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Techno-Economic Analysis of Solar Energy Developing Technologies in Libyan Residential Communities

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Solar Energy, Electrical Grid Network, Photovoltaic System (PV), HOMER Software, MATLAB Simulink Software.

ABSTRACT

These days, renewable energy is becoming increasingly vital. Renewable energy sources that are widely used include biomass, geothermal, wind, solar, and hydroelectric power. Because solar energy is sustainable, inexpensive to operate, and emits fewer greenhouse gases than fossil fuels, it has displaced them. The peak demand of Libya's inadequate public electrical network, which typically happens at midday, is one of the biggest issues. This problem is more prevalent in the summer, when heat waves, higher electrical loads (overload), and decreased energy plant efficiency cause voltage decreases.

It is essential to address Libya's high radiation levels around midday in order to solve this issue. It can also be helpful to research and suggest ways to integrate solar energy systems in Libyan residential communities while designing and evaluating the techno-economic implications of doing so. This study assesses the techno-economic viability of the suggested solar system, design a plan for integrating solar energy into Libyan residential areas to support the electrical grid network, and maximize the installation of supported solar systems in residential communities. Both MATLAB/Simulink and HOMER were used in the simulation process. The obtained results demonstrated Libya's residential communities' successful incorporation of solar energy systems. Three electrical loads display net present value, and the work is important for analyzing the discount payback of the three loads. In contrast to low and medium load, big system high load completion is more practical in terms of a fast payback period and will result in a financial cost return in 6.2 years. Therefore, solar energy particularly photovoltaic energy has the potential to be a very practical solution for Libya's power interruptions and oscillations.

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التحليل التقني- الاقتصادي لتقنيات تطوير الطاقة الشمسية في المجتمعات السكنية الليبية

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ملخص: تأصبحت مصادر الطاقة المتجددة بالغة الأهمية في العصر الحالي. وتشمل مصادر الطاقة المتجددة المستخدمة على نطاق واسع طاقة الكتلة الحيوية، والطاقة الحرارية الجوفية، وطاقة الرياح، والطاقة الشمسية، والطاقة الكهرومائية. لقد بدأت الطاقة الشمسية، على وجه الخصوص، في إحلال محل الوقود الأحفوري نظرًا لاستدامتها، وتكاليف تشغيلها المنخفضة، وانبعاثاتها المحدودة للغاية من غازات الدفيئة. وتعد ذروة الطلب على شبكة الكهرباء العامة غير الكافية في ليبيا، والتي تحدث عادةً حول منتصف النهار، واحدة من التحديات الرئيسية التي تواجه البلاد. وتتفاقم هذه المشكلة في فصل الصيف، حيث تتسبب موجات الحرارة والأحمال الكهربائية المرتفعة، وانخفاض كفاءة محطات الطاقة، في حدوث انخفاضات في الجهد الكهربائي. لذا، فإن معالجة مستويات الإشعاع الشمسي المرتفعة في ليبيا عند منتصف النهار أمرٌ ضروري لتخفيف حدة هذه المشكلة. علاوة على ذلك، فإن دراسة واقتراح طرق لدمج أنظمة الطاقة الشمسية في المناطق السكنية الليبية، مع تصميم وتقييم الآثار التقنية والاقتصادية لهذا الدمج، قد تكون مفيدة للغاية. يقوم هذا البحث بتقييم الجدوى التقنية والاقتصادية للنظام الشمسي المقترح، وتطوير استراتيجية لدمج الطاقة الشمسية في المناطق السكنية الليبية لدعم شبكة الكهرباء، وتهدف إلى تعظيم تركيب الأنظمة الشمسية المدعومة في المجتمعات السكنية. تم استخدام برمجيات MATLAB/Simulink وHOMER في عملية المحاكاة. وقد أظهرت النتائج نجاح دمج أنظمة الطاقة الشمسية في المجتمعات السكنية الليبية. على وجه التحديد، تم تحليل ثلاثة أنواع من الأحمال الكهربائية، وأظهرت قيمًا صافية حالية إيجابية، ويعتبر هذا البحث ذا أهمية في دراسة فترات السداد المخصومة لهذه الأحمال. وبالمقارنة مع الأحمال المنخفضة والمتوسطة، فإن النظام الكبير ذي السعة العالية يكون أكثر جدوى، حيث يوفر فترة سداد أسرع، ويحقق عائدًا ماليًا خلال 6.2 سنوات. وبالتالي، فإن الطاقة الشمسية، وخاصة الطاقة الكهروضوئية، لديها إمكانيات قوية كحل عملي للغاية لمعالجة انقطاعات الطاقة وتذبذبات الشبكة الكهربائية في ليبيا.

الكلمات المفتاحية – الطاقة الشمسية، شبكة الكهرباء، منظومة كهروضوئية، برنامج هومر، برنامج ماتلاب سمولنك.

1. INTRODUCTION

Unprecedented growth in the processes of globalization was noted back in the 1990s. Aiming to wean itself off of fossil fuels, the global renewable energy industry has been expanding and changing quickly over the past few decades. It is currently shifting to more sustainable and renewable energy sources. Naturally, renewable energy sources are ones that replenish themselves and are thought to be long-term sustainable [1]. Direct solar power generation comes in two flavours: photovoltaic solar power (PV), which uses the photovoltaic effect in a semiconductor to convert sunlight directly into electricity, and Concentrated Solar Power (CSP) generates electricity by using mirrors or lenses to focus sunlight onto a receiver, where it heats a fluid. This heat creates steam to drive a turbine connected to a generator. CSP is efficient in sunny regions and can store thermal energy, allowing power generation even without sunlight. Common CSP systems include parabolic troughs, solar towers, and Fresnel reflectors, each using different methods to concentrate sunlight effectively. This storage ability gives CSP an advantage over photovoltaic systems for consistent power supply. [2]. Due to its ability to generate clean electricity, residential PV systems are growing in popularity. It helps lessen reliance on fossil fuel-based conventional power, emits less carbon dioxide, and may save households money over the long run by bringing down monthly electricity costs. A single-phase inverter for grid integration, an array of PV panels, a DC-link capacitor between the inverter and DC-DC converter, and an integrated control unit are the five main parts of a typical home solar PV system. DC-DC converters are used to capture energy from PV arrays [3].

Solar PV capacity factors vary from 12 to 27%. Fixed tilt photovoltaic systems have lower capacity factors, whereas single axis tracking is usually used for better capacity factors. PV capacity credit is usually 15-25% due to sunlight variability and lack of storage. PV capacity credit can reach 75%

with storage and grid enhancements. [4], with lower values conceivable in electrical networks with little correlation between PV output and demand patterns and high solar penetration levels. Further analysis shows that where there is a high degree of synchronicity between solar PV supply and demand, as there often is, there is the potential for significant capacity credit with low solar PV penetration. [5]. Inverters are used by network-connected photovoltaic systems to interface with the grid, allowing for the control of electrical properties necessary for grid integration [6]. PV can even offer active power regulation through the plant inverters with extra controls, although PV production is always lost in the process [7]. A system or device that is connected to and works in tandem with the primary electrical grid is referred to as an electrical on-grid or grid-tied system. Power is taken in from the grid and sometimes discharged back into it in an on-grid system. Its electrical source is reliant on the public utility grid [8]. An area or property that is not connected to the main electrical infrastructure of the utility companies is referred to as being off-grid. When a place is off the grid, it produces and consumes its own electricity on its own. Usually, it does this by utilizing renewable energy sources like solar panels, wind turbines, or a mix of various energy-generating technologies [9].

Photovoltaic panels use light to directly produce electricity. The materials absorb and release electrons and photons. These materials can be used to create generators. From solar energy, these cells produce direct current. Semiconductors such as diodes are used to create PN junctions in photovoltaic cells [10]. Photovoltaic system optimization can also be achieved by using a new class of direct current (DC) - alternate current (AC) converter, which has a 3% efficiency advantage over all other products on the market. It was developed especially for integrated systems that monitor the maximum power point and silicon carbide (SiC) devices. There has also been development of a prototype inverter for PV systems that has an operational energy protection subsystem and a high-quality diagnosis [11].

Electronic devices are crucial to the production of solar electricity. The solar power system uses a number of significant electronic equipment, such as batteries, solar panels, converters, and inverters. The fundamental tools for turning sunlight into power are solar panels. It converts solar energy into a DC supply using semiconductor-based solar cells [12]. The DC generated by solar panels is converted into AC by inverters, which is then frequently used in houses and other structures. The inverters adjust the voltage and transform DC electricity into AC current at the proper voltage and frequency. Capacitors are also utilized to store energy, offer stability in electrical work, and enhance system performance. PV systems use intensities to increase system efficiency or to supply more energy at peak hours. Reverse transformers are also used to change the frequency (AC) produced by solar energy into a frequency current that is compatible with the nearby electrical grid. The reverse transformer modifies the frequency and effort of electricity generation to meet the electrical needs of buildings and residences [13]. While integrating solar power into buildings can be challenging, particularly in historic buildings where space is limited, there are some successful examples in a few countries that use PV tiles or PV panels, such as the Carlow Church in Germany, the downtown area of Catania, Italy, and the Hôtel de La Sage in Avolène (Vallese, Switzerland). The Anatta House in Monte Verità (Ascona, Switzerland), the Real Albergo de Poveri in Napoli, Italy, and Santiago de Compostela, Spain's ancient city core are further examples of this [14] The case study in Libya showed the impact of seasonal variations on energy demand, with temperatures reaching 40°C in summer and solar radiation peaking at 1000 W/m² from May to September. Figures indicated that smaller PV systems (1000 kW to 3000 kW) reduced Net Present Costs (NPC) by 39.23% compared to grid systems, while larger systems (5000 kW to 7000 kW) resulted in higher NPCs. High-load systems with PV ratings of 5000-7000 kW recovered investments in 6.2 years. The renewable fraction for a 7000 kW PV system reached 91% for low loads, while carbon emissions decreased with larger PV systems, especially in medium and high load scenarios.

