lot of energy, it works for long hours every day to make meals for patients, staff, and visitors. It is equipped with a range of heavy-duty appliances that contribute significantly to overall energy use. After measuring and calculating all devices, the estimated annual consumption is 52,410 kWh (All in Appendix B).

4.5.7. Pumps in the Hospital

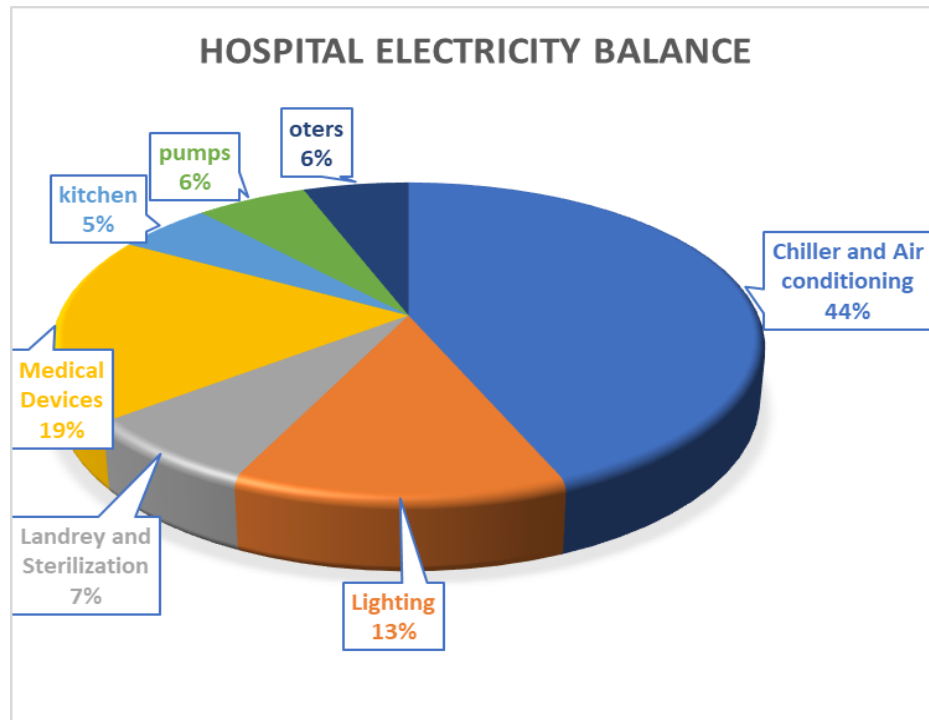
The hospital consumes a lot of energy since it has so many different types of pumps. These pumps utilize around 61,200 kWh of electricity each year (All in Appendix B).

4.6. Electrical Energy Balance

Figure 5 depicts how different areas of the hospital use electricity. Chillers and air conditioning consume the greatest energy, accounting for approximately 44% of all power utilized in a year. Medical devices are the second-largest user, accounting for around 19%. lighting systems about 13%, and 7% are laundry and sterilization systems. The kitchen added 5% and the pumps 6%. About 6% of the total is comprised of other categories. The analysis reveals the proportion of the hospital's overall energy use that may be attributed to the HVAC systems.

Figure 7

Hospital Electricity Balance



4.7. RET Screen Expert

Natural Resources Canada (NR Can) developed RET Screen Expert, a sophisticated software application for assessing energy projects and strategizing for sustainability. Research on the environmental, social, and economic impacts of energy efficiency and renewable sources is a common use case. Users are able to assess the present energy situation and offer recommendations for improvements using the software, subsequently estimating the potential savings in energy, finances, and greenhouse gas emissions resulting from these changes.

A notable attribute of RET Screen is its cohesive methodology. It consolidates data on meteorological conditions, equipment efficacy, expenditures, and the financial status of the company into a unified model. This facilitates comprehension of how various design or operational choices can influence a project's energy efficiency and profitability. RET Screen

features an extensive international library of climate data and technological alternatives, enabling users to precisely model projects globally.

RET Screen is a widely utilized instrument for both study and practice, owing to its reliability and user-friendliness. It has been utilized by colleges, government entities, and corporations to evaluate building retrofits, renewable energy systems, and energy management methods. The RET Screen is an appropriate framework for evaluating the energy efficiency and financial feasibility of suggested alterations at Nablus Specialty Hospital in this study, facilitating a clear and quantifiable connection between energy metrics and economic results(24).

To ensure that the RET Screen simulations accurately represented the energy profile of Nablus Specialized Hospital, certain assumptions and input parameters were meticulously formulated. The model was predicated on regional weather conditions. To determine the seasonal impact of the weather on the heating and cooling requirements of the hospital, we analyzed climatic data for Nablus, Palestine, which included variables like humidity, temperature, sun radiation, and wind speed.

A wealth of data regarding the building's electrical loads is located within. The lighting system was developed with the primary considerations of light types, power consumption, and daily on/off duration in mind. A variety of electrical and medical instruments were also included in the reproduction. A power rating and specific use plan were assigned to each hospital component to demonstrate its functionality.

Maintaining a pleasant temperature for patients is of the utmost importance in healthcare facilities. The RET Screen was therefore provided with the AC and chiller sizes, performance coefficients, and seasonal runtimes. This allowed the model to determine the annual heating and cooling needs of the hospital.

We took a financial and technical look at our energy consumption. By comparing power and gas prices in various regions, the study sought to understand the impact of energy consumption on the economy. It is now possible to estimate the effort and time required to calculate potential savings and payback periods for various efficiency projects(25).

The financial evaluation of the project was carried out using the following financial indicators: Simple Payback Period (SPB), Internal Rate of Return (IRR), Net Present Value (NPV), and Yearly Cash Flow. These indicators are integrated within the RET Screen software, which automatically calculates them based on the project input data, including the initial investment, operating costs, annual savings or revenues, project lifetime, and discount rate. The equations used for these indicators are as follows (26)(27):

- Simple Payback Period

$$SPB = \frac{\textit{Initial Investment}}{\textit{Annual Savings}}$$

- Net Present Value: NPV represents the difference between the present value of future cash flows and the initial investment.

$$NPV = \sum [CF_t / (1 + r)^t] - \textit{Initial Investment}$$

Where CF_t represents the cash flow in year t , r represents the discount rate, and t represents each year within the project lifetime.

- Yearly Cash Flow: Yearly Cash Flow represents the net annual financial benefit generated by the project after deducting annual operating costs from annual savings or revenues.

$$\textit{Yearly Cash Flow} = \textit{Annual Savings or Revenues} - \textit{Annual Operating Costs}$$

Chapter Five

5. Data Analysis and Problem Identification

5.1. Data analysis

Because it identifies actual issues using numbers instead of assumptions, data analysis is a crucial component of energy management.

Lighting, HVAC, sterilization, and medical equipment all require a steady flow of energy, which hospitals must have. Total energy expenses alone do not provide a complete view of efficiency.

You can find patterns of consumption and areas of energy waste by thoroughly examining data on energy use, the efficiency of equipment, and the operations of departments. You can use this data to set reasonable goals, select feasible development projects, and predict outcomes. With the RET Screen, it's much simpler to model present energy consumption and make educated guesses about potential savings in both costs and emissions.

5.2 Heating, Ventilation, and Air Conditioning System

The hospital has a heating and cooling system. This system has two machines called chillers that make the air cool. These chillers help cool the fan coil units. The hospital also has split cooling units in many places.

Observations:

- We looked at the airflow from the Fan Coil Units during the site study. We used an Extech AN320 anemometer to check the airflow from the Fan Coil Units. The air was not moving fast as designed value, which could mean that the units aren't working as well as they should or that there are problems like clogged filters, fans that aren't working properly, or mechanical problems. In several units, the measured airflows were lower than the design values. This could mean that the filters are clogged, the ducts are leaking, or the

machines aren't working as well as they should. The Fan Coil Units will cost 278,907 NIS, per year to run (Appendix B).

- Several split units were operating at set temperatures lower than 20°C. This is not good for hospitals. They use energy and might make patients feel cold. The best practice for hospitals is to keep the temperature between 24°C and 26°C. The split unit costs 75,913 NIS every year. The whole HVAC system costs 354,820 NIS per year (table 2 in appendix B).

The airflow speed that we measured with an anemometer is given in Cubic Meters per Minute. We use some equations to figure out the airflow in Cubic Meters per Hour for the Fan Coil Units. We then compare this to the value that was designed for the Fan Coil Units, and find out how different it is, from the designed value (all in Appendix C)(28).

$$CMH = CMM \times 60 \quad (3)$$

$$Performance \% = \frac{Measured\ CMH}{Design\ CMH} \times 100 \quad (4)$$

5.3. Lighting System Observation and Energy Management

During my visit to the hospital, I noticed that the current lighting system is not energy-efficient.

- The corridor lights are always on even when there are no people around which wastes electricity.
- In rooms the lights are always on at full brightness even when less light is needed, like during the day.
- We measured the levels in different parts of the hospital and found that some areas, like hallways and offices were too bright.

The hospital spends 108,000 NIS per year on lighting. To save energy we suggest installing motion sensors in areas with traffic using dimming systems that adjust to natural light in patient rooms and offices and adjusting the lighting levels to meet standards, such as 100–200 lux for corridors and 300–500 lux, for offices (Appendix B).

These changes will help reduce electricity consumption while providing the amount of light for workers and patients.

5.4. Hospital Hot Water System Assessment

- During the field tour, we learned that the hospital uses a diesel boiler to heat water for both patients and visitors every day. The annual cost of fuel for the boiler is around 35,100 NIS, or 5,400 gallons. It is difficult to determine the technical features and efficiency of the present boiler due to its age and lack of a nameplate. The annual hot water demands of approximately 796,000 liters of the hospital can be met by heating the water to 60°C using the boiler.
- The unclean, broken, or nonexistent panels on the roof were preventing the solar water heating system from performing adequately. Because of this, its water-heating efficiency decreased.

5.4.1 Evacuated Tube Collectors

A viable option for harnessing solar energy for water heating is the Evacuated Tube Collector (ETC). No matter how chilly or dark it becomes, the system will still function well because to the vacuum layer inside each tube that traps heat. ETCs outperform conventional flat-plate solar collectors in terms of heat absorption and heat loss. Because of this, they are more dependable and productive throughout the year. They're sturdy and low-maintenance; you can simply replace a broken tube. Furthermore, the system may be easily scaled, whether for a little dwelling or a large hospital. By using ETC systems, facilities can cut down on diesel or electricity use for heating water, saving money and reducing harmful emissions at the same time.

Calculation of solar water heating system (ETC) (29):

Let's assume hot water temperature to be 60°C, as it's the ideal hot water. For human usage, normal water temperature is 26°C; the temperature difference(ΔT) is 34°C.

Available space on the roof of the hospital building = 30 m².

Specific heat of water: 4.186 KJ/Kg C

Mass of water: 2100 L/day.

Efficiency of ETC is 60%(30) .

Rad is 5.5 kWh/m²/day(31).

Energy balance equation

$$m * cp * \Delta T = Efficiency * average radiation * Area of collector$$

$$Ab = \frac{m * cp * \Delta T}{\eta * Rad} \quad (5)$$

After all unit conversation and then putting the value in the above equation, we get the following:

Absorbers are of evacuated tube collector solar water heaters.

$$ETC \quad Ab = \frac{298880}{11880} = 25 \text{ m}^2$$

The absorber area of evacuated tube collector solar water heater is 25 m²

If we have the datasheet (Apricus ETC-20):

Aperture (effective) area: $\approx 1.89 \text{ m}^2$

Tubes per collector: 20

Typical daily thermal output: $\approx 3 \text{ kWh/day}$ per 1.89 m² (in good sun conditions)

The number of collectors needed $N = \frac{25}{1.89} = 13$ collectors.