2. LITERATURE REVIEW

Photovoltaic (PV) systems as an electricity source in residential areas of particular countries have been the subject of several prior studies. Furthermore, Pinto et al. (2022) examined ways to enhance that, including: (i) creating an energy model for the building (using energy plus) while considering the state of the building's architectural and technical components as of right now, (ii) An entirely new integrated configuration for the energy systems is proposed, taking into account all the technical and architectural constraints imposed by the building's historical significance. This is done prior to the energy retrofit and involves simulating the building's annual energy performance in terms of its primary energy needs for heating and cooling [15]. Additionally, the significance of residential solar PV systems as a clean energy source is fast growing on a global scale. The majority of residential solar photovoltaic systems link to the utility grid for power distribution via a single-phase inverter. It is crucial that the single-phase PV system's control optimizes the array's power generation while ensuring the overall dependability, performance, safety, and controllability of the system as it interacts with the electrical grid [16].

Narayanan et al. (2017) concentrated on creating a vector control technique for an artificial neural network (ANN) that was based on an LCL-filter and intended for a single-phase solar inverter. Using MATLAB Simulink's approximative dynamic programming, the ANN controller was given the command to carry out optimal control. The performance of the solar PV system using the adaptive dynamic programming (ADP)-based neural network controller was superior to that of proportional resonant and conventional standard vector control methods. Better damping resistance was not required, utility grid integration was more dependable, the DC-link voltage was more constant, and solar energy extraction was more dependable, among other reasons given for this. To evaluate the performance of the ANN-based solar PV system, simulations for grid integration and maximum power extraction from a residential PV application were conducted. Additionally, a solar PV system prototype was built in order to validate the hardware [17]. According to Darshan et al. (2022), as integrated renewables become more and more prevalent in the urban energy mix, it is critical to assess their effects using TRNSYS simulation software, beginning at the city scale and working your way down. When assessing renewable energy policies, it would be beneficial to estimate the overall energy supply, the capacity of renewable energy sources, variations in the quantity of energy drawn from the grid, and CO_2 emissions. However, it is difficult to analyze the combined effects of all the buildings in a city while also taking into account the most appropriate energy system for each unique structure because of the large number of structures in a city [18]. Research by Ibrahim et al. (2022) evaluated the viability of using PV technology on pitched roofs in Port Fouad City, Egypt. Pitched roofs are generally found on historic buildings in cities along the Mediterranean Sea. The study takes into account the challenges that affect the preservation of architectural identities. The procedure starts with a filtration step to identify the top PV technologies. Next, it advances to a simulation step where all roof surfaces are evaluated using PV sol Premium. After finishing the last optimization step, the best possible design is produced. The simulation analysis indicates that the dominating technologies are monocrystalline and thin-film. However, with respect to this kind of villa and the given meteorological conditions, the application of polycrystalline technology demonstrates insufficient performance ratio (PR), PV-generated energy, and annual production. Apart from that, thin-film tiles are not heavy. On the other hand, because of their smaller coverage area and overall lesser weight, monocrystalline arrays are preferred. The optimization results show that the monocrystalline array, with an area of 7.2 m2 and a weight of 78.2 kg, has the largest annual production (1715.1 kW h/kWp) and PR (79.4%). However, thin films are more important in terms of colour complementation, especially when it comes to the architectural motif [19]. According to Barakat et al. (2021), floating photovoltaic systems (FPVs), which use solar panels floating on the water's surface, are a relatively new invention in Brazil. In addition to being more affordable than ground-mounted solar farms, floating photovoltaic (FPV) systems have other advantages include reducing water evaporation from reservoirs and algal growth, as well as reducing conflicts with adjacent land uses. There isn't a thorough examination of Brazil's technological potential for FPVs, despite the country's intense enthusiasm with this technology and its potential benefits. The national and state uses of FPVs in artificial bodies of water are examined in this groundbreaking study. A nation's potential is determined by two things: whether or not it has natural water bodies and whether or not it has protected regions. For the purpose of mapping water features and georeferencing meteorological records, the Quantum Geographic Information System (QGIS) is employed. According to the results, FPVs can provide enough energy to supply about 16% of Brazil's electricity demand with just 1% coverage of suitable locations [20]. It is acceptable to provide power (with a supplied probability of 99.9%) and water (for irrigation) at a net current cost, according to Nasir Uddin et al. (2022). The Government of Bangladesh (GOB) has announced plans to produce 6000 MW of solar PV energy by 2041; these efforts were emphasized in a 2022 article by Nasir Uddin et al. The researchers have suggested building a mini-grid in Bangladesh's rural western coastline region that would include a 1.4 MW floating photovoltaic (FPV) system in order to achieve this. The goal of the proposed FPV system is to provide stable, long-lasting power to the isolated area's inhabitants. In their proposal and the study simulated using HOMER and MATLAB software, the researchers have considered a wide range of parameters, including the region's geography and energy needs [21]. Barakat et al. looked at Egypt's potential for on-grid hybrid solar, wind, and biomass power generation in light of the country's recently implemented feed-in tariffs for renewable energy projects. Using the HOMER programme, the introduced systems were scaled, optimized, and evaluated economically [22]. According to Al-Ahmed et al. (2022), stand-alone photovoltaic systems (PV) in the USA are constructed by selecting important and balance of system (BOS) elements that satisfy load requirements through adequate specifications and weather-related characteristics. Computer-aided design simplified dependability and cost. PV watts and the System Advisor Model (SAM) were used in the system's design and optimization. Studies of the costs and system performance for a PV array, battery storage, inverter, and load were modelled. The findings of the simulation suggested that the initial cost of installation would be substantial. But during the system's lifetime, it would help generate a sizable income and swiftly recover the initial investment [23]. In a case study in northern Algeria, Laib et al. (2018) investigated the energy balance of residential buildings and the grid-connected PV system. The house uses the photovoltaic system on sunny days and the grid at night. Energy performance is calculated through rationalization, optimization, and energy savings. In-home energy profiles, actual data, and meteorological circumstances are taken into account. The residential house's grid-connected photovoltaic system and energy conservation have resulted in a positive annual electricity balance. 67.6% of the energy in the house came from PV. Just 33.4% are purchases from the grid. Every day, energy is positive by 2 kWh. It was discovered that the monthly average electrical findings show a positive net energy gain each month using MATLAB software. This beneficial effect results from the fact that each month, much more energy is delivered to the grid than must be purchased from it. The PV system produced the equivalent of 88% of the annual electricity required in the building, even though the total amount of electricity obtained from the utility was equal to 12% of that amount [24]. The most eco-friendly option, with no pollutant emissions, is a PV/battery hybrid, according to research done in China by Chong Li et al. (2022). The most polluting system, however, is the Diesel Generator (DG)-only setup. According to the results of the sensitivity research, the cost of the hybrid PV/BG/battery system might be decreased by the Biogas Generator (BG) and battery expenses. Using HOMER software, the 400 kWp PV modules, 100 kW biogas generators (BGs), 400 batteries, and a 200-kW converter that made up the PV/BG/battery hybrid system were examined. The best load following (LF) system has a total net present cost (NPC) of $1,808,992 and a cost of energy (COE) of 0.24/kWh. Annual carbon dioxide savings of 1,297,174 kg are achieved when comparing the suggested solution to a diesel generator (DG) [25]. Alfagi (2022) projects that there will be a rise in the demand for non-renewable petrol and oil, which will lead to a shortage. One suggestion for meeting energy demands is to invest in renewable energy. Sunlight-derived solar energy is emphasized as a major and sustainable energy source. It has been observed that PV systems are most economical in distant locations because of the average 3200 hours of solar radiation per year, which generates 6 kW hours per square meter every day. It is not feasible to use an 11 KV electric grid line over a distance of 2 km for a CP (15 kWh/day). In the Dahra oil field CP stations, 300 photovoltaic systems with a capacity of 540 kWp were in use by 2005 [26]. As the demand for electrical energy rises by 50% over the next four years, Macken et al. (2022) predicted that Libya's energy sector would change. That means that by 2030, thirty percent of the power network will come from renewable sources. Libya's energy transition and energy mix greatly benefit from the integration of solar photovoltaic (PV) installations. Nonetheless, in the context of integrating PV power plants into the Libyan electricity system, it is imperative to address and overcome the issues pertaining to safeguarding power and managing power flow. An eight-bus simulation model for the Kufra PV power plant (10 MW) is specifically designed to evaluate the power network performance in terms of voltage profile, power quality, and power losses, including harmonics. Under varied operating conditions, the effect of the PV plant on the short-circuit level and the power-protection system is proven. The Libyan grid code is used to verify the fault ride-through (FRT) at standard ambient temperatures and irradiation intensities. PV plant grid integration has a significant effect on the FRT and short-circuit level at all fault levels and network sites. Due to a decrease in root mean square value voltages during the early phase of the three-phase fault, the PV plant will be removed from the grid whenever the grid's reactive and active power exceeds 938 MVAR and 261 MW, respectively. These results suggest that active power injection is increased by fault level. This is the first thorough investigation of power protection and current power-flow management in Libya [27].

The need to include renewable energy sources in residential areas is growing as the globe progresses towards a more sustainable and green energy future. However, before achieving this objective, a number of issues must be resolved. One issue is that renewable energy sources, such as wind and solar energy, are not always reliable. A major issue with Libya's inadequate public power system is the peak load, which typically happens at midday, particularly during the summer. This is caused by the efficiency of the generating stations as well as the rise in electrical loads during that time. This paper analyses the techno-economic viability of deploying the recommended solar energy system in Libya and offers methods for employing one because the amount of tactile radiation peaks at noon. In the present study, three distinct electrical loads are compared in order to do a techno-economic analysis of the integration of grid-connected solar systems into residential areas of Libya. Examining payback times, renewable energy percentages, and Net Present Value, the study assesses the financial feasibility and environmental advantages of solar adoption. It evaluates the possible grid-wide reductions in carbon emissions and the influence of photovoltaic systems on Libya's energy environment. With the goal of striking a balance between technical effectiveness and financial viability, this report provides insights into Libya's strategic deployment of solar solutions for the advancement of sustainable energy.

This study investigates the viability of grid-connected photovoltaic systems in terms of the following:

- Energy demand in Libyan residential communities: The study can start by examining the patterns and trends of energy demand in Libyan residential communities, taking into account the variables that affect these communities' energy consumption, such as household size, income level, population density, and type of housing.

- Libya's potential for solar power: This study will be able to examine whether solar energy is a feasible source of electricity in Libya. This investigation will address issues such sun irradiation levels nationwide, the suitability of different solar technologies in the Libyan climate, and the possibility of obstacles to the widespread use of solar energy.
- The integration of solar energy in residential areas of Libya may have social and environmental implications that warrant further investigation. These could include the environment, public health, and local communities.
- The present policy environment may be evaluated, possible policy roadblocks to solar energy integration may be noted, and policy opportunities to facilitate the installation of solar power in Libyan communities may be explored by this research. Both MATLAB/Simulink and HOMER will be used in the simulation process.

The principal research contributions contained in this publication are as follows:
- Assist our nation in boosting the use of renewable energy sources, expanding energy access, producing income, and advancing sustainable development.
- The study can clarify the financial benefits of solar energy use, including increased energy independence in Libya, cost savings, and job development.
- This research could improve the well-being of society and the environment by lowering petrol emissions and encouraging Libya to switch to clean energy as its main energy source.

3. RESEARCH METHODOLOGY

3.1. Introduction

This study assesses the power-generating capacity of solar photovoltaic systems in various locations of Libya. The forecasted output for the northern coastal districts is 5 kWh/kWp each day, or 1826 kWh/kWp annually. While the daily average solar PV power potential in southern Libya exceeds 6.5 kWh/kWp, the annual average exceeds 2045 kWh/kWp as well. Libya's solar energy potential, particularly in the south of the country, is displayed in Table 1 below [26]. Furthermore, Libya's renewable energy resources can provide energy equivalent to about seven million barrels of crude oil per day, which is four times as much as the amount of crude oil produced prior to the conflict (1.6 million barrels). Libya boasts one of the highest solar radiation levels in the world (see Figure 1) [26].

Table 1. The Daily and Yearly Average Solar PV Power Potential at Different Regions of Libya [26].

Region	Daily Average (kWh/kWp)	Yearly Average (kWh/kWp)
Northern Coastal Districts	5	1826
Southern Libya	> 6.5	> 2045

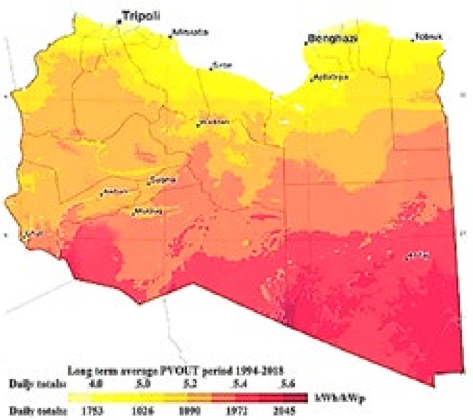

Figure 1. Global Horizontal Irradiation in Libya (kWh/m²) [26].

Due to frequent power outages and decaying infrastructure, which is largely the result of damage to numerous power plants and system assets combined with a lack of maintenance, thousands of Libyans live without electricity for a few hours each day [27]. Moreover, (Figure 2) depicts a high-voltage transmission network. As previously mentioned, one of the primary facilities found to have been harmed in 2011 was Libya's national electrical grid. Damage to more than 300 substations was estimated to be worth $1.0 billion in (Figure 2) [27].

Figure 2. High-Voltage Transmission Network in Libya [26].

Libya's economy and energy are based on fossil fuels. The hydrocarbon industry, which includes the production of oil and gas, accounts for over 65% of the state GDP, which indicates that this industry contributes significantly to Libya's economic output and activity plus 96% of the country's income. Nonetheless, annual budget deficits and inflation are brought on by changes in the demand and commodities futures markets. Oil prices were less than $20 per barrel before to 2000. They gained to $147 by the middle of 2008. It returned to $112 in 2011. After then, it decreased gradually to $22.5 in the first quarter of 2016 before increasing to more than $40 in the following quarter. Prices at the end of 2019 were almost $60 per barrel. 2020 saw unexpected price swings because to the COVID-19 pandemic, even with oil reserves on the spot market and unsold cargoes. The OPEC reference basket fell to $17.66, the lowest monthly level since December 2001, a 48% monthly decline. By 2050, the US Energy Information Agency predicts that oil prices will rise by $212 per barrel [27, 28].

3.2. PV Mathematical Modeling

Output power generated from PV in (watt) as given in the equation (1) [29]:

$$P_{pv} = PSTC\left[1 + \beta p(Tc - TSTC\right]\frac{Ht}{HSTC} \qquad (1)$$

Where P STC is the maximum power output (W) at the standard test conditions (STC), βp is the power temperature coefficient at STC, TSTC is the reference temperature at STC, HSTC is the solar irradiance in W/m2 at STC (usually 25 ∘C). The Tc_{STC} can be obtained by equation (2) [30]:

$$Tc_{STC} = T_{amp} + \frac{NOCT}{800}G(t) \qquad (2)$$

The equation calculates the temperature of a photovoltaic (PV) module under Standard Test Conditions (STC). It considers the ambient temperature (T_amp), solar irradiance G(t), and the difference between the NOCT and the ambient temperature to estimate the temperature rise caused by solar radiation. By adding this temperature rise to the ambient temperature, the equation provides an approximation of the PV module's temperature under STC.

LCOE is declared as average price per kWh of the energy (useful) generated by the system and it can be given as in equation (3) [31].

$$LCOE = \frac{Total\ anual\ cost\left(\frac{\$}{Year}\right)}{Avarge\ eanual\ electricty\ generation} \qquad (3)$$

3.3. Homer Simulation

in order to shed light on the economics of solar initiative simulation, HOMER computes economic metrics like net present value (NPV). It also plots the result based on Net Present Cost, Payback Period, technical part will sublimate, renewable fraction percentage in grid-connected PV systems, and carbon emission percentage for low, medium, and high electric loads. In order to optimize system design and identify practical solutions for the cost-effective installation of solar energy systems, HOMER is widely employed in both academia and industry [32].

3.4. Research Design

Table 2 shows the research design.

Table 2. The Research Design.

Activities	**Design the path of the project**	**Simulation**
Purpose	To achieve the problem statement	To get the real data from the simulation
Time	4months	4 months
Facilities / Tool	HOMER available	HOMER available

3.5. The Electricity Pricing and Net Energy Metering

In Libya, Net Energy Metering (NEM) offers a uniform electricity rate to encourage energy integration and efficiency. Energy-saving and renewable installations are encouraged by the set rate of $0.008/kWh, which supports national energy consumption reduction targets. The goal of Libya's energy policy is to move away from fossil fuels and toward sustainable energy. There are also public awareness campaigns and energy efficiency guidelines to direct consumer behavior and the adoption of new technologies.

3.6. The Size of PV System

For a grid-connected system, the number of solar panels needed is determined by first calculating your average daily electricity demand in kWh using the information from your utility bills. Next, ascertain the typical peak hours of sunlight in your area.

Each panel produces 1 kW, according to HOMER software calculations. This is typically between 100% and 150% of the inverter's rated capacity in this particular scenario. Table 3.1 displays the PV and inverter sizing ratings. PV ranged from 1038 to 1042 KW, while inverter ratings ranged from 800 to 7700 KW. Table 3 shows the range of inverter ratings optimal for photovoltaic systems of different sizes for low electrical load, Table 4 shows the range of inverter ratings optimal for photovoltaic systems of different sizes for medium electrical load and Table 5 shows the range of inverter ratings optimal for photovoltaic systems of different sizes for high electrical load.

Table 3. The Range of Inverter (Inv.) Ratings Optimal for Photovoltaic Systems of Different Sizes for Low Electrical Load.

PV Rating	Inv. 100%	Inv. 110%	Inv. 120%	Inv. 130%	Inv. 140%	Inv. 150%
1038	1038	1141.8	1245.6	1349.4	1453.2	1557.0
1039	1039	1142.9	1246.8	1350.7	1454.6	1558.5
1040	1040	1144.0	1248.0	1352.0	1456.0	1560.0
1041	1041	1145.1	1249.2	1353.3	1457.4	1561.5
1042	1042	1146.2	1250.4	1354.6	1458.8	1563.0

3.7. Type-Style and Fonts3.7 Cost of Input Parameters

3.7.1. Grid Extension Cost

The term "capital cost" describes the $8,000/Km cost of extending the electrical grid's facilities. Operation and maintenance costs, or "O&M cost" for short, are $1160 per year per kilometer and indicate the annual cost of upkeep for the grid extension. The grid power price, which is $0.06/kWh, can refer to the selling price of electricity or the cost of purchasing electricity from the grid.

Table 4. The Range of Inverter Ratings Optimal for Photovoltaic Systems of Different Sizes for Medium Electrical Load.

PV system size (kW)	Inverter rating: sizing from 100% to 150%				
1000	800	900	1100	1000	1200
2000	1800	1800	2200	2000	1200
3000	2700	2700	3300	3000	3600

Table 5. The Range of Inverter Ratings Optimal for Photovoltaic Systems of Different Sizes for High Electrical Load.

PV system size (kW)	Inverter rating: sizing from 100% to 150%				
1000	800	900	1000	1100	1200
2000	1600	1800	2000	2200	1200
3000	2400	2700	3000	3300	3600
4000	3200	3600	4000	4400	4800
5000	4000	4500	5000	5500	6000
6000	4800	5400	6000	6600	7200
7000	5600	6300	7000	7700	8400

3.7.2. PV System Cost

Using HOMER software, a generic flat plate PV system is connected to the grid. A PV system is defined as a flat plate type produced by an unspecified business with a rated capacity of 1 kW. For example, a generic manufacturer of PV systems with a maximum rating of 1500 kW capacity would charge $2,000,000 for capital and replacement costs as well as $5000 per year for operation and maintenance (O&M) when using PV in low electrical load consumption with a rated capacity of 1 kW. On the other hand, a manufacturer of PV systems with a medium electrical load consumption capacity would charge $2,500,900.00 per unit for capital and replacement costs as well as $1000.00 per year for O&M. PV systems have a 25-year lifespan. It is stipulated that there will be a derating factor of 80%, which could explain real-world efficiency decreases relative to ideal conditions. The system uses a flat plate type photovoltaic (PV) with a rated capacity of 1 kW for high electrical loads. According to a generic manufacturer, the cost of a PV system with a maximum rating of 7000 kW is $10000 per year for operation and maintenance (O&M) and $6,800,000 for capital and replacement costs.