5.5. Evaluation of Thermal Loss via Doors and Windows

During the energy audit, we noticed that

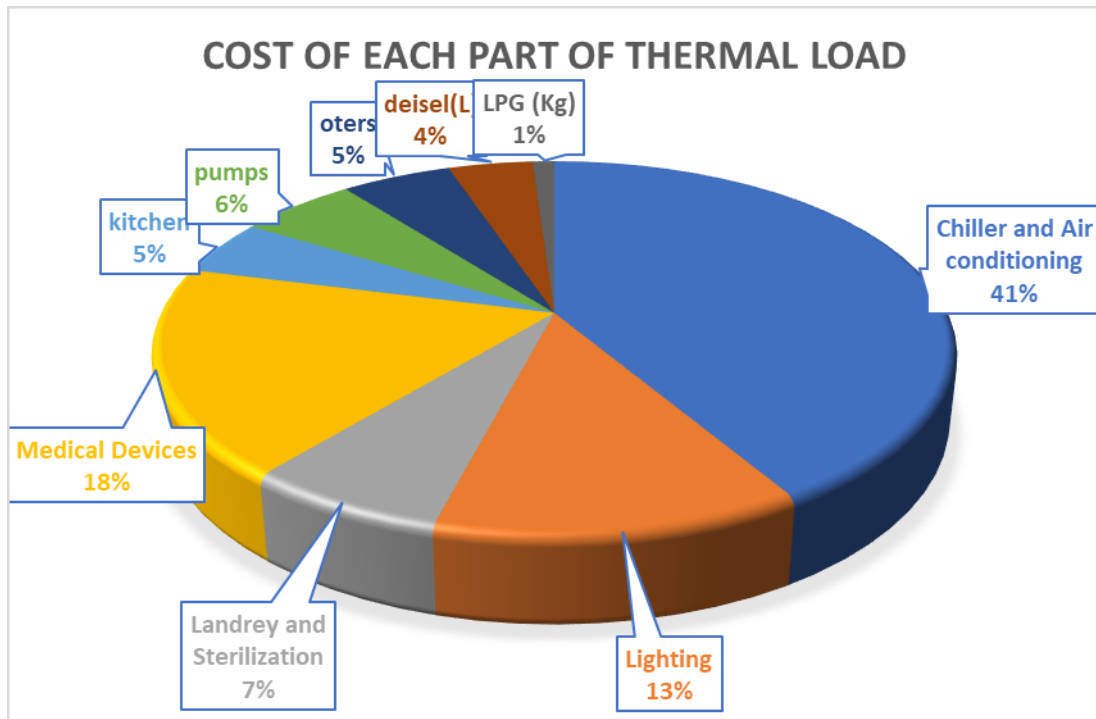
- The hospital's main entrances didn't have air curtains (air breakers). Because of this, outside air was constantly flowing in and cooled air was escaping, which caused noticeably higher temperatures near the entrances. The problem was really easy to see in the camera pictures we took. A lot of people including patients and workers and visitors go in and out of these doors all day. The doors are often left open. This makes things worse. The air conditioning systems have to work a lot to keep the inside of the building at a comfortable temperature. This means the air conditioning systems use energy and it is harder, on the equipment. The thermal camera images really showed us what was happening with the air conditioning systems and the doors.
- The thermal pictures showed that the windows of the building were really warm. A lot of the building's windows are the kind with only one pane of glass which probably makes the inside of the building feel even hotter. This is especially true in the director's office at the building because the windows, at the medical director's office take up a lot of space.

5.6. Summary of Annual Thermal Costs by Sector in 2024

The hospital uses a lot of money for thermal energy . It spends around 811,679 NIS every year for electricity. The hospital spends most of this money on chillers and air conditioning. This costs around 354,820 NIS. That is half of the total money the hospital spends on energy. Medical equipment is another expense for the hospital. The hospital spends around 154,055 NIS on equipment. The hospital also spends money on lighting. Lighting costs the hospital around 108,001 NIS. The hospital laundry and sterilization cost around 59,325 NIS. The hospital spends around 48,409 NIS on pumps. The hospital kitchen is also a user of energy. The hospital kitchen costs, around 41,456 NIS. In addition, diesel costs about 35,100 NIS/year, while LPG has the lowest contribution, with an annual cost of 9,073 NIS. Overall, the results show that chillers and air conditioning systems are the main contributors to the hospital's annual energy cost (Table 4 in Appendix C).

Figure 8

Summary of cost percentage for thermal consumption by sectors



Chapter Six

6. Energy Saving Opportunities

6.1. Energy auditing Results and Discussion

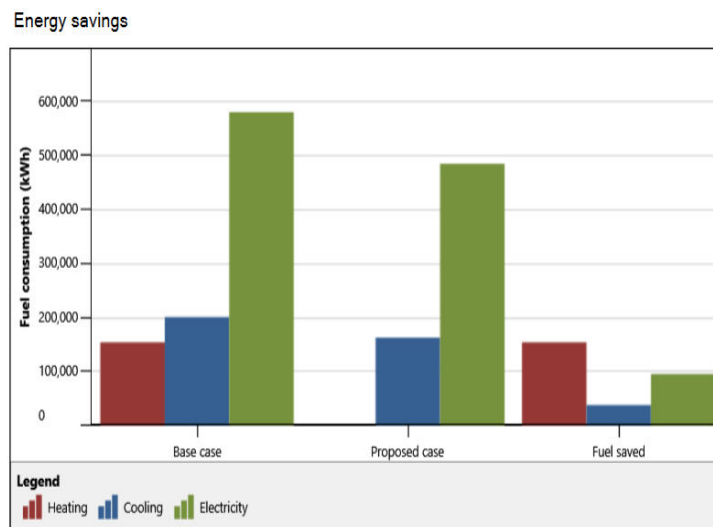
RET Screen is used to check saving energy. It looked at the equipment. How long it was on and how often it was used. The hospital was open for a time and used a lot of energy. When they made some changes to make things more efficient like getting lights and a better cooling system the hospital used less energy.

The RET Screen analysis showed that the hospital would save money if it made these changes. Figure 9 shows that the new plan would save a lot of money compared to what the hospital was doing. The RET Screen analysis showed that making a simple change can make a big difference and save the hospital a lot of money.

Figure 9

The energy saving of Base and proposed case of the hospital

Energy savings | Fuel summary



If we look at Figure 9, we can see that the hospital saved 100 percent of the heating equipment and also saved 18.9 percent of the cooling equipment in the proposed case. This means the

hospital saved a lot of money by saving energy with the heating equipment and the cooling equipment.

6.2. HVAC System

The hospital's heating and cooling system uses a lot of energy. It uses 44 percent of the total electricity. This costs around 354,820 NIS every year. The hospital has a cooling system that uses a YORK air-cooled chiller. This chiller uses a lot of energy around 352,600 kWh per year. The hospital also has heating and cooling split units. These units consume about 95,971 kWh per year to run. Because the heating and cooling system uses much energy, so making it more efficient is the best way to reduce energy use and save money. The HVAC system is a deal. Improving the HVAC system can make a difference.

1. To get the fan coil units working at their best: you need to make sure they are running properly. A lot of the fan coil units are not moving much air as they should be. This is probably because the filters are clogged. The fan coil units will work better if you clean and change the filters. You should also seal any leaks. This will help the fan coil units work the way they are supposed to. The fan coil units will then be able to perform at their best. With these adjustments, the chiller's energy consumption might be reduced by 5-8% (32).
2. Improving the chiller operation: The hospital has one main chiller used for cooling and a second chiller kept as a backup. To make the active chiller more efficient, install variable speed drives (VSD) on the compressors and condenser fans, adjust the control settings to optimize performance at partial loads, and perform regular maintenance tasks such as cleaning the coils and inspecting the chiller. These changes can reduce the energy consumption of the chiller by 10 to 15%(32) .
3. Turn the split unit's temperature up or down. In order to save energy, some split units are programmed to extremely low temperatures, like as 20°C, which is far too cold for hospital rooms. Resetting these to a more appropriate range of 24–26°, this reduces their energy consumption by 10 to 12% (32).

4. Set up a Building Management System (BMS): connect chillers, AHUs, FCUs, and split units to a smart BMS so you can monitor them, schedule them, and match their loads in real time. To cut down on unnecessary work during off-peak hours, use automatic night setbacks and demand-based cooling strategies. This could cut HVAC energy use by 8 to 10% (32).

According to the results of the RET Screen simulation including in Table 5, updating the hospital's cooling systems can be very good for the environment and for how much energy it uses. The central chiller system is expected to save about 82,344 kWh each year, which is equal to \$19,694 in lower costs. The payback period is only about 2.4 years. Enhancing the split unit systems is estimated to save an extra 8,176 kWh per year, which is about \$7,347, and achieve payback in just 1.8 years. By taking these measures, we can avoid releasing about 63.7 tons of CO₂ into the air each year and save over 90,520 kWh of energy. The hospital's activities would be more efficient and less harmful to the environment if this were to happen.

Table 5

HVAC Energy-Saving Opportunities, Cost and Payback

Energy-Saving Measure	Estimated Investment (\$)	Estimated Savings (kWh/year)	Estimated Savings (\$/year)	Payback period
Improving the chiller system	46,511	82,344	19,694	2.4
Improving the split unit	14,534	8,176	7,347	2
Total	61,045	90,520	27,041	2.2

* The investment cost was estimated based on local market prices.

6.3. Lighting system

Approximately 136,537 kWh, or 13% of the hospital's annual electricity demand, and 108,001 NIS are incurred by the lighting system. We identified three primary areas where energy efficiency might be enhanced:

1. Stairwell occupancy sensors can reduce unnecessary illumination when no one is present.
2. Another recommendation is to install dimmer switches in all of the administrative offices and patient rooms. Thus, the amount of light can be adjusted according to the level of activity and the amount of natural light.
3. Adjusting the light settings such that they adhere to the guidelines without being overly intense.

A RET Screen simulation included in table 6 found that the planned lighting modifications, which include occupancy sensors in common areas, controls to lower the brightness of individual rooms, and adjustments to meet regulations, should save 37,715 kWh of energy per year, or \$8,675. If the hospital could reduce its annual CO₂ emissions by 26.6 tons, it could meet environmental sustainability standards and recoup its costs in around six months.

Table 6

Lighting Energy-Saving Opportunities, Cost and Payback

Energy-Saving Measure	Estimated Investment (\$)	Estimated Savings (kWh/year)	Estimated Savings (\$/year)	Payback period (RET Screen)
Install occupancy sensors in corridors and Recalibrate illumination levels to standards	1,300	25,229	5,803	0.2

Implement dimming controls in patient rooms	942	9,543	2,195	0.4
Install occupancy sensors in stairs and Recalibrate illumination levels to standards	581	2,943	677	0.9
Total	2,823	37,715	8,675	0.5

* The investment cost was estimated based on local market prices.

6.4. Boiler and Solar Water Heater

Boiler and Solar Water Heating System Savings Opportunities:

1. Replacing the old boiler with a new one: Replacing the old boiler with a new one 90% efficiency instead of the old one with 60% efficiency.
2. Install Evacuated tube collector (ETC) solar water heater.

According to our calculations, the facility can be adequately heated with a 25 m² ETC system. As a result, the boiler acts as a backup and diesel is completely unnecessary. 13 collectors covering 25 m², a 2,500 L thermal storage tank, circulation pumps, and complete installation are included in the evacuated tube collector (ETC) solar water heating system, which costs approximately \$39,393.

According to a RET Screen simulation included in table 7, installing an ETC system in place of the existing boiler will result in annual energy savings of roughly 59,486 kWh, or \$19,952. By reducing CO₂ emissions by 35.7 tons annually, these modifications will assist the hospital in achieving its sustainability objectives. The measures have a payback period of only 2.8 years, so they are good for both the environment and your cash.

Table 7*Boiler and Solar Water Heating System Energy-Saving Opportunities, Cost and Payback*

Energy-Saving Measure	Estimated Investment (\$)	Estimated Savings (kWh/year)	Estimated Savings (\$/year)	Payback period
Boiler replacement	11,627	22,181	3,635	3.2
ETC system	39,393	37,304	16,317	2.4
Total	51,020	59,486	19,952	2.8

* The investment cost was estimated based on local market prices.

6.5. Thermal Loss via Doors and Windows

The hospitals glass doors do not have air curtains. They are often left open for a time. This lets a lot of heat escape from the hospital. The windows are likewise made of single-layer glass, which does not retain heat particularly effectively.

An evaluation found three main opportunities to improve thermal losses through doors and windows.

1. Installing plastic door curtains at emergency and primary hospital entrances. Air curtains create a continuous flow of air that acts as an invisible wall, preventing the air within and outside from mixing. This easy and inexpensive solution can assist to keep temperatures steady, making the building more comfortable, and minimize the stress on the air conditioning systems. In many hospitals and public buildings, air curtains will save around 10% of energy used for cooling and heating.

2. Replace single glass windows with double glass ones to enhance thermal performance.
3. Add insulation to the roof to keep even more heat from escaping through the building envelope.