3.7.3. Inverter Cost

With a maximum capacity of 2500 kW, the Table 6. shows the Cost and Performance Metrics for Grid Extension (Gird Exte.), PV Low Load (PV L. L.), PV Medium Load (PV M. L.), PV High Load (PV H. L.), Inverter Low Load (Inv. L. L.), Inverter Medium Load (Inv. M. L.), and Inverter High Load (Inv. H. L.).

Table 6. shows the Cost and Performance Metrics.

	In. H. L.	In. M. L.	In. L. L.	PV. H. L.	PV. M. L.	PV. L. L.	Gird Exte.
Capacity (kW)	8750	3000	2000	7000	3000	1	-
Capital Cost ($/yr)	$1.0x10^6$	$1.15x10^5$	$1.15x10^5$	$6.8x10^5$	$25x10^6$	$2.0x10^6$	8000/km
Replacement Cost ($/yr)	$1.0x10^6$	$1.15x10^5$	$1.05x10^5$	$6.8x10^5$	$25x10^6$	$2.0x10^6$	8000/km
O&M Cost ($/yr)	10000	1000	1000	10000	1000	1000	160/km
Derating Factor	15	15	15	25	25	25	-
Efficiency (%)	-	-	-	80	80	80	-
Life Time (yr)	95	95	95	-	-	-	-
Gird Power Price ($/kWh)	-	-	-	-	-	-	0.06

converter is used in low electrical load consumption scenarios. Its capital and replacement costs are $115,000.00 and $105,000.00, respectively, while its operating and maintenance (O&M) costs are $100.00 annually. With a 95% efficiency, the inverter has a 15-year lifespan. As a general system converter, use System Converter. The costs of an inverter with a 3000-kW capacity that is used for medium electrical load consumption include $1,500,000 for both the capital and replacement costs, as well as $1000.00 for their ongoing maintenance. 15 years is the anticipated lifespan of the 95% efficient converter. For high load electrical consumption, the costs section details a capacity of 8750 kW with capital and replacement costs of $1,000,000.00 and an annual O&M operation and maintenance cost of $10000.00/yr. An inverter connected in parallel grid and PV in the system can convert AC to DC or DC to AC current. There is a clear comparison of the costs and specifications for grid extensions, PV systems under various load conditions, and inverters in Table 6, which summarizes the input parameters in terms of type of parameters and system and capacity of parameters, capital cost ($), replacement cost ($)/yr., O&M Cost ($/yr.), lifetime (years), derating factor (%), efficiency (%), and grid power price ($/kWh).

4. RESULTS AND DISCUSSION

4.1. Input Parameters Data

The case study's geographic location is distinguished by four distinct seasons: winter, spring, summer, and autumn. The case study's hourly yearly data, which was gathered between January 1 and December 31, 2022, shows that solar irradiance ( ) ranged from 7.1 to 8.1 kWh/m /day. The average temperature and irradiance for the winter months of December, January, and February are displayed in Figure (3). The temperature starts out at roughly 15°C in December, increases to just over 20°C in January, and then declines slightly to roughly 20°C in February. December has about 600 W/m^2 of radiation, January has about 400 W/m^2 of decrease, and February has about 600 W/m^2 of rise. In particular, irradiance falls as temperature rises from December to January, suggesting an inverse relationship between the two factors.

In February, when the irradiance increases and the temperature somewhat decreases. Due to the cold weather during the three winter months and the fact that every single house uses an electrical heater as one of the input parameters, load demand increases in Libya during the winter season. Figure 4 shows the power load demand for a residential community made up of houses, with consumption measured in the three winter months by (kWh).

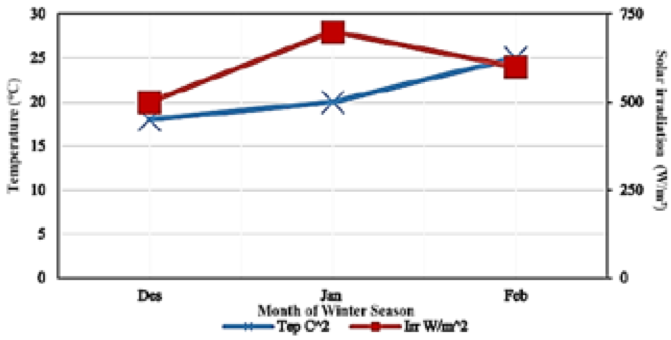

Figure 3. Solar Irradiation and Temperature for Community in Winter Season.

Figure 4 illustrates the winter season's energy demand for the months of December (Des), January (Jan), and February (Feb) in terms of Minimum (Min) load and Maximum (Max) load. The maximum load in December is over 700 MWh, while the minimum load is slightly over 200 KWh. As January approaches, there is a marginal decline in the amount of energy consumed; the maximum load falls to roughly 600 MWh, while the minimum load remains constant. The Min and Max loads do, however, significantly increase in February; the Min load rises to about 400 KWh, while the Max load reaches its peak in December at about 800 MWh. This shows that February had higher energy requirements at peak and during increases, which may be related to lower temperatures causing higher heating needs. The steady Min load in December and January and the abrupt increase in February might point to a very cold winter's end, or they could point to other variables influencing energy use, such population patterns or economic activities.

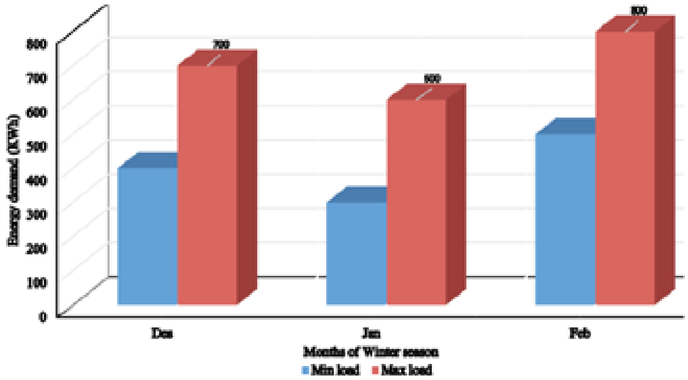

Figure 4. Electrical Load Demand for Residential Community in Winter Season in Libya.

The temperature and irradiance variations for the months of March, April, and May are shown in Figure 5. The temperature (°C) has been steadily rising as the seasons change from spring to early summer. It started at about 20°C in March, increased to about 30°C in April, and reached about 40°C in May. On the other hand, irradiation (w/m²) has a declining pattern, peaking at about 720 w/m² in March, then falling to about 680 w/m² in April, and finally falling to about 640 w/m² in May. Each month, the temperature rises by around 10°C, while the irradiance falls by about 40 w/m² from March to April and by an additional 40 w/m2 from April to May.

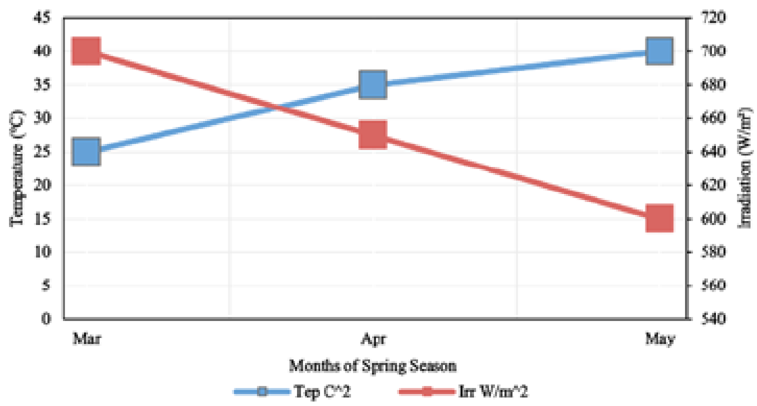

Figure 5. Solar Irradiation and Temperature for Community in Spring Season.

Figure (6) shows the energy demand for the spring season for the months of March, April, and May in terms of the minimum and maximum load in kilowatt-hours, or kWh. March is the month with the lowest minimum and maximum energy demands, indicating that less energy will be used during this month. In particular, it looks that the highest load is little over 1000 kWh, and the minimum load is just over 0 kWh. As April approaches, there's a discernible spike in energy consumption—the minimum load reaches about 500 kWh, while the highest load reaches about 2500 kWh. This pattern persists into May, when the maximum load sharply increases to about 3000 kWh, while the lowest load rises somewhat again, hovering around 500 kWh. This pattern suggests that as the season goes on, the maximum energy demand will rise significantly, maybe as a result of increasing air conditioning usage brought on by warmer temperatures. A continuous baseline energy requirement is suggested by the steady minimum load, while a rapid increase in the maximum load from March to May may indicate a larger variation in daily or peak energy usage as spring approaches.

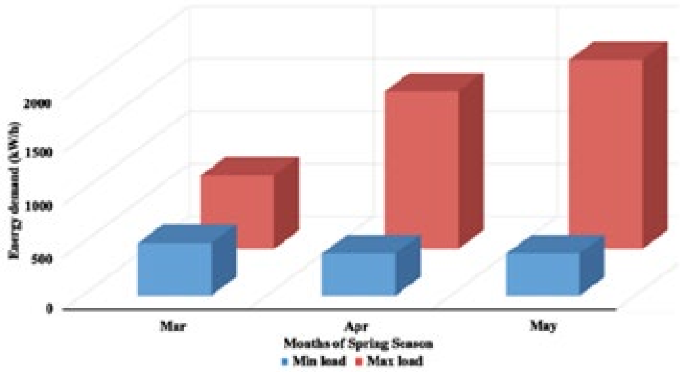

Figure 6. Electrical Load Demand for Residential Community in Spring Season in Libya.

In contrast, Figure (7) shows trends in temperature (°C) and irradiance (W/m²) for the months of June, July, and August. June temperatures are about 40°C with peak radiation levels of about 1000 W/m². In July, the temperature rises slightly to reach about 40 °C, but there is a visible dramatic decline in solar radiation too little under 950 W/m². August sees a convergence of the tendencies, with the temperature sharply falling to just about 38 °C and the irradiance climbing back up near 1000 W/m². It's interesting to note that in July, there is an inverse link where temperature increases even though irradiance decreases. This could indicate a delayed thermal response or the influence of other meteorological or environmental factors. The convergence in August may be a sign that the expected relationship between heat and sun exposure is aligned.

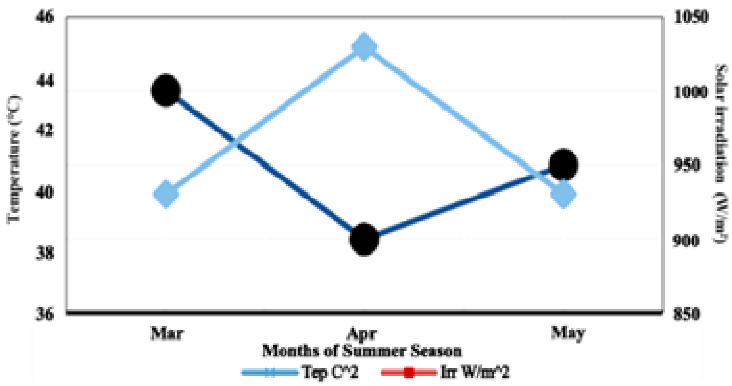

Figure 7. Solar Irradiation and Temperature for Community in Summer Season.

Figure (8) shows the energy demand during the summer months of June, July, and August in terms of Minimum (min.) load and Maximum (max.) load. June has a wide variation in energy consumption, as seen by the min. load, which starts at about 500 kWh, and the max. load, which is much greater at almost 2000 kWh. Both the minimum and maximum loads fall in July, reaching approximately 400 kWh for the minimum and 1500 kWh for the maximum, indicating a decrease in energy use from June.

But in August, the maximum load rises once more to about 1800 kWh, while the minimum load stays at 400 kWh in July. This pattern might represent the usual summertime cooling need, with potentially lower July temperatures negating the need for air conditioning and higher August temperatures returning. While the variance in max. load may be caused by temperature fluctuations that impact the use of cooling systems, the consistent min. load indicates a stable baseline energy consumption throughout the season.

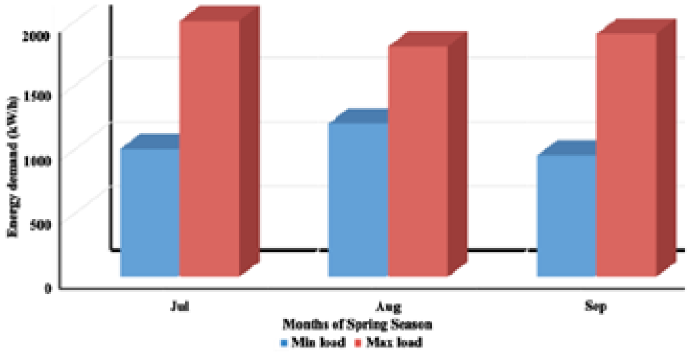

Figure 8. Electrical Load Demand for Residential Community in Summer Season in Libya.

Together with the temperature, which peaked in Figure (9) at about 35 °C in the autumn, sun irradiation also peaks at 950 W/m². Figure (8) presents a comparison between temperature (°C) and irradiance (W/m²) for three different autumn seasons: September, October, and November. September sees a temperature of roughly 36 °C and an irradiation rating of about 900 W/m². However, in October, there was a noticeable divergence between the two parameters: irradiance drops significantly to about 860 W/m², while temperature peaks inversely at about 39 °C. This suggests that temperature is not solely influenced by solar irradiance during this time. In November, this trend reverses; the temperature drops significantly to approximately 35 °C while the irradiance rises to values closer to that of September at about 920 W/m². Despite increasing solar radiation, this month's link between increased irradiance and lower temperatures is more in line with expectations, and may signal the arrival of milder weather. The graph depicts the dynamic and possibly intricate relationship-which may be influenced by seasonal weather patterns, geographic considerations, or other environmental influences-between solar irradiance and atmospheric temperatures throughout these autumnal months.

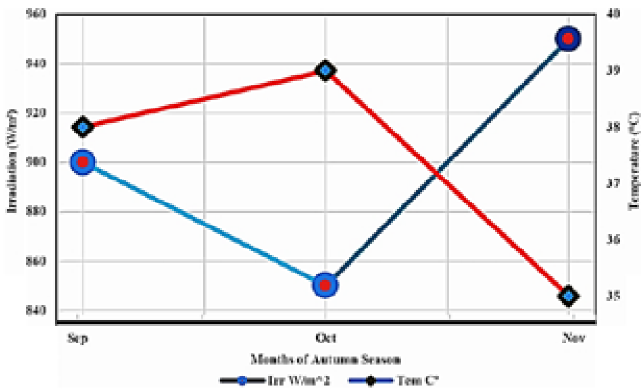

Figure 9. Solar Irradiation and Temperature for Community in Autumn Season.

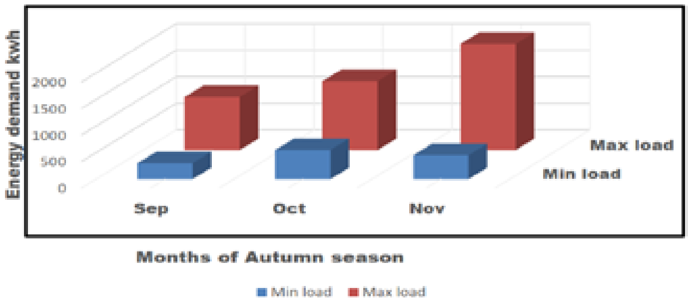

Figure 10. Electrical Load Demand for Residential Community in Autumn Season in Libya.

4.2. Simulation Result

Considerations such as Net Present Cost (NPC), Cost of Energy, Payback Period, and projected Return on Investment should be carefully considered when determining the dimensions of photovoltaic (PV) systems and related inverters. Reducing the number of non-player characters (NPCs) implies exercising more economic prudence when considering the initial capital investment, ongoing maintenance and operating costs, replacement costs, and possible profits. Making sure the PV panel's capacity is greater than the inverter's is essential for grid-integrated PV systems. Both operating efficiency and energy output will rise as a result. Furthermore, evaluating the electrical load that the grid can manage, its inherent capacity, and the location's specific solar irradiation all depend on conducting a thorough technical investigation. These elements are essential for raising the photovoltaic (PV) system's power production. Four separate seasons are experienced in the given geographical location: winter, spring, summer, and fall. The data set gathered for the case study, covering the period from January 1st to December 31st shows that solar irradiance (G) ranges from 7.1 to 8.1 kw/m² as shown in Figure (10). Figure (11) illustrates the maximum and minimum values of seasonal irradiation. The minimum value is roughly 300 w/m² in July, while the highest value is approximately 1000 w/m² from May to September. The second component that needs to be taken into account is the ambient temperature (TC), which changes daily between 3 and 7 kW and is shown in Figure 11(a, b) to fluctuate between 10 and 45 °C. These variables are taken into account as project input data. The load demand data was obtained from the General Electricity Company of Libya (GECOL), whilst the environmental statistics were obtained from the Centre for Solar Energy Research and Studies (CSERS). parameters information.

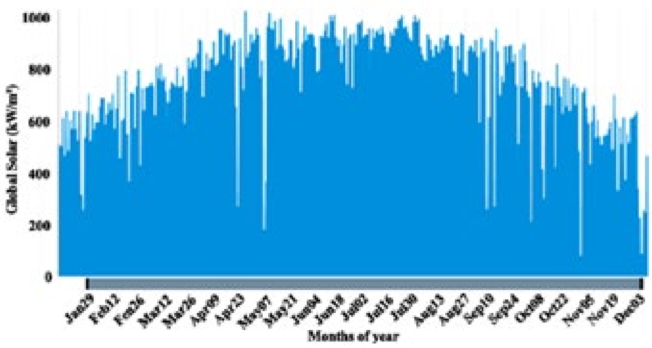

Figure 11. Annual Solar Irradiance (G) Ranges from 7.1 to 8.1 kW/m² for Tripoli Region -Libya.

The ambient temperature (T_{amb}°C), which varies between 10 and 45 °C, is the second component that needs to be taken into account. As seen in Figure (11) the temperature began to rise in May and continued to do so until it decreased once more in December. The seasonal ambient temperature maximum and minimum values are displayed in Figure (12). The minimum value was roughly 5 °C in July, while the maximum value occurred throughout the summer, when it was roughly 45 °C.

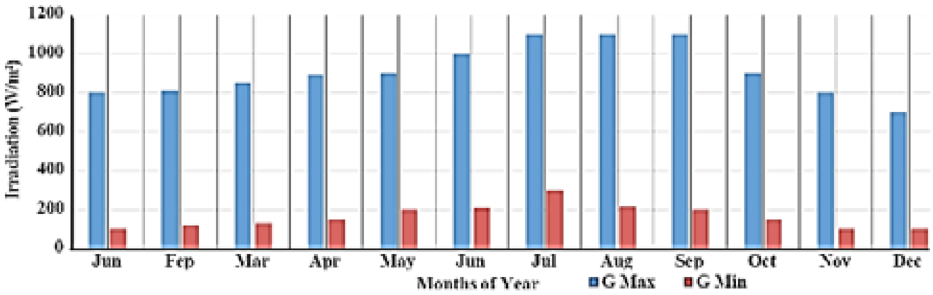

Figure 12. Annual Maximum and Minimum Solar Irradiance for Tripoli Region -Libya.

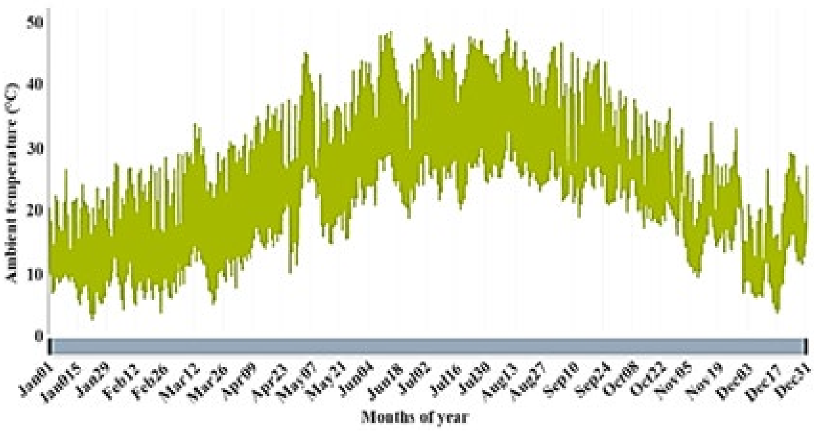

Figure 13. Annual Ambient Temperature (T_amb) in Tripoli-Libya.