The results of the RET Screen simulation included in table 8 show that installing a vent door air curtain and plastic curtains, along with planned building envelope improvements like replacing single glass windows and adding roof insulation, can greatly improve energy performance. The energy-saving measure can save 72,072 kWh annually, which is \$16,577 in cost savings, and it is estimated to cut CO₂ emissions by 63.4 tons a year. This measure will pay for itself in about 2 years.

Table 8

Thermal loses Energy-Saving Opportunities, Cost and Payback

Energy-Saving Measure	Estimated Investment (\$)	Estimated Savings (kWh/year)	Estimated Savings (\$/year)	Payback period
Install vent door air curtain, plastic curtains	1,351	103,888	40,173	2
Replace single-glass windows	34,883			
Add roof insulation	40,697			
Total	80,281	103,888	40,173	2

* The investment cost was estimated based on local market prices.

6.6. Installing PV system

There is a 400 m² area behind the hospital that is now just a parking lot. A PVsyst simulation shows that turning this area into a modern, solar-powered parking lot with a 63 KWp

photovoltaic system could greatly improve both its functionality and its environmental impact. The system is expected to produce about 87,441 kWh per year, which is about 10% of the hospital's total electricity needs of 1,026,225 kWh. With an investment of \$49,419 and a payback period of only 2.5 years, this would save about \$20,080 a year. The PV system would also stop about 53 tons of CO₂ from getting into the air each year, reducing the hospital's carbon footprint while providing shaded, more comfortable parking for staff and visitors and showing a strong commitment to taking care of the environment table 9 included the PV system results.

Table 9

Installing a solar power system: Estimated Cost, Savings, and Payback

Hospital consumption (KWH)	1,026,225
Proposed photovoltaic system (KWp)	63
PV generation (kWh/year)	87,441
PV Contribution (%)	10
PV saving (\$/year)	20,080
PV investment (\$)	49,419
Payback period (year)	2.5

* The investment cost was estimated based on local market prices.

6.7. Greenhouse Gas Emissions

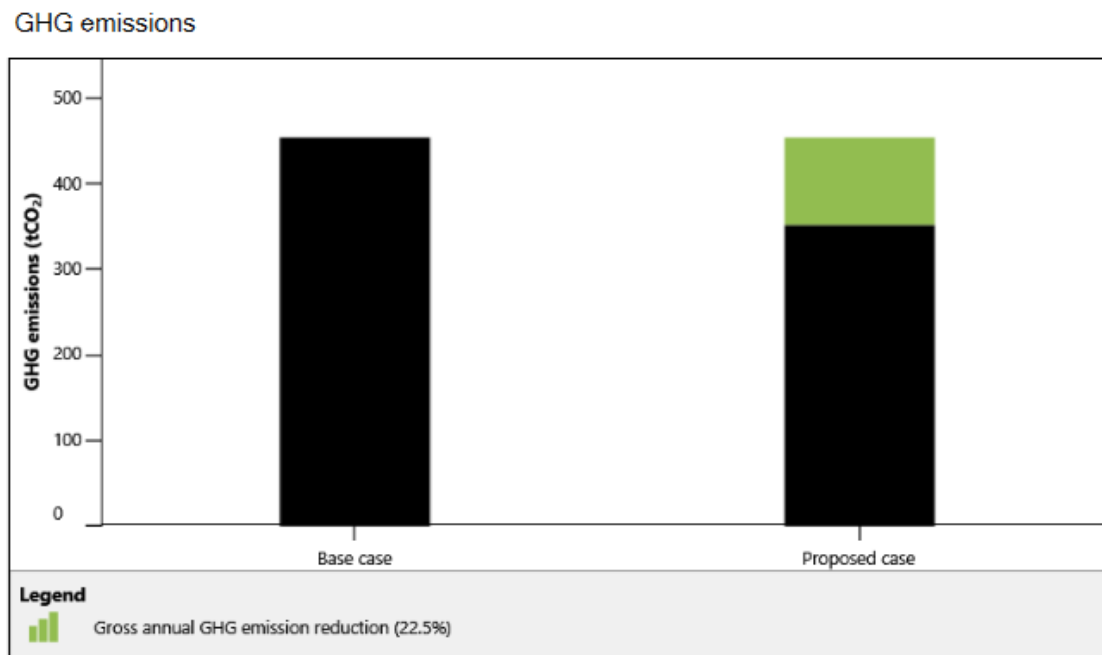
Making the suggested changes significantly improves the emissions analysis done in RET Screen. Annual greenhouse gas emissions for the base case were 455 metric tons of carbon dioxide (CO₂). The proposed case, on the other hand, said that this number would go down to 332 tons of CO₂. This means that CO₂ emissions will go down by 102 tons per year. To put this in perspective, the amount that has been cut is the same as taking more than 18 cars and light trucks off the road every year. These results show not only that the proposed energy measures will save the hospital money, but also that they will have a big impact on the

hospital's environmental footprint. Figure 10 from RET Screen shows the difference in CO₂ emissions between the base case and the proposed case.

Figure 10

Hospital annual GHG reduction emission

GHG emissions



6.8. Total Saving

Using all of the suggested energy-saving measures together on HVAC, lighting, boiler and solar water heating systems, building envelope improvements and a photovoltaic system is expected to greatly improve performance. These steps are expected to save about 379,050 kWh of energy each year, which is 30% less fuel used. This will save about \$115,921 a year in costs. The total amount of CO₂ emissions avoided is about 102 tons per year. The hospital has set a goal of becoming more energy efficient, environmentally friendly, and environmentally conscious, and this is a major step in that direction.

Table 10

Total Energy Saving

System Saving opportunities	Fuel Savings (kWh/year)	Estimated Savings (\$/year)	Saving %	saving CO2 (ton)
Total	379,050	115,921	30	102

6.9 Benchmark Analysis

The hospital consumes 258 kWh/m²•year of energy, which is 17% higher than the average for similar hospitals, which is 220 kWh/m²•year, as revealed by the RET Screen benchmark research. It is evident that the baseline performance is inadequate for this particular facility. The hospital's energy use will drop to 207 kWh/m²•year if these suggestions are implemented. This is around 10% more than what is needed. You may also notice this shift in the chart for the RET Screen plan. The operating point is not the same as the baseline scenario; it evolves toward the 19% target along a route that will eventually lead to operations with net-zero and positive energy. Even while the current situation doesn't lead to a net-zero hospital, it has a big impact. The results reveal that the suggested changes are both achievable from a technical point of view and a good method to construct a hospital that is healthier for the environment and works better. All in figure 13 in appendix D.

6.10. Financial and Environmental Assessment Using RET Screen

We used RET Screen to look at the project's money and analyze how the proposed ways to save energy will affect the hospital's economy and environment. The research was paid for using a grant, not a loan, therefore the analysis didn't include any payments for debt or interest. They thought that the benefit would be enough to pay back the complete investment and not have to pay back the money.

Fuel costs went boosted by 5% to indicate how energy prices are likely to go up over time. This was done to make sure the test was right. Based on what is going on in the neighborhood right now, we estimated out how much money we could save by applying a 9% discount rate

and a 2.5% inflation rate. The reinvestment rate was the same since it was assumed that the money that had been made would make the same amount. The project was scheduled to endure for 20 years, which is how long the systems were supposed to work. This study, which was funded by grants, did not examine income tax. These assumptions are a strong and crucial basis for working out how financially stable and energy-efficient the project will be in the long run.

The financial data shows that the project will make a lot of money and pay off shortly. The fundamental payback period was 3.4 years, which meant that the money spent would be swiftly recovered back through savings on operations. The Net Present Value (NPV) was \$785,976 USD, and the Internal Rate of Return (IRR) on equity was 33.2%. A Benefit-Cost Ratio (B/C) of 3.6 suggests that for every dollar spent, the economy gets about 3.6 dollars back. Efficacious, low-cost, and promising long-term returns are the hallmarks of the recommended energy-saving measures.

It is possible to implement the proposed improvements to reduce building energy consumption without negatively impacting the environment, incurring excessive financial costs, or making excessive use of technology, according to the RET Screen results. This program sets a high standard for similar ones in the area's healthcare facilities. Greenhouse gas emissions are reduced and significant financial savings are achieved.

The RET Screen displays the project's annual profit and loss. Spending a much in the first year is normal, but you'll see a return on your investment in around 3.4 years because to compound interest. Approximately \$2.35 million USD should be available at the conclusion of the 20-year initiative. This indicates that the project's funding is satisfactory.

Chapter seven

7. Conclusion General Recommendation

7.1. Conclusion

An extensive energy audit was carried out to assess current energy usage, identify potential areas for efficiency gains, and develop suitable plans for improvement, as shown in this report. The purpose of the study was to use the audit's findings to enhance the facility's environmental performance through more efficient operations, longer equipment life, and reduced emissions of greenhouse gases. Each recommended modification was examined in terms of its impact on the environment, economy, and technology using the RET Screen Expert program.

Implementing all of the recommended energy-saving measures, including enhancing the building's façade, HVAC systems, lighting, boilers, photovoltaic panels, and solar water heating systems. With these changes, annual fuel consumption should drop by 30 %, or around 379,050 kWh. Annual savings amount to around \$115,921. A 102-ton reduction in CO₂ emissions per year is fantastic for the planet.

With an annual use of about 354,345 NIS and accounting for 44% of the overall electricity use, the HVAC system was the hospital's largest energy consumer. The annual savings for the hospital should be close to \$27,041 if they implement the recommended energy-saving measures. More than 90,000 kWh of annual electricity consumption will be reduced as a result of this.

After implementing the suggested improvements, the lighting system reduced its energy consumption. As a result of the adjustments, an estimated 37,715 kWh of power can be saved annually, amounting to \$8,675. On an annual basis.

An annual energy savings of around 59,486 kWh and a cost reduction of around \$19,952 might be achieved by installing a new 90% efficient boiler with an ETC solar water-heating system.

Adding roof insulation, a vent-door air curtain, and plastic strip curtains to the building envelope increased its performance. It also replaced single-glazed windows. These energy-saving measures are projected to reduce consumption by 103,888 kWh annually, saving \$40,173.

A 63 kWp solar photovoltaic system is proposed for a parking space adjacent to the hospital. An estimated 87,441 kWh of power will be produced annually by this system, accounting for more than 10% of the hospital's 1,026,225 kWh of total electricity use. It is anticipated that the project will save roughly \$20,080 annually, for a total cost of \$49,419. About two and a half years will pass before you receive your money back.

According to the financial data, the concept is highly lucrative and will soon begin to generate revenue. The initial investment will be promptly recouped through operational savings, as the fundamental payback period was determined to be 3.4 years.

According to the report, both the economy and the environment may benefit greatly from well-thought-out and executed energy audits and modifications to increase efficiency. When it comes to encouraging eco-friendly practices and effectively managing energy, other hospitals and other organizations in the region can learn from the experience of the Nablus Specialized Hospital.

7.2. Energy Efficiency plan

- Start with fast-payback actions like lighting controls, operational HVAC tuning, and routine maintenance.
- Establish real-time monitoring, performance indicators, and a structured energy management plan.
- Continue renewable-energy deployment and staff awareness efforts to sustain the gains over time.

7.3. Recommendation

To better manage and save energy in hospitals, a number of concrete steps need to be performed, such as the ones listed below:

1. To make people more aware of how much energy they use, every hospital staff should develop easy and responsible practices that cut down on their energy use.
2. Looking into if it is possible to use renewable energy sources such photovoltaic solar systems or solar thermal systems.
3. Get rid of the old air conditioners, pumps, and lights and replace them with new ones that are more energy-efficient and include smart controls and occupancy sensors. This will assist you improve the systems and equipment in your ancient building.
4. Use real-time monitoring and performance indicators to find problems with your energy and help you make informed choices about how to use your energy. This way you can see what is going on with your energy. Make good decisions, about your energy. You can use your energy better when you know what is working and what is not working with your energy.
5. Making it easier for technical teams and hospital management to communicate with each other. This way energy-saving initiatives always meet needs. They keep patients comfortable and meet safety regulations. Hospital management and technical teams can talk to each other. Energy-saving initiatives are important. They help hospitals save energy. Patients get care. Safety regulations are also met.
6. Provide ongoing technical training for engineering and maintenance staff, enabling them to operate advanced systems effectively, diagnose performance issues accurately, and apply best practices in energy management.
7. Adopt and implement the energy-saving measures proposed in this study, integrating them into the hospital's operational plans to improve overall performance and achieve measurable, long-term reductions in energy consumption.