The load demand is the third parameter on the input side that must be taken into account. As seen in Figure (13), the greatest electrical consumption load was 8000 kW at its peak. The HOMER programme was used to ensure that the monthly electrical load served remained continuously near to 8000 kW for the entire year.

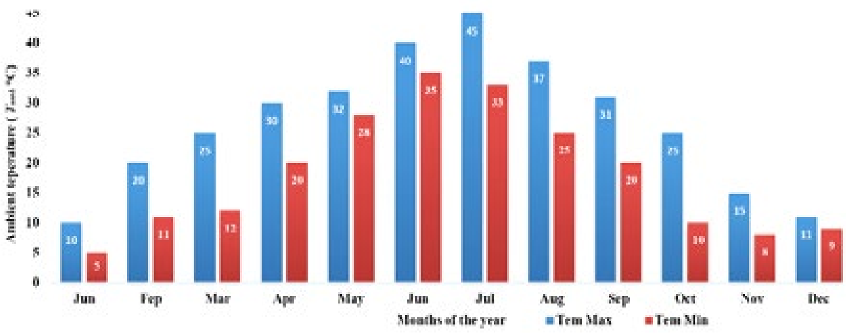

Figure 14. Man. and Max. Annual Ambient Temperature in Tripoli -Libya.

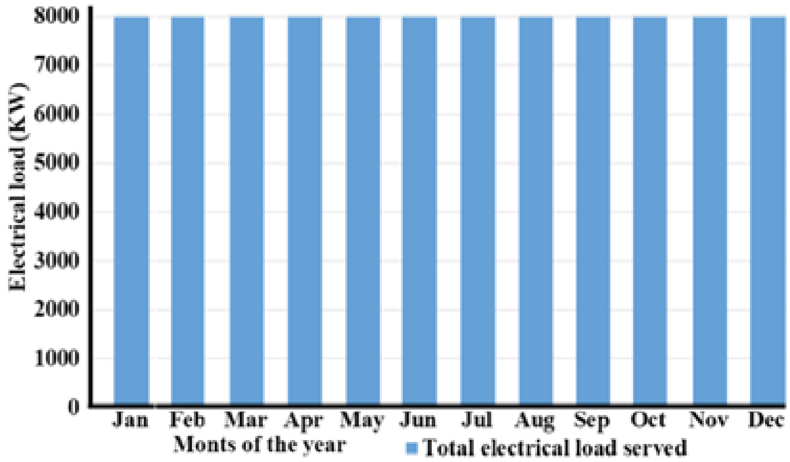

Figure 15. Total Electrical Load Consumption Durin the Year Months.

4.3. PV and Inverter Input

The PV and the inverter are the fourth parameter that must be taken into account. By modelling the three different loads with the HOMER software, these components must be handled in order to produce the optimal input needed for the low and medium loads. The PV and inverter ratings are displayed in Figure (14), which depicts the input of PV panels with a power range of 1000–7000 kW. An inverter with a high load need of 7000 kW, a medium load requirement of 3000 kW, and a low load requirement of up to 1400 kW is required. To obtain the ideal size for any load scenario, PV should have the same inverter values. When the temperature is 25°C and the solar radiation is 1000 W/m^2, the panel can generate this much power under ideal circumstances. This type of inverter usually converts power from direct current (DC) to alternating current (AC) or the other way around. This would be the highest DC current that a photovoltaic system could safely produce.

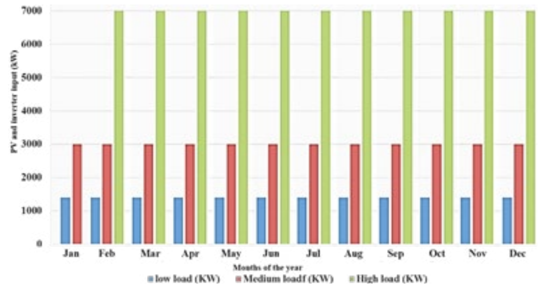

Figure 16. PV & Inverter Inputs (low, medium & high electric loads).

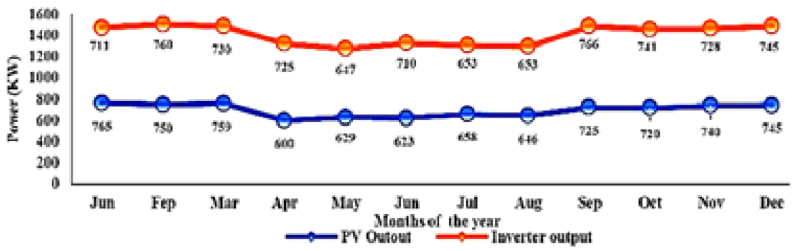

Figure 17. PV & Inverter Outputs.

4.4. PV and Inverter Output

The monthly comparison of the electricity produced by inverters and photovoltaic (PV) panels over the course of a year is displayed in Figure (15).

4.5. PV and Grid Production

The monthly energy production by photovoltaic (PV) and grid sources over a year is compared in Figure (16). There is an upward tendency in the output of PV production. January had a start of 2750 MWh, reaching a peak of 3200 MWh in March, and then witnessing another increase to 3650 MWh in December. The manufacture of PV panels varies throughout the year, declining in April and September, indicating potential seasonal fluctuations or environmental conditions that could impact the output of solar energy. As opposed to this, the output of the grid production is comparatively more consistent throughout the year, rising gradually from 500 MWh in January to a peak of 700 MWh in April, then plateauing at 600 MWh for a few months before declining slightly to 550 MWh in December. The steady production on the grid could be an indication of a capacity or demand that is independent of the seasonal variations that affect PV production. The data demonstrates how well the PV system complements the grid; this is especially evident in March and December, when the increased PV output may be able to balance the grid demand caused by the HOMER software.

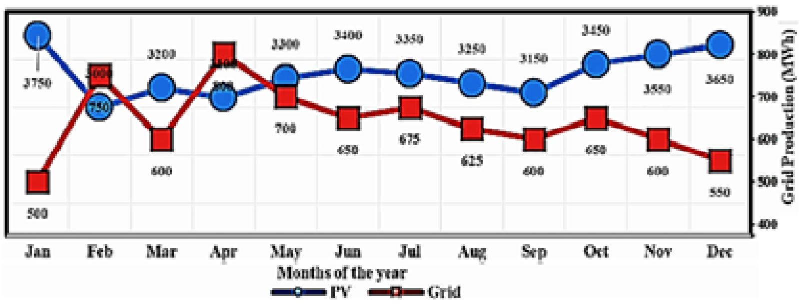

Figure 18. Comparison of Monthly Energy Production Between Photovoltaic (PV) and Grid Sources Over a Year.

4.6. Component System Cost

The Net Present Costs (NPC) of the different solar power system components-the inverter, grid connection, and photovoltaic (PV) panels-are shown in Figure (17). The prices are as follows: the inverter ($5.1 million), grid connection ($24.6 million), and PV panels ($43.3 million), which represent a significant share of the first solar infrastructure investment.

4.7. Analyzing the Economic Feasibility of PV Systems Connected to the Electrical Grid with a Variety of Low, Medium and High Electric Loads

4.7.1. Single Fhase Residential-Medium Load: (CASE 1)

the net current cost result is shown in Figure (18) for a single-phase residence with a modest daily power consumption of 5500 kWh. This load requires less energy use from electrical appliances, making it appropriate for affordable dwellings. The total kilowatt-hours (kWh) utilized in Libya for the sole purpose of billing power is determined using the first block tariff, expressed in dollars ($), over the course of a month. The cost of the tariff for residential consumption in Libya is relatively low, ranging from Libyan Dinar 0.05 to 0.07 per kWh, or $0.6 per kWh. In Libya, the Net Energy Metering programme is implemented on a personal level.

The selling price and the buying price of energy will be the same for each individual. Plotting the net current cost was done using several combinations. The simulation utilizes inverters with the following power ratings: 1000 kW AC, 1500 kW AC, 2000 kW AC, 2500 kW AC, 3000 kW, 3500 kW, 4000 kW, 4500 kW, 5000 kW, 5500 kW, 6000 kW, 6500 kW, and 7000 kW. The NPC of PV system connected to the grid, the NPC of 5000 kW PV: 7000 kW PV linked to inverter rating (4500:7000) KW have highest NPC$37,560,000 compare to the grid reference system ($25,000,000) with low electrical load.

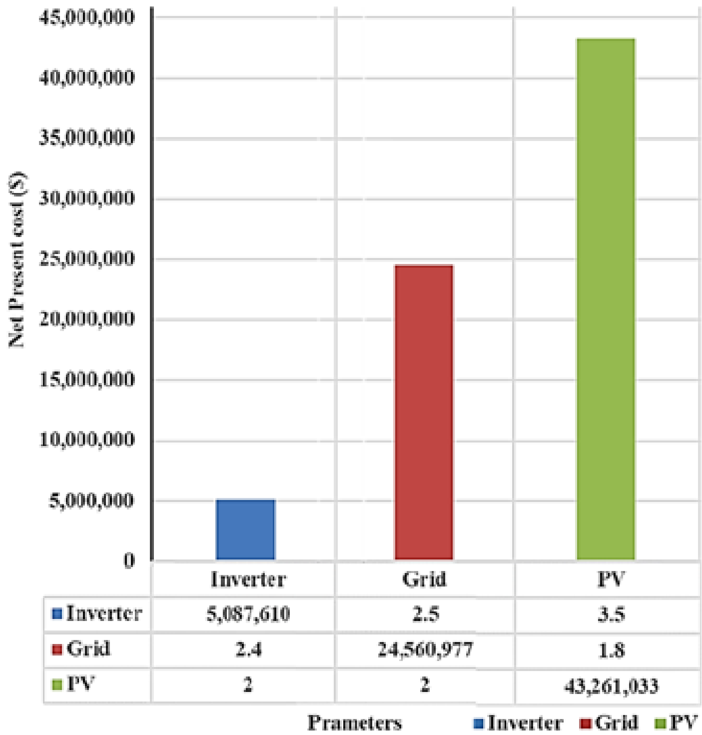

Figure 19. The Net Present Costs (NPC): PV, Grid, and Inverter.