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Appendix B

Energy Consumption and Energy Balance Tables

1. Chiller and Air conditioning system tables and calculation

Figure 1

The nameplate of the existing chiller

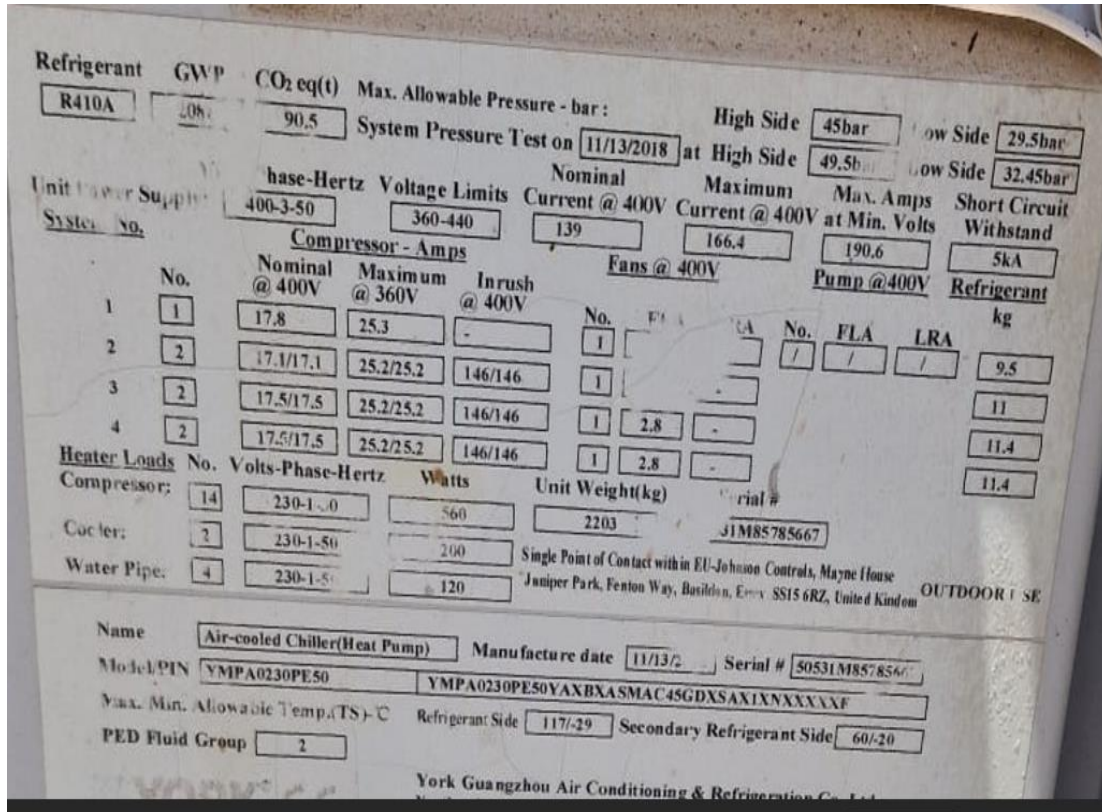


Table 1

Chiller and split unit energy consumption

No.	equipment	operation time (h/year)	power (KW)	Energy consumption (KWH/year)		
1	chiller1 summer	2880	82	229,600		
2	chiller 1 winter	1500	82	123,000		
3	Total			352,600		
Split unit	place	NO	Capacity (ton)	power input (Kw)	Daily Use (hrs./day)	total consumption (kWh/year)

Basement floor	laboratory	1	4	4.2	12	15725
	MRI	3	2	1.2	1	1123
	CT scan	1	2	1.2	12	4493
	CT scan office	1	1	1.2	7	2621
Ground floor	office1	1	1	1.2	7	2621
	office2	1	1	1.2	7	2621
	cafeteria	1	2	2.3	8	5741
	pharmacy	1	1.5	1.8	12	6739
First floor	daily surgery	3	2	2.3	4	8611
	doctors room	4	1	1.2	4	5990
Fourth floor	Catheterization	3	2	2.3	12	25834
	CCU	2	1	1.2	7	5242
	Lasik and Eye surgery	1	2	2.3	12	8611
Total						95,971

Table 2

Electricity consumption and total cost of the hospital's air conditioning systems

device	total consumption (kWh/year)	coast (NIS)
chiller	352,600	278,407
split unit	95,971	75,913
total	448,571	354,820

* The electricity tariff from the energy bills =0.791 NIS/KWH

2. Lighting

Table 3

lighting energy system energy consumption

0	Column2	Column3	Column4	Column5	Column6	Column8	Column9	Column7	Column72	Column73
place		Number of lamp(N)	consumtion (W)	operation time	total consumption (kwh/year)	after occupancy and dimer(h)	total consumption after (KWH)	Measured Lux	Recommended Lux	Compliance
Basement Floor	laboratory and blood	34	45	24	11016		11016	1100	500	Over-Range
	x-ray	12	45	12	1944		1944	1000	300	Over-Range
	CT scan	12	45	12	1944		1944	1100	300	Over-Range
	coredoors	28	45	24	9072	8	3024	700	200	Over-Range
	lundery& sterilization	14	45	16	3024		3024	450	300	Within Range
	kitchen	20	45	24	6480		6480	600	500	Within Range
	Maintenance Dep	12	45	12	1944		1944	550	300	Over-Range
Ground floor	offices(3)	14	45	12	2268		2268	900	500	Over-Range
	pharmacy	10	45	24	3240		3240	1100	500	Over-Range
	cafeteria	12	45	12	1944		1944	300	200	Within Range
	emergency	29	45	24	9396		9396	1000	500	Over-Range
	outpatient clinics	44	45	12	7128		7128	600	300	Over-Range
	Reception &coredoors	24	45	24	7776	8	2592	500-700	200	Over-Range
First floor	Administration offices& other offices	20	45	12	3240		3240	1100	500	Over-Range
	secretaria	10	45	12	1620		1620	700	500	Within Range
	patiant rooms (4)	15	45	12	2430	6	1215	200	200	Within Range
	surgery room	14	45	12	2268		2268	1000	1000	Within Range
	coredoors	14	45	24	4536	8	1512	450	200	Over-Range
second floor	Delivery rooms	20	45	12	3240		3240	600	1000	Over-Range
	Premature babies' rooms	24	45	12	3888		3888	500	1000	Over-Range
	waiting area and coredoor	24	45	24	7776	8	2592	1200-850	500	Over-Range
	patient rooms (8)	22	45	12	3564	6	1782	500	200	Within Range
third floor	ICU	14	45	24	4536		4536	1200	1000	Within Range
	waiting area and coredoor	14	45	24	4536	8	1512	700-500	300	Over-Range
	Internal Medicine , Surger	12	45	12	1944		1944	1000	1000	Over-Range
	patient rooms(8)	22	45	12	3564	6	1782	550	300	Within Range
fourth floor	ccu	12	45	24	3888		3888	1000	300	Within Range
	lasik and Eye surgery	12	45	12	1944		1944	1350-1200	1000	Over-Range
	waiting area and coredoor	24	45	12	3888	8	2592	800	1000	Over-Range
	patiant rooms(7)	24	45	12	3888	6	1944	300	300	Within Range
pathrooms	all in the hospital	62	20	12	4464		4464	500	300	Over-Range
Staircase house	all in the hospital	32	18	24	4147.2	10	1728	1000	200	Over-Range
total		656			136,537		103635			
total coast					108,000.93		81871.65			

3. Landrey

Table 4

Landrey and Sterilization system energy consumption

Device	NO.	Power (kw)	Operation time (hr./day.)	Energy consumption (kWh/year)
Washing machines	3	3	12	32,400
Dryer machine	1	6	12	21,600
Sterilizers (Autoclaves)	1	7	10	21,000
Total				75,000

4. Medical devices

Table 5

Medical Devices system energy consumption

place	devices	Rated power(kw)	operation hr./day	NO.	Energy (kWh/year)
rooms	MRI Machine	20.0	1	1	6,000
	X-Ray Machine (Digital)	8.0	4	1	9,600
	Surgical Laser	6.0	2	1	3,600
	CT Scanner	15.0	1	1	4,500
	Patient Monitor, Ventilator	1.2	24	10	86,400
laboratory	blood gas analyzer	0.2	24	1	1,080
	Cobas c 311 Analyzer	1.0	24	1	7,200
	Access 2 Device Specifications with Computer	2.0	24	1	14,400
	CBC Device Specifications	0.4	24	2	5,760
	Lab Refrigerator	0.3	24	2	4,320
blood bank	blood bank refrigerator	1.0	24	2	14,400
Total					157,260

5. Kitchen

Table 6

Kitchen system energy consumption

kitchen	NO.	Rated power (KW)	operation (hr./day)	total consumption (kWh/year)
freezer	4.0	0.6	24.0	17,280
Refrigerator	3.0	0.5	24.0	10,800
Kettle	1.0	1.0	1.0	300
microwave	1.0	1.2	3.0	1,080

Food Mixer	1.0	0.3	1.0	90
total				29,550

6. Pumps

Table 7

Pumps energy consumption

Pumps	Rated power (KW)	operation (hr./day)	total consumption (kWh/year)
Water pump	1	8	2,400
Hot Water Pumps	3	12	10,800
Vacuum Pumps	2	12	7,200
Air compressor	7	12	25,200
Total			45,600

7. Energy balance table

Table 8

Electricity balance table

TYPE	kWh/year
Chiller and Air conditioning	448,571
Lighting	136,537
Landrey and Sterilization	75,000
Medical Devices	194,760
kitchen	52,410
pumps	61,200
others	57,747
Total	1,026,225

Appendix C

Data Analysis and Energy Management Opportunities

1. HVAC system

Table 1

Measured vs. Design Airflow for FCUs for the chiller

Unit ID	Location	Measured Airflow (CMM)	Calculated Airflow (CMH)	Design Airflow (CMH)	Performance (%)	Remarks
FCU1	Emergency	54	3,240	4,000	81%	Below design value
FCU2	Outpatient Clinic	45	2,700	3,500	77%	Needs filter cleaning
FCU3	Administration Office	50	3,000	3,800	79%	Below design value
FCU4	Corridors	60	3,600	3,800	95%	Acceptable
FCU5	Delivery Rooms	60	3,600	4,000	90%	Acceptable

Figure 1

The chiller



2. Hospital Hot Water System Assessment

Figure 2

Evacuated tube collector solar water heater and its specification



Figure 3

The boiler existing in the hospital



Figure 4

Solar water heating system existing in the hospital



3. Evaluation of Thermal Loss via Doors and Windows

Thermal pictures that captured by thermal camera

Figure 5

Thermal camera images showing higher temperatures at hospital entrances

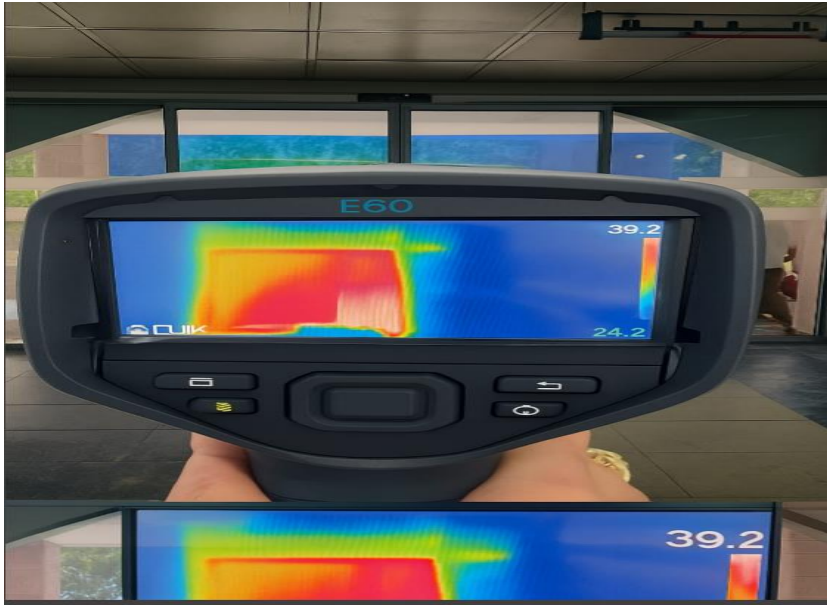


Figure 6

Thermal Image Showing High Window Temperatures in the Medical Director's Room



4. Summary of Annual Energy Costs by Sector

Table 4

Summary of Annual Thermal Consumption Costs by Sector

TYPE	kWh/year	Coast (NIS)	cost %
Chiller and Air conditioning	448,571	354,820	41
Lighting	136,537	108,001	13