While PV rating from 1000KW to 3000KW have less NPV than the grid $10,150,000 and $20,235,000 respectively. As a result, it's noted that the NPC increases in case of the bigger size of PV systems that connected with higher inverter ratio, for example, 7000KW PV with ratio of inverter from (6000: 7000) kW resulted an NPC of $37,560,000. While compared to a grid-connected system with an NPC of $25,000,000, PV systems with ratings of 1000 kW and 3000 kW reduce Net Present Cost (NPC) approximately 39.23%. that mean NPC of PV systems average lower by 39.23%than than NPC of grid-connected systems. This reason is enough to prove that smaller-sized rooftop PV systems became more feasible than the grid reference system.

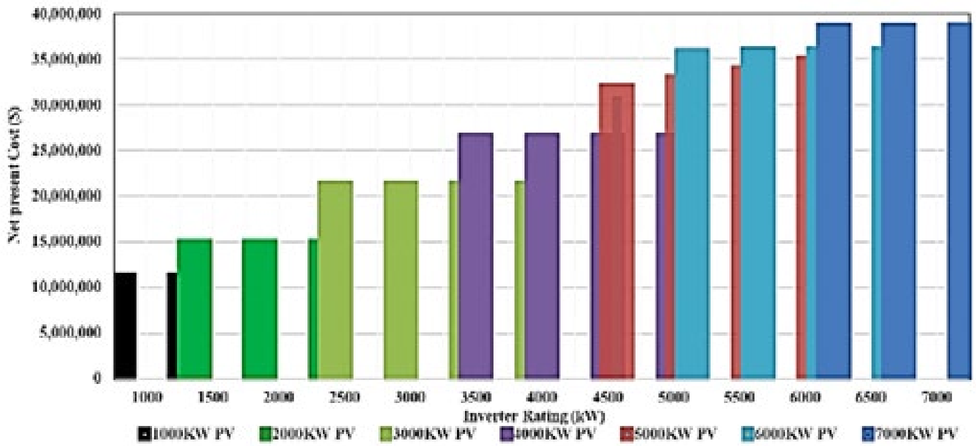

Figure 20. The Impact of PV & Inverter Ratings on the Net Present Cost of PV Systems in a Scenario of Low Electric Load.

4.7.2. Single Phase Residential-Medium Load: (CASE 2)

The net present cost result for a single-phase home system with a medium daily electrical load consumption of 10,000 kWh is shown in Figure (19). HOMER's examination of smaller-scale PV systems revealed a discernible increase in NPC from $23,130,000 to $49,995,000 in the 1000 kW to 3000 kW range. The greater material and installation requirements that go along with system size are the cause of this rise. The PV rating of $58,355.000 for the grid indicates that its NPC is marginally higher than all other NPCs. Nevertheless, the NPC increased with larger PV system ratings linked to inverter ratios, and the NPC was further decreased by a lower PV rating linked to inverter ratios. For example, an NPC of $23,130,000 and $49,000,995,000, respectively, was obtained when a 1000 kW PV and a 1000 kW to 3000 KW PV were connected to an inverter. This reduction was roughly 63.61% less than the NPC of the grid system. 5% NPC linked to the 1000kW to 3000KW inverter with a system suggests that this scenario is the less expensive over its lifetime compared to the other combinations, even though the reduction percentage for PV rating from 4000KW to 7000KW PV under rating of inverter from 3500 to 7000kw NPC was 55,000,00 to $56,550, respectively. Nevertheless, the Net Present Cost (NPC) numbers for the largest inverter rating—4000KW to 7000KW photovoltaic (PV) system sizes—indicate that, for this specific inverter size, the costs eventually outweigh the advantages. Due to its much lower net present cost (NPC) than the grid system, the 1000 kW photovoltaic (PV) system appears to be more financially practical. In order to offset the higher initial costs, larger systems could be necessary if there were incentives or bigger energy demands.

4.7.3. Single Phase Residential-High Load: (CASE 3)

The net present cost of a single-phase residential high-load power system in the eastern part of Libya is depicted in Figure (20). The current simulation, which determines the PV panels pick rating, uses the computed size of the PV panels rooftop (7000 kW). The HOWER software ranges this size from a minimum of 1000 kW to a maximum of 7000 kW. One of the key parts of the system is the inverter, which must be sized using the PV rating value in conjunction with various inverter rating values. The inverter system rating must be slightly higher by 150% or lower by 100% than the PV rating. The PV rooftop system ratings in this instance ranged from 1000 to 7000 kW, while the inverter ratings ranged from (1000-1500), (2000-2500), (3000-3500), (3500-4000), (4500-6500), and (7000-8000) kW, in that order. Furthermore, the grid's Net Present Value (NPV) was compared to that of connected photovoltaic (PV) systems by taking into account the grid's connection to the PV system. The NPV of the grid was $13,090,000, which was higher with a PV system that was 1000:4000 KW, but it started to decrease slightly as the PV system increased, reaching $12,220,000. This indicates that the grid price is more realistic in situations with heavy load demand than the cost of a rooftop PV system with large panels. The highest NPV range for a PV system in Libya with high load consumption is 1000 kW, while the lowest NPV is $33,438,000 million for an inverter rated between 1000 and 1500 kW. The net present value (NPV) varies as system sizes reach 3500 kW. Some ranges indicate a minor increase in NPV of about $97,590,000; this rating of NPV is growing to $118,684,000, which is equal to LD 712,104,000 in Libyan currency. The value increases as PV rooftop power increases from 6000 to 7000 kW. When integrating PV systems for heavy load consumption in Libyan villages, the greatest cost that must be taken into consideration is $170,156,000, which is equivalent to L.D. 1,020,936,000 for Libyan supper. Although this net current cost is the highest of the three types of loads in Libya, the payback period must also be taken into account in order to highlight which type of load is most economically feasible for the suggested solar system.

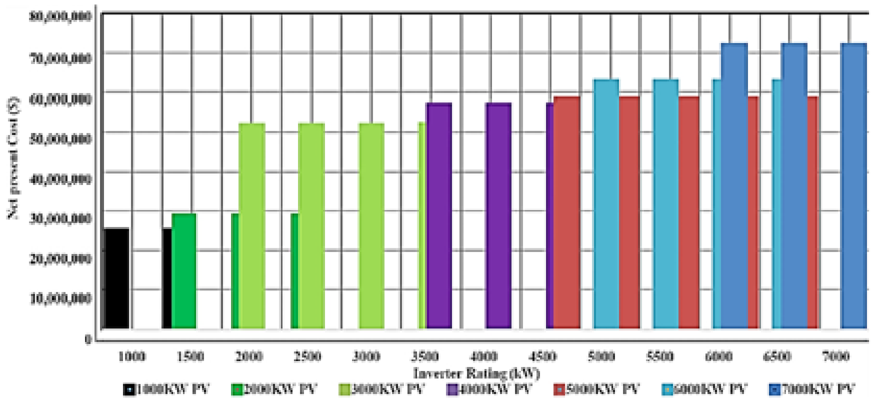

Figure 21. The Impact of PV & Inverter Ratings on the Net Present Cost of PV Systems in a Scenario of Medium Electric Load.

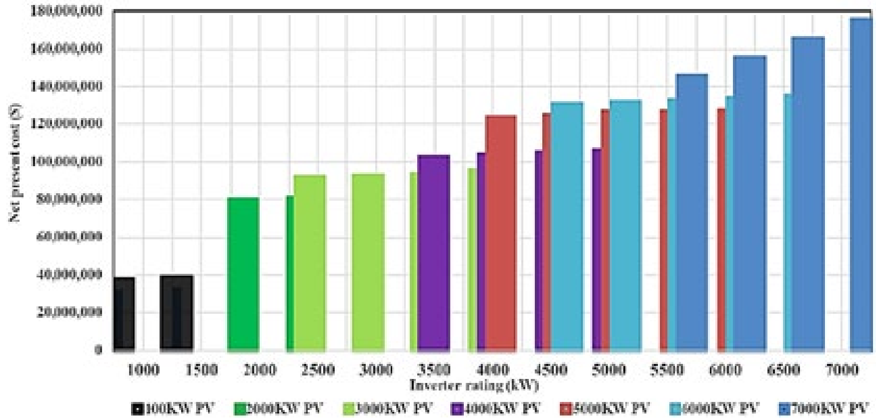

Figure 22. The Impact of PV & Inverter Ratings on the Net Present Cost of PV Systems in a Scenario of High Electric Load.

Payback period is the second element that must be taken into account when choosing an optimization design for a residential grid-connected solar rooftop system. The discount payback period under three different electrical load scenarios-low, medium, and high-is where the effect of the PV sizing from the inverter will manifest itself. Figure (21) shows that, for the three different loads in the short payback period, there is a longer period for returning the initial investment. This is especially true for low load, where the PV can save more money than using the grid when using more electricity, meaning the initial investment will be repaid faster. On the other hand, low-load PV with a high rating will be used in place of the utility grid, but it will require a lengthy payback period of around 12.84 years. In comparison to a low load, under a medium electrical load. It's payback time, which ranges from 7 to 11 years, is somewhat brief.

Furthermore, the PV rooftop has a high rating between 5000 and 7000 kW under heavy load consumption, which makes it very economically feasible. This is because a large PV system will provide a high rating of energy for consumers, which will help to lower PV costs and shorten the payback period. It simply needs to recover the initial investment in 6.2 years. This means that, in comparison to low and medium load, high load consumption is more economically possible.

Renewable fraction percentage is the third component that must be taken into account when choosing an optimization design for a residential grid-connected photovoltaic system with low, medium, and high electrical loads. Maintaining grid stability, maximizing energy use, evaluating the impact of buildings, determining economic viability, and ensuring the dependable and efficient integration of PV systems into the electrical power supply all depend on the analysis of the renewable portion. For low, medium, and heavy electrical loads, the inverter's renewable fractions percentages are 20, 40, and 60%, respectively. The maximum renewable portion rating of 91% under low electrical demand, 83% under medium load, and 55% under heavy electrical load has been reached using 7000 kW of PV.

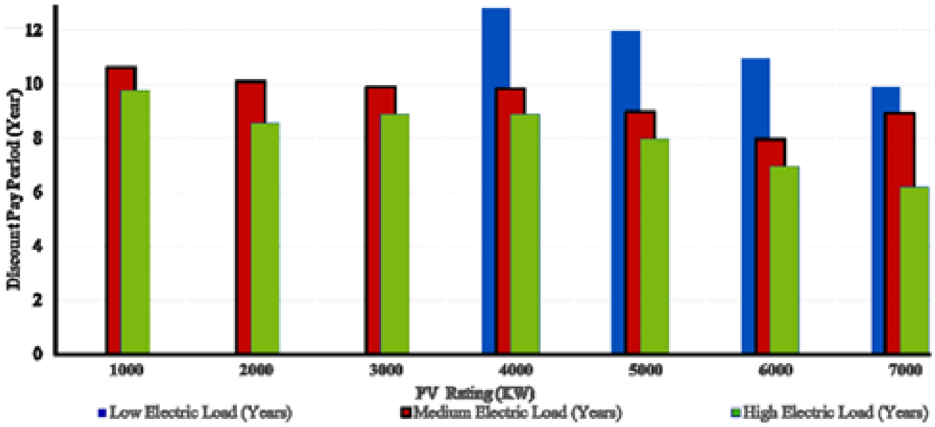

Figure 23. The Effect of PV Sizing on Three Key Factors of the Analysis Discount Payback Period: (Low, Medium, and High Electric Loads).

The impact of PV design on the renewable fraction of grid-connected PV systems for low, medium, and high electric loads is depicted in Figure (22). The graph shows that as load increased, the percentage of renewable energy decreased. This suggests that larger photovoltaic (PV) systems can produce more electricity, better match energy demand, take advantage of economies of scale, and integrate with the grid infrastructure more successfully, all of which contribute to increases in the percentage of renewable energy.

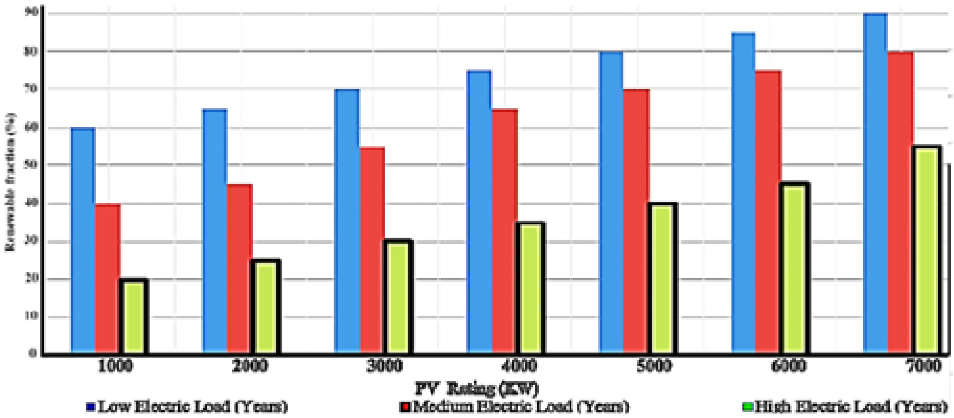

Figure 24. The PV Design Influence on the Renewable Fraction for Low, Medium and High Electric Loads.

It is necessary to take into account the carbon emissions from the grid as the fourth factor. Efficient management of carbon emissions across PV system installation ratings and loads is critical. The three different scenarios for managing the percentage of carbon emissions from the various PV systems and the power load are depicted in Figure (22). The most pollution is caused by high energy cargo, indicating how challenging it is to supply energy needs in an environmentally friendly way. Emissions are decreasing at high PV rates, demonstrating the effectiveness of PV systems in lowering carbon yields. The highest emissions, which exceed 4 million kg/year, are seen with a 1000 kW PV rating under high load. Significantly, emissions fall as PV size increases from 2000 kW to 7000 kW, particularly in scenarios with medium and high loads, however high loads still result in significant emissions. The pattern indicates that, especially at medium loads, there is an ideal PV system size that strikes a balance between a considerable reduction in emissions and a capacity increase. The research shows that in order to optimize the environmental benefits of solar electricity, care must be taken in PV sizing and load management. Larger systems have been shown to be more successful in reducing carbon emissions, particularly in high-demand scenarios.

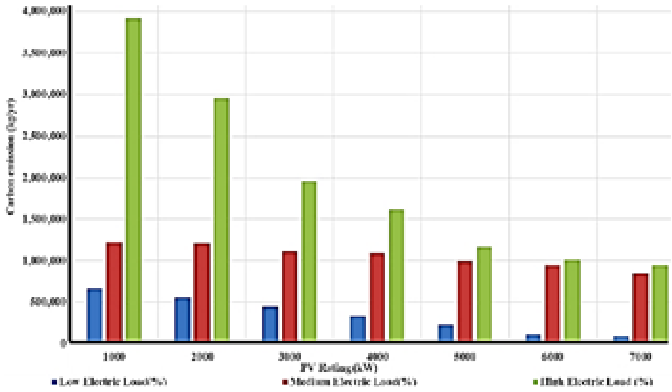

Figure 25. The most pollution is caused by high energy cargo.

5. Comparison with previous study

A previous study [35] from the aspect of economic feasibility focuses on On-Grid Solar PV in Libya and offers detailed financial metrics, including an initial cost of $9,570 and a cost of energy (COE) as low as $0.0314 in the best location (Al-Kufra).

Table 7. Comparison between the Previous and Current Study.

Category	Previous Study	Current Study
Criteria	Feasibility Study for On-Gird Solar PV in Libya	Techno-Economic Analysis of Solar in Libyan Residential Communities
Methodology	HOMMER Software for Economic and Energy Analysis	HOMMER And MATLAB Used for Boarder Simulation and Economic Analysis
Best Location	Al-Kufra: The Lowest System Cost, COE (0.0314 $), and CO_2 Emission (56,982 kg/yr)	South West of Libya: The Highest Solar Potential (>6.5 kWh/kWp Daily)
Economic Feasibility	The Initial Cost: (9,570 $)The Minimal Maintenance Cost COE (0.0314 $)	Focuses on Payback Periods and Net Present Value for Different Loads
Energy Production	Covers of the 85% of Required Household Energy The Monthly Energy Production Varies with Seasons	Southern West Regions Performs Better, with Over (2045 kWh/kWp)/yr
Environmental Impact	Specific Reduction in CO_2 Emissions Detailed Data for each City, e.g., Al-Kufra: (56,982 kg/yr)	General Reduction Benefits Fossil Fuel Reliance, but no Specific Emission Data Provided
Payback Period	Explicitly, not Expected	Focuses on Payback Periods for Three Different Loads
Focus	Detailed Financial and Environmental Results for Gird-Connected PV Systems in Specific Cities	Broader Analysis of the Potential for Integrating Solar Energy in Residential Areas

This provides a clear and practical understanding of upfront costs and the long-term savings, especially since the maintenance costs are minimal. Although this work focuses on techno-economic analysis, it also makes a compelling economic argument. However, unlike the previous study, it does not specify upfront expenditures; instead, it stresses payback periods and net present value (NPV) across three different electrical loads. This more comprehensive method illustrates possible financial gains in different situations.

6. CONCLUSIONS

Libya's renewable energy initiatives face a number of intricate legal, economical, and cultural issues that must be carefully considered. But solar energy—particularly photovoltaic energy—has the potential to be a very practical solution for Libya's power interruptions and oscillations. Additionally, by lowering reliance on fossil fuels, renewable energy technologies benefit the US economy. Residential photovoltaic (PV) systems will be able to return environmentally friendly energy to the power grid in accordance with the Feed-in Tariff (FiT) policy, which was created to stimulate the development of renewable energy sources by guaranteeing producers an above-market price. The feed-in tariff has the potential to make a major contribution to the growing adoption of solar PV technology, based on the literature and the collected findings. Based on current research, photovoltaic (PV) systems with lower inverter ratios (1000 kW to 3000 kW) are more economically viable due to their lower net present cost (NPC) when compared to the grid system. The analysis shows that there is a positive relationship between the PV system's size and the NPC. When compared to the grid, the PV systems continue to be more affordable despite this rise. The study looks into photovoltaic (PV) systems with a capacity ranging from 1000 kW to 3000 kW, primarily targeting medium electrical loads, in the (case 2) for the medium load (10000 KWh/day). As system sizes expand, there is a noticeable increase in NPC (Net Present Cost), which may be caused by rising material and installation costs. However, as compared to the grid system, the NPC (Net Present Cost) for these photovoltaic (PV) systems is still significantly lower. According to the study's findings, photovoltaic (PV) systems in this particular range offer substantial financial advantages, highlighting their applicability for homes with modest energy usage. Nevertheless, in instance three, high load consumption (32389.5 KWh/day), this study looks at a situation where there is a lot of demand in a specific location in Benghazi. The analysis covers various photovoltaic (PV) panel and inverter capabilities, with an emphasis on larger system sizes (up to 7000 kW). It has been observed that larger systems consistently show greater net present value (NPV) outcomes, indicating diminished financial feasibility, but smaller systems (up to 3500 kW) showed varying NPV outcomes. It is shown that the costs associated with these large investments outweigh the benefits on the basis of current economic assumptions. In spite of the most practical of the three scenarios is Case 1 (Low Load, 5500 kWh/day). This is because, when compared to both the grid system and bigger PV systems, smaller rooftop PV systems for affordable housing exhibit the most cost-effectiveness, with lower Net Present Costs (NPC). This scenario offers the best balance between system size and cost efficiency, making it the most practical choice for implementation. In contrast to low and medium load, big system high load completion is more practical in terms of a fast payback period and will result in a financial cost return in 6.2 years.

7. RECOMMENDATIONS AND FUTURE SCOPE OF WORK

This report conducts a thorough analysis of the evolving PV technology landscape. The following suggestions must to be taken into account:

- Setting priorities includes researching the effects of government subsidies on residential solar uptake, assessing the cost-effectiveness of new PV innovations, and examining maintenance costs and long-term performance;

- Researching the advantages for the environment, particularly with regard to lowering carbon emissions and encouraging the use of sustainable energy;
- Examining how consumer behaviour affects how effective PV systems are;
- investigating the potential for expanding photovoltaic systems in diverse residential and geographic settings and combining them with smart grid technology to enhance utility distribution and management;
- In order to enhance energy distribution and management, investigate how far solar systems may be integrated with smart grid technologies. Additionally, find out how scalable these systems are in different household and geographic settings.

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