Landrey and Sterilization	75,000	59,325	7
Medical Devices	194,760	154,055	18
Kitchen	52,410	41,456	5
Pumps	61,200	48,409	6
Others	57,747	45,678	5
Deisel(L)	7,500	35,100	4
LPG (Kg)	156	9,073	1
Total		855,917	100

Appendix D

Energy Saving Opportunities

RETScreen Energy auditing Results and Discussion

1. HVAC System

Figure 1

RET Screen analysis for chiller in summer

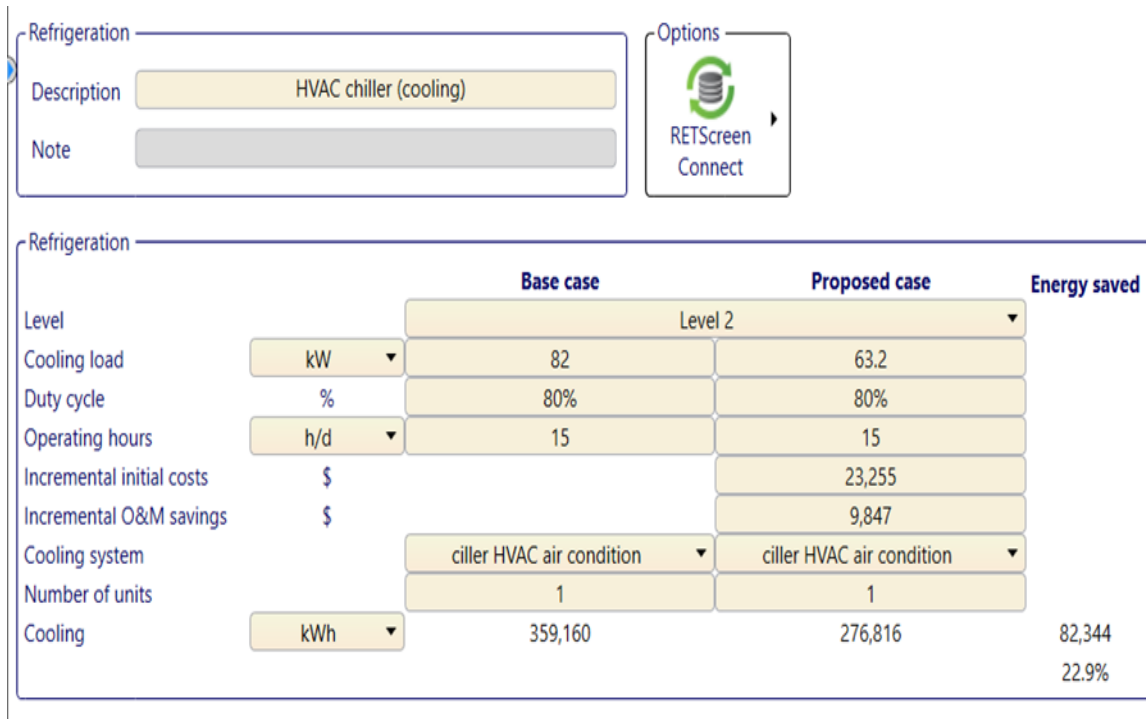


Figure 2

RET Screen analysis for split unit

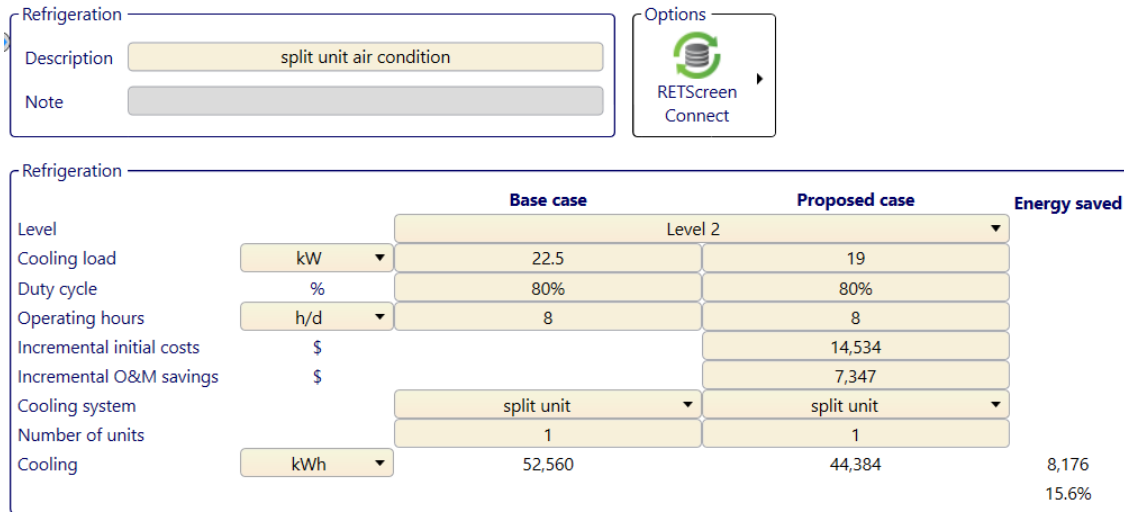
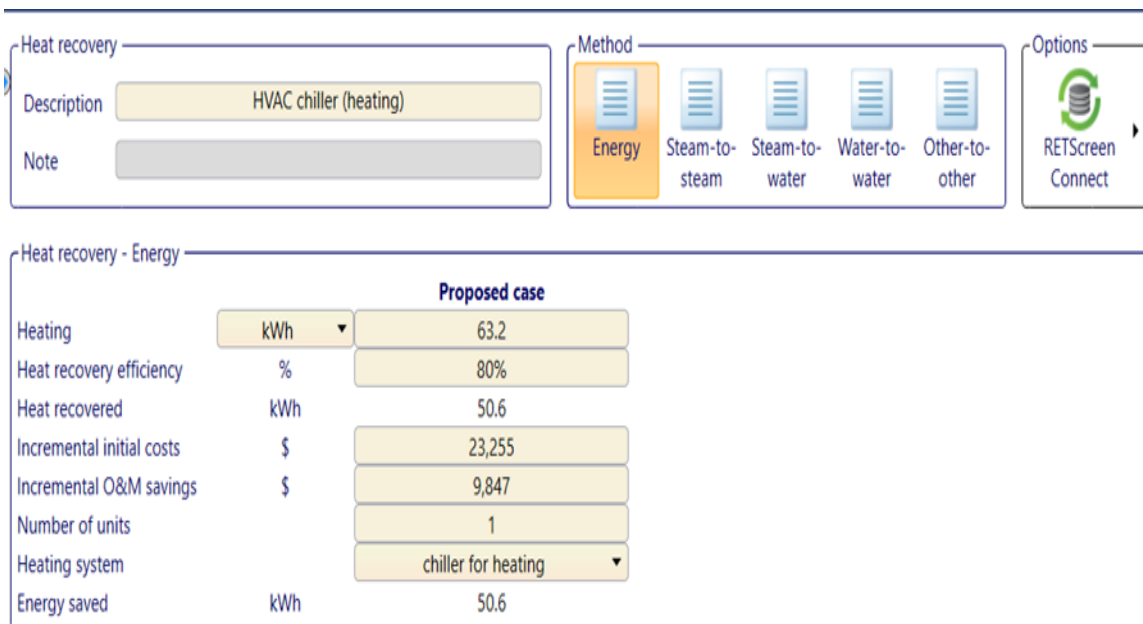


Figure 3

RET Screen analysis for chiller in winter



2. Lighting system

Figure 4

RET Screen analysis for lighting Install occupancy sensors in corridors and Recalibrate illumination levels to standards

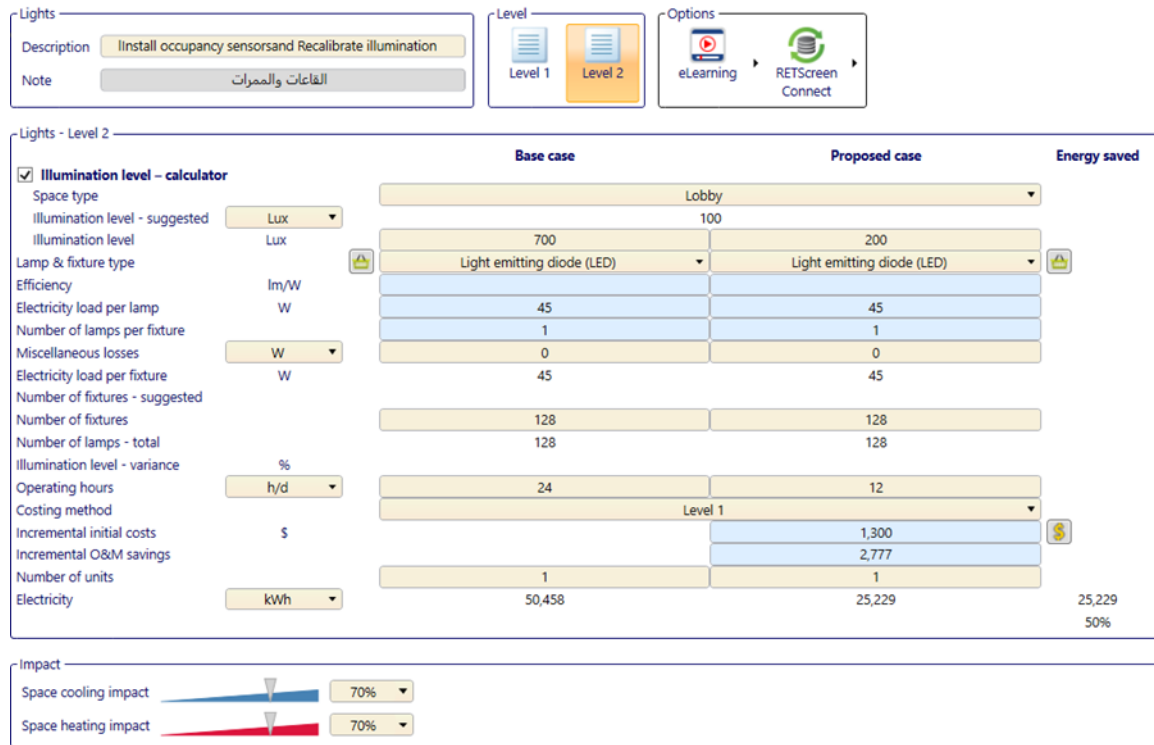


Figure 5

RET Screen analysis for lighting Implement dimming controls in patient rooms

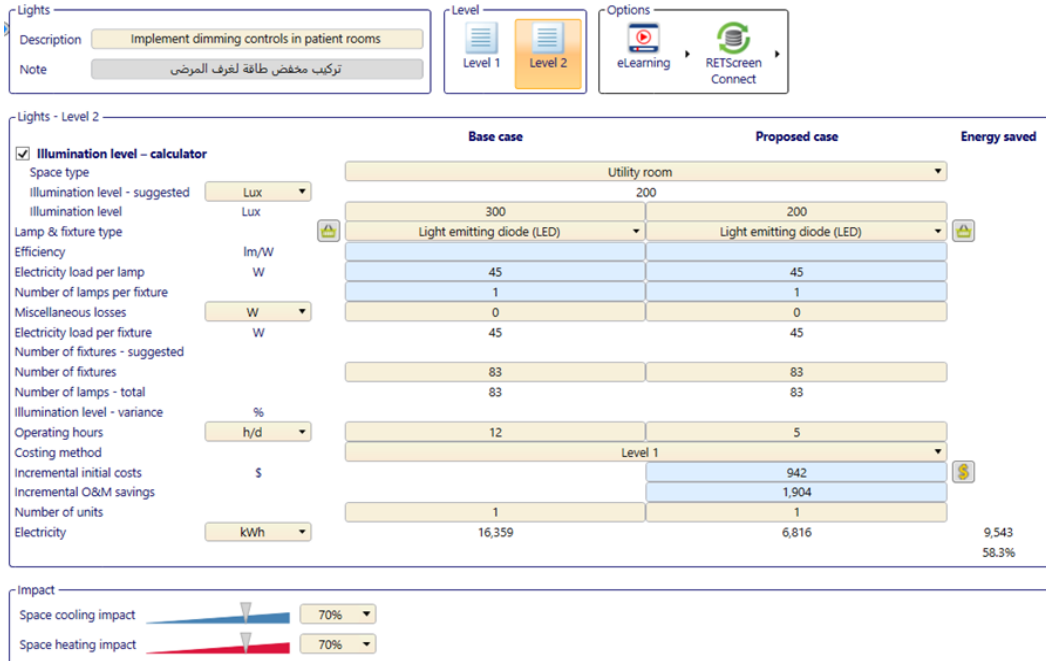
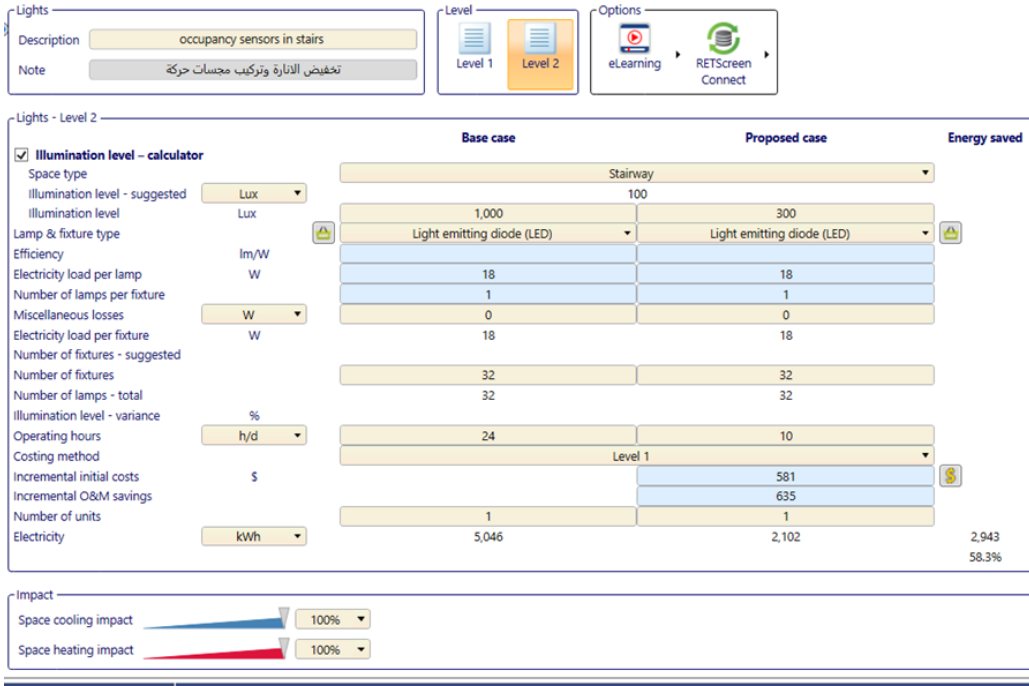


Figure 6

RET Screen analysis for lighting Install occupancy sensors in stairs and Recalibrate illumination levels to standards.



3. Boiler and Solar Water Heating System

Figure 7

RET Screen analysis for implementing solar water heater system

Annual solar radiation - horizontal	MWh/m ²	1.29
Annual solar radiation - tilted	MWh/m ²	1.50
Solar water heater		
Type		Glazed
Manufacturer		
Model		
Gross area per solar collector	m ²	25
Aperture area per solar collector	m ²	2.78
Fr (tau alpha) coefficient		0.64
Fr UL coefficient	(W/m ²)/°C	4.65
Temperature coefficient for Fr UL	(W/m ²)/°C ²	
Number of collectors - suggested		13
Number of collectors		13
Solar collector area	m ²	325
Capacity	kW	25.3
Miscellaneous losses	%	4%
Balance of system & miscellaneous		
Storage	yes/no	Yes
Storage capacity / solar collector area	L/m ²	75
Storage capacity	L	2,711
Heat exchanger	yes/no	Yes
Heat exchanger efficiency	%	80%
Miscellaneous losses	%	3%
Pump power / solar collector area	W/m ²	0
Electricity rate	\$/kWh	0.23
Initial costs	\$	39,393
O&M costs (savings)	\$	16,317
Summary		
Electricity - pump	kWh	0
Energy saved	kWh	0
Solar fraction	%	0%

4. Thermal Loss via Doors and Windows

Table 1

Improve window and roof insulation

Description	Aria (m ²)	U insulation before (w/m ² /w)	U after insulation(w/m ² /w)
windows area	100	5	2
rooftop aria	700	2	1

Figure 8

Vent door air curtain

Figure 9

plastic door air curtain



Figure 10

RET Screen analysis for building envelope improvements

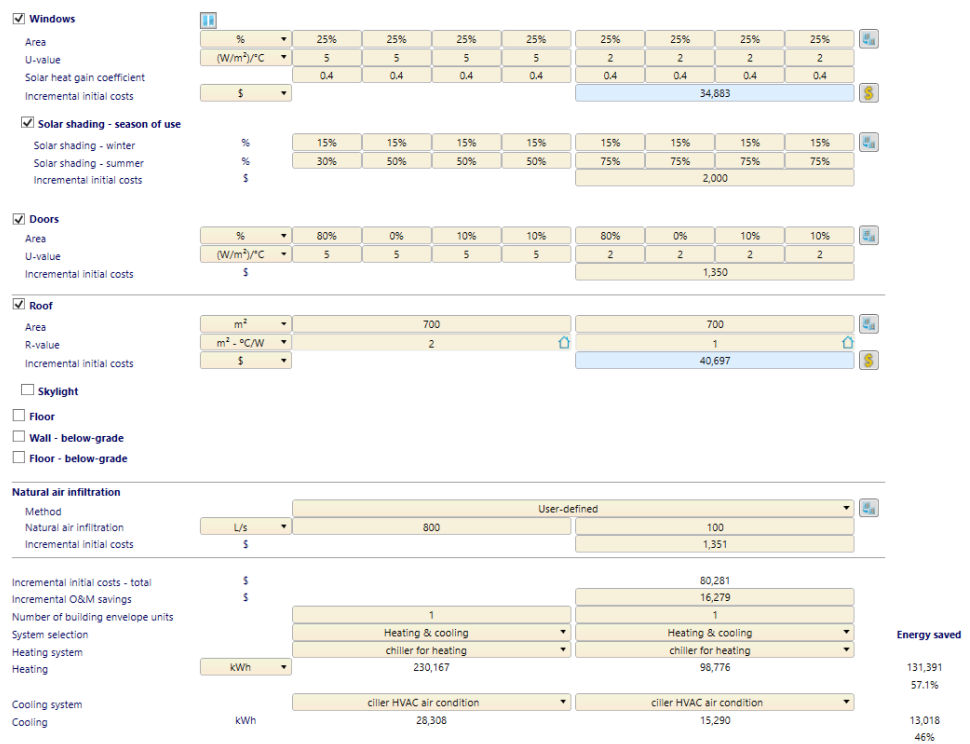


Figure 11

Financial analysis of the project

Financial parameters		Costs Savings Revenue		Yearly cash flows		
General		Initial costs		Year	Pre-tax	Cumulative
Fuel cost escalation rate	% 5%	Incremental initial costs	100% \$ 305,631	#	\$	\$
Inflation rate	% 2.5%	Total initial costs	100% \$ 305,631	0	-305,631	-305,631
Discount rate	% 9%	Yearly cash flows - Year 1		1	90,533	-215,098
Reinvestment rate	% 9%	Annual costs and debt payments		2	93,960	-121,138
Project life	yr 20	O&M costs (savings)	\$ -42,915	3	97,531	-23,607
Finance		Fuel cost - proposed case	\$ 152,968	4	101,252	77,646
Incentives and grants	\$ 0	Debt payments	\$ 0	5	105,131	182,776
Debt ratio	% 0%	Total annual costs	\$ 110,053	6	109,173	291,949
Income tax analysis <input type="checkbox"/>		Annual savings and revenue		7	113,388	405,337
		Fuel cost - base case	\$ 197,297	8	117,782	523,119
		GHG reduction savings - yrs	\$ 2,556	9	122,364	645,482
		CE production revenue	\$ 0	10	127,142	772,624
		Total annual savings and revenue	\$ 199,852	11	132,126	904,750
		Net yearly cash flow - Year 1	\$ 89,800	12	137,324	1,042,074
Annual savings and revenue		Financial viability		13	142,748	1,184,822
GHG reduction savings		Pre-tax IRR - equity	% 33.3%	14	148,406	1,333,228
Gross GHG reduction	tCO ₂ /yr 102	Pre-tax MIRR - equity	% 16.2%	15	154,310	1,487,538
Gross GHG reduction - 20 yrs	tCO ₂ 2,045	Pre-tax IRR - assets	% 33.3%	16	160,472	1,648,010
Carbon shadow price	\$/tCO ₂ 25	Pre-tax MIRR - assets	% 16.2%	17	166,903	1,814,913
GHG reduction savings	\$ 2,556	Simple payback	yr 3.4	18	173,616	1,988,528
Carbon shadow price duration	yr	Equity payback	yr 3.2	19	180,623	2,169,151
Gross GHG reduction - yrs	tCO ₂	Net Present Value (NPV)	\$ 785,976	20	187,939	2,357,090
Carbon shadow price escalation rate	%	Annual life cycle savings	\$/yr 86,101			
Other revenue (cost) <input type="checkbox"/>		Benefit-Cost (B-C) ratio	3.6			
Clean Energy (CE) production revenue <input type="checkbox"/>		Debt service coverage	No debt			
		GHG reduction cost	\$/tCO ₂ -842			

Figure 12

Yearly cash flow of the project

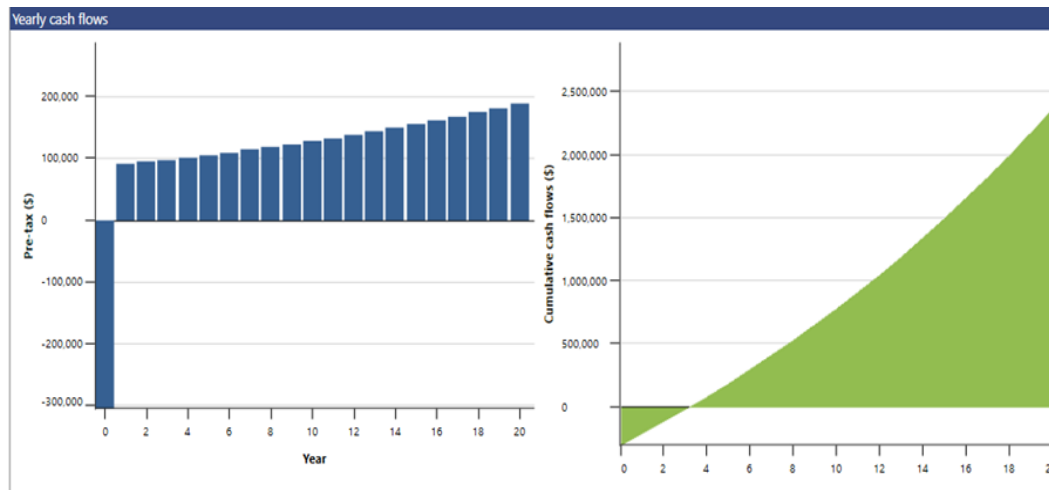
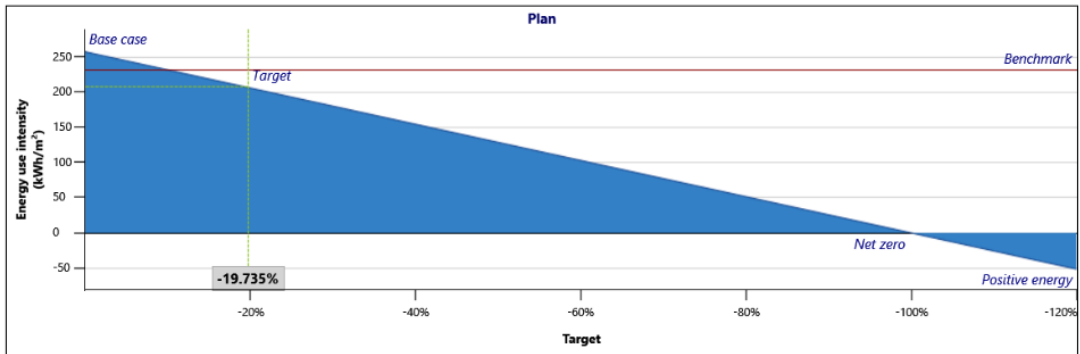


Figure 13

RET Screen plan chart for the hospital showing base-case, proposed, and benchmark energy performance.

Plan



Facility size: 4,200 m²

Fuel type	Fuel consumption		Facility - Plan			Energy use intensity			
	Fuel consumption - base case	Fuel consumption - Equivalent kWh	Set target	Proposed case	Base case	Proposed case	Benchmark	Variance Proposed case	
									kWh
Electricity - kWh	1,026,225	1,026,225	-20%	820,980	244	195	220	-11.1%	
Diesel (#2 oil) - gal	1,427	57,469	-15%	48,849	13.7	11.6	11	5.7%	
Total		1,083,694	-19.7%	869,829	258	207	231	-10.3%	

Appendix E

Energy Analyzer Data for Main Distribution Board

The results of the energy analysis have been included in the link attached below

<https://docs.google.com/spreadsheets/d/1f2nlPc-YB7YPV7GpV6LvSA9cAumLfMxW/edit?usp=sharing&oid=111621154046266206770&rtpof=true&sd=true>

Appendix F

PV syst Solar System Design Result



Version 7.2.11

PVsyst - Simulation report

Grid-Connected System

Project: New Project Nablus Specialized Hospital

Variant: New simulation variant

Sheds on a building

System power: 63.0 kWp

Nablus - Palestine, State Of

| Author



Project: New Project Nablus Specialized Hospital

Variant: New simulation variant

PVsyst V7.2.11

VCO, Simulation date:
03/08/25 18:29
with v7.2.11

Project summary

Geographical Site	Situation	Project settings
Nablus	Latitude 32.22 °N	Albedo 0.20
Palestine, State Of	Longitude 35.25 °E	
	Altitude 593 m	
	Time zone UTC+2	
Meteo data		
Nablus		
Meteonorm 8.0 (2006-2011), Sat=100% - Synthetic		

System summary

Grid-Connected System	Sheds on a building	User's needs
PV Field Orientation	Near Shadings	Unlimited load (grid)
Fixed planes 2 orientations	According to strings	
Tilts/azimuths 20 / 0 °	Electrical effect 100 %	
20 / 180 °		
System information		
PV Array	Inverters	
Nb. of modules 105 units	Nb. of units 3 units	
Pnom total 63.0 kWp	Pnom total 63.0 kWac	
	Pnom ratio 1.000	

Results summary

Produced Energy 87441 kWh/year	Specific production 1388 kWh/kWp/year	Perf. Ratio PR 73.74 %
--------------------------------	---------------------------------------	------------------------

Table of contents

Project and results summary	2
General parameters, PV Array Characteristics, System losses	3
Near shading definition - Iso-shadings diagram	5
Main results	7
Loss diagram	8
Special graphs	9



Project: New Project Nablus Specialized Hospital

Variant: New simulation variant

PVsyst V7.2.11

VC0, Simulation date:
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with v7.2.11

General parameters

Grid-Connected System		Sheds on a building		Models used	
PV Field Orientation		Sheds configuration		Transposition Perez	
Orientation		Nb. of sheds	3 units	Diffuse	Perez, Meteorom
Fixed planes	2 orientations	Sizes		Circumsolar	separate
Tilts/azimuths	20 / 0 °	Sheds spacing	11.8 m		
	20 / 180 °	Collector width	5.42 m		
		Ground Cov. Ratio (GCR)	45.9 %		
		Shading limit angle			
		Limit profile angle	15.5 °		
Horizon		Near Shadings		User's needs	
Free Horizon		According to strings		Unlimited load (grid)	
		Electrical effect	100 %		

PV Array Characteristics

Array #1 - PV Array		Array #2 - Sub-array #2	
Orientation	#1	Orientation	#2
Tilt/Azimuth	20/0 °	Tilt/Azimuth	20/180 °
PV module		PV module	
Manufacturer	Omnis Power USA	Manufacturer	Omnis Power USA
Model	OP600M60-P4	Model	OP600M60-P4
	(Original PVsyst database)		(Original PVsyst database)
Unit Nom. Power	600 Wp	Unit Nom. Power	600 Wp
Number of PV modules	45 units	Number of PV modules	60 units
Nominal (STC)	27.00 kWp	Nominal (STC)	36.0 kWp
Modules	3 Strings x 15 in series	Modules	2 Strings x 15 in series
At operating cond. (50°C)		At operating cond. (50°C)	
Pmpp	24.56 kWp	Pmpp	16.37 kWp
U mpp	465 V	U mpp	465 V
I mpp	53 A	I mpp	35 A
Inverter		Inverter	
Manufacturer	Siel	Manufacturer	Siel
Model	Soleil 30	Model	Soleil 20
	(Original PVsyst database)		(Original PVsyst database)
Unit Nom. Power	27.0 kWac	Unit Nom. Power	18.0 kWac
Number of inverters	1 unit	Number of inverters	2 units
Total power	27.0 kWac	Total power	36.0 kWac
Operating voltage	330-600 V	Operating voltage	330-600 V
Pnom ratio (DC:AC)	1.00	Pnom ratio (DC:AC)	1.00



Project: New Project Nablus Specialized Hospital

Variant: New simulation variant

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PV Array Characteristics

Array #3 - Sub-array #3			
Orientation	#1		
Tilt/Azimuth	20/0 °		
Number of PV modules	30 units	Number of inverters	1 unit
Nominal (STC)	18.00 kWp	Total power	18.0 kWac
Modules	2 Strings x 15 In series		
At operating cond. (50°C)		Operating voltage	330-600 V
Pmpp	16.37 kWp	Pnom ratio (DC:AC)	1.00
U mpp	465 V		
I mpp	35 A		
Total PV power		Total inverter power	
Nominal (STC)	63 kWp	Total power	63 kWac
Total	105 modules	Number of inverters	3 units
Module area	297 m ²	Pnom ratio	1.00

Array losses

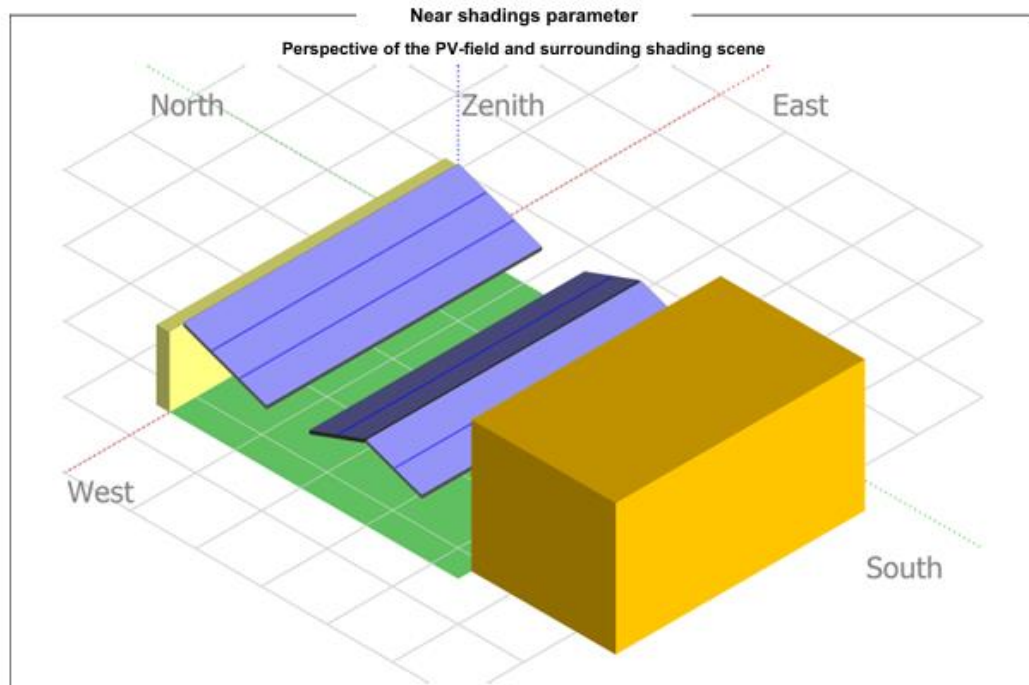
Thermal Loss factor		Module Quality Loss		Module mismatch losses				
Module temperature according to irradiance		Loss Fraction	-0.8 %	Loss Fraction	2.0 % at MPP			
Uc (const)	20.0 W/m ² K							
Uv (wind)	0.0 W/m ² K/m/s							
Strings Mismatch loss								
Loss Fraction	0.1 %							
IAM loss factor								
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

DC wiring losses

Global wiring resistance	10 mΩ		
Loss Fraction	1.5 % at STC		
Array #1 - PV Array		Array #2 - Sub-array #2	
Global array res.	146 mΩ	Global array res.	219 mΩ
Loss Fraction	1.5 % at STC	Loss Fraction	1.5 % at STC
Array #3 - Sub-array #3			
Global array res.	219 mΩ		
Loss Fraction	1.5 % at STC		



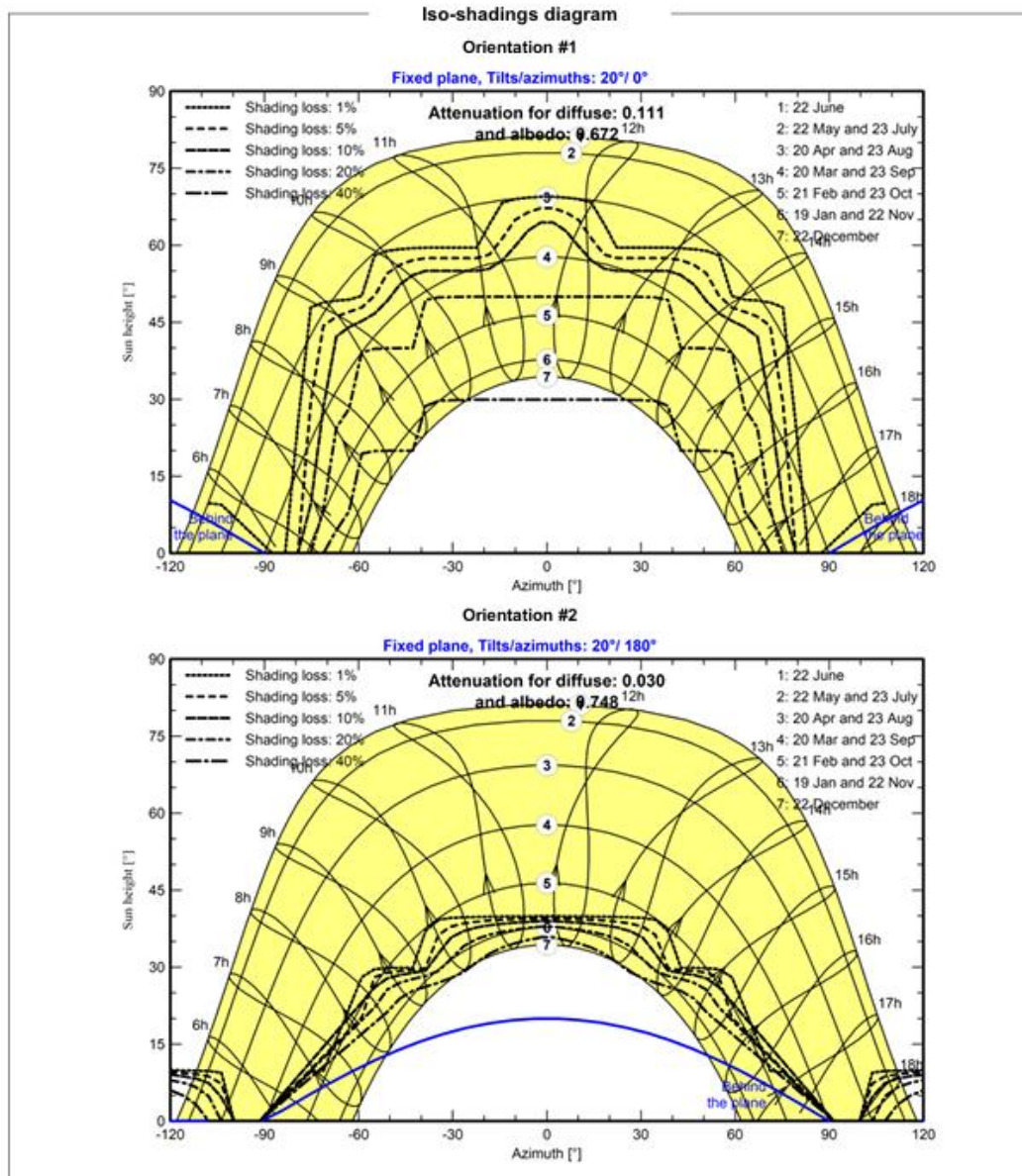
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Project: New Project Nablus Specialized Hospital

Variant: New simulation variant

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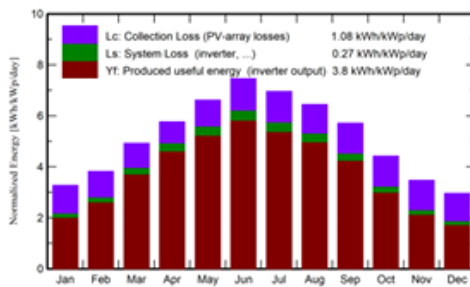
Main results

System Production

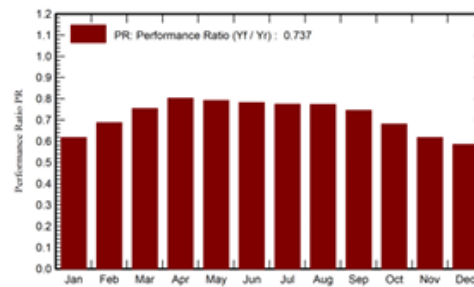
Produced Energy 87441 kWh/year

Specific production 1388 kWh/kWp/year
Performance Ratio PR 73.74 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray kWh	E_Grid kWh	PR ratio
January	90.0	37.93	8.35	101.5	76.5	4285	3949	0.618
February	98.7	43.70	9.66	106.8	88.2	4974	4622	0.687
March	146.5	61.94	13.41	152.6	138.9	7775	7255	0.755
April	172.8	76.79	17.22	172.9	164.1	9349	8736	0.802
May	210.4	86.39	21.59	205.1	195.6	10935	10234	0.792
June	233.3	65.49	24.26	223.7	215.3	11777	11026	0.782
July	223.3	74.89	26.60	215.6	206.6	11253	10524	0.775
August	201.5	70.08	26.33	199.7	191.1	10413	9735	0.774
September	167.0	57.35	24.06	171.4	160.6	8592	8044	0.745
October	128.0	50.95	21.15	137.0	117.5	6326	5881	0.681
November	93.5	38.72	14.82	104.1	80.1	4381	4049	0.618
December	80.3	31.76	10.09	91.7	66.3	3692	3385	0.586
Year	1845.4	696.00	18.18	1882.2	1700.9	93752	87441	0.737

Legends

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

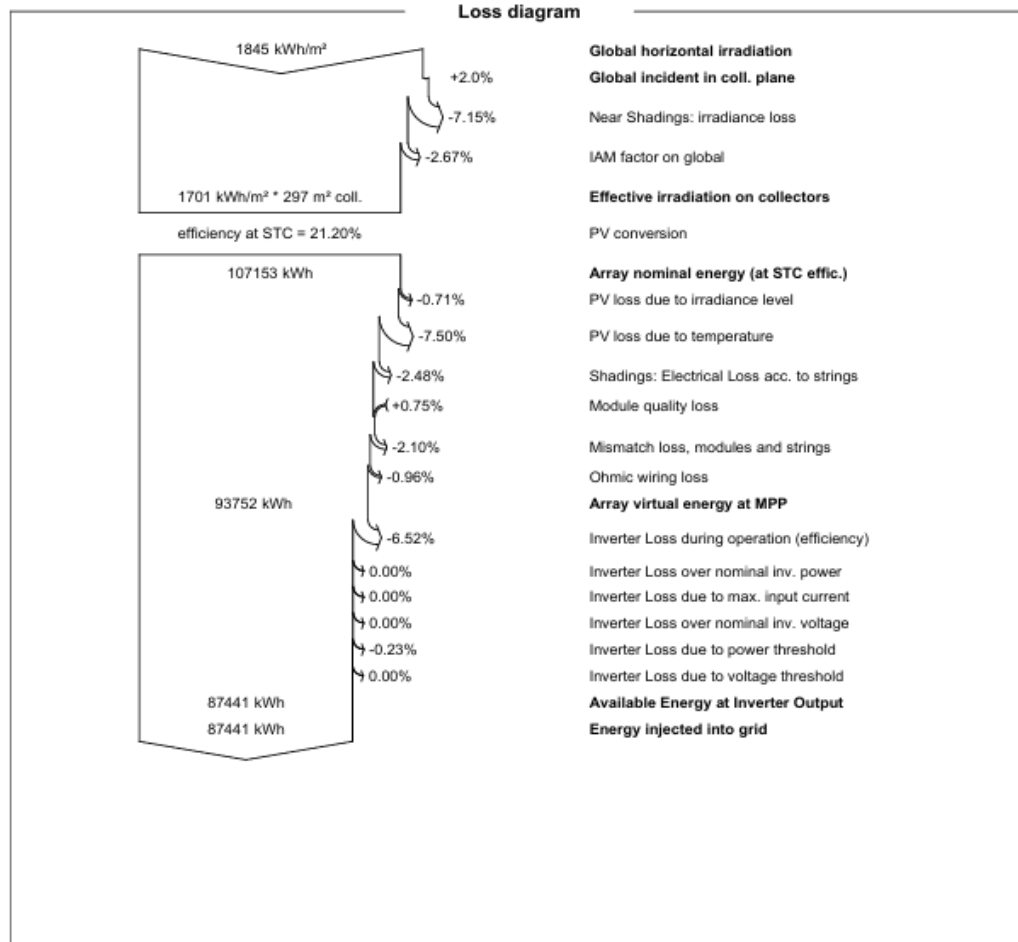


Project: New Project Nablus Specialized Hospital

Variant: New simulation variant

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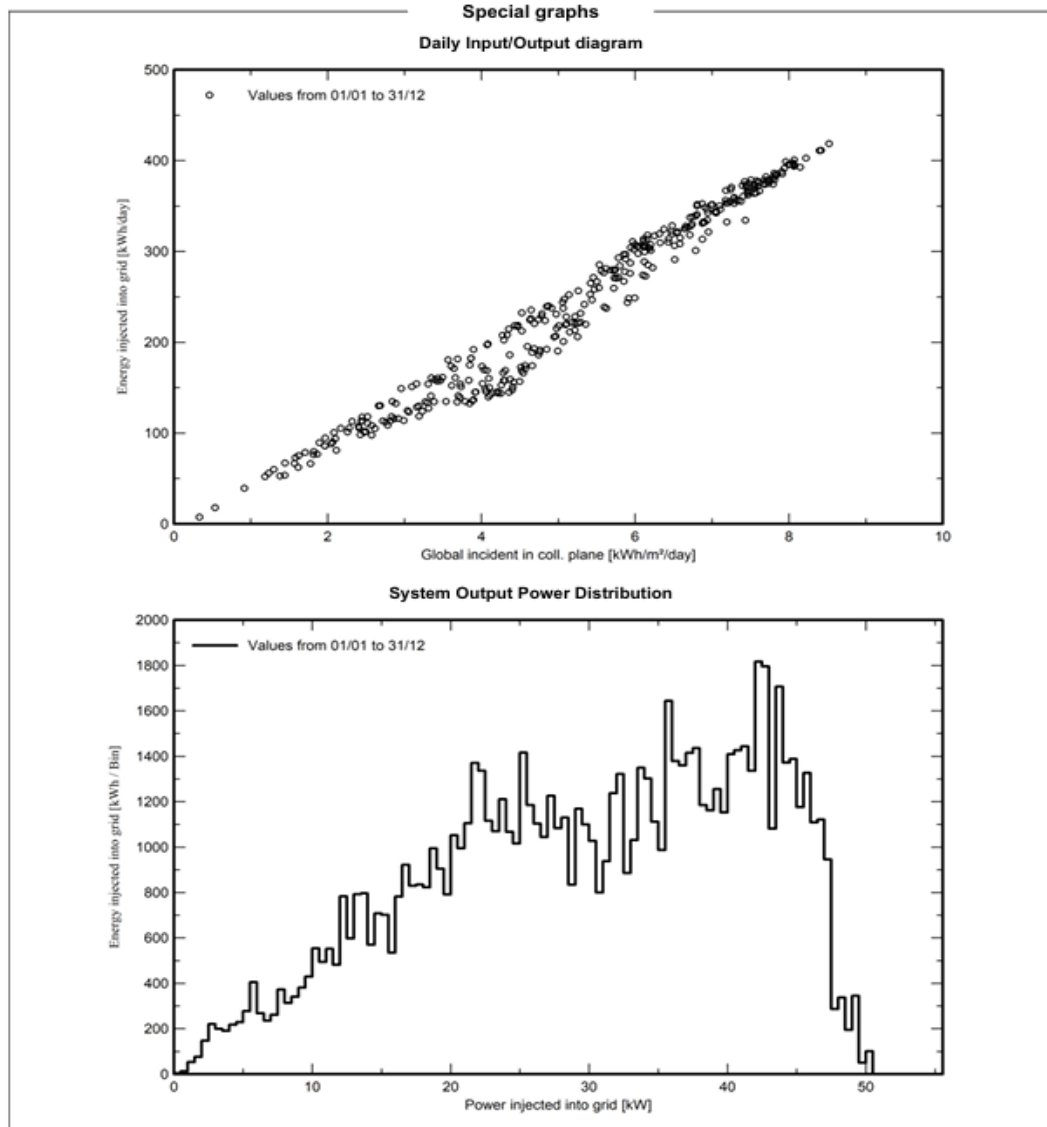


Project: New Project Nablus Specialized Hospital

Variant: New simulation variant

PVsyst V7.2.11

VC0. Simulation date:
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جامعة النجاح الوطنية

كلية الدراسات العليا

إدارة الطاقة في القطاع الصحي: دراسة حالة لمستشفى نابلس التخصصي

اعداد

رميسة نادر سميج دريدي

اشراف

د: أيسر ياسن

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

2026

إدارة الطاقة في القطاع الصحي: دراسة حالة لمستشفى نابلس التخصصي

اعداد

رميسة نادر سميح دريدي

اشراف

د. أيسر ياسين

الملخص

تستكشف هذه الدراسة طرقاً عملية لتحسين كفاءة الطاقة في مستشفى كبير بمدينة نابلس، فلسطين. وقد بدأ العمل بإجراء تدقيق طاقي شامل لفهم كيفية استهلاك المستشفى للطاقة في التشغيل اليومي، وتحديد مواقع الفاقد وأوجه عدم كفاءة رئيسية لتقييم الوضع الحالي ومقارنة خيارات Rescreen Expert الكفاءة الرئيسية. وتم استخدام برنامج التحسين المختلفة

وتقترح الدراسة مجموعة من الإجراءات العملية، تشمل: تركيب نظام لتسخين المياه بالطاقة الشمسية، وتحديث نظام الإضاءة إلى تقنيات أكثر كفاءة، وتحسين عزل المبنى، ورفع كفاءة نظام التدفئة والتهوية وتكييف الهواء (HVAC) من خلال ضبط الأداء بشكل أفضل وإجراء صيانة دورية منتظمة، إضافةً إلى تركيب نظام طاقة شمسية كهروضوئية (PV) فوق منطقة مواقف السيارات لتوليد جزء من احتياج المستشفى من الكهرباء، وذلك بالاعتماد على نتائج التدقيق الطاقي.

تم في هذه الدراسة تحليل الآثار البيئية والمالية وتأثيرات توفير الطاقة الناتجة عن الإجراءات المقترحة. أظهرت النتائج أن تطبيق إجراءات تدقيق الطاقة يمكن أن يقلل استهلاك الطاقة بنسبة تقارب 30%، أي ما يعادل حوالي 379,050 كيلوواط ساعة/سنة. بالإضافة إلى ذلك، يمكن تحقيق وفر سنوي في التكاليف يبلغ حوالي 115,921 دولارًا أمريكيًا، مع خفض انبعاثات ثاني أكسيد الكربون بحوالي 102 طن من ثاني أكسيد الكربون سنويًا. كما أشارت النتائج إلى إمكانية تقليل تكاليف تشغيل المستشفى، ومستويات التلوث، واستهلاك الطاقة في الوقت نفسه. ومن المهم التأكيد على أن أكثر حلول توفير الطاقة فعالية هي تلك التي تحقق فوائد بيئية ومالية معًا. لذلك، يمكن تشجيع

متخذي القرار في مرافق الرعاية الصحية على اعتماد مثل هذه الإجراءات، لأنها تساهم في تحسين أداء الطاقة مع تقليل التكاليف التشغيلية والآثار البيئية.

الكلمات المفتاحية: تحليل Rescreen، استهلاك الطاقة، كفاءة الطاقة.