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Novel Study Strength and Development of Solar Energy Practical Applications in Egypt

Marwa M. Ibrhaim[1], Manu Ahuja[2]

[1]*Mechanical Engineering Department, National Research Centre (NRC), Dokki, Cairo, 12622, Egypt*
[2]*Project Consultant, Technology Development Board, India*

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ABSTRACT
Egypt has a lot of potential for solar energy because it is a tropical nation in the sun belt. Most of Egypt receives adequate solar radiation, with daily averages of 2000–3200 kWh/m^2/year. Egypt's energy deficit budget requires an energy transition from finite fossil fuel reserves to plentiful renewable energy sources. Over the past few decades, Egypt's primary energy consumption has grown significantly, and the nation is currently dealing with severe energy shortage issues. One of the most popular renewable energy sources is solar energy, which can be obtained either directly or indirectly from sunshine. Street lighting, water desalination applications, electric community systems, electric vehicle transportation, residential water pumping applications, and swimming pool heating are among the fields being studied. This study also demonstrates that the Egyptian government ought to support research institutes in their efforts to use industrial solar energy more seriously. The findings show that solar energy may be used on a massive scale in Egypt to generate electricity and heat water. Benban Park in Egypt, where the average monthly solar radiation exceeds 250 kWh/m2, is the best location for power plant construction.

1. Introduction

Even in overcast weather, solar energy can be directly harvested. Worldwide, solar energy is being used more and more to heat or desalinate water as well as to generate power. The solar radiation power of the solar energy resources reaching the upper boundary of the earth's atmosphere is 1.73 × 1011MW, or approximately 3 × 104 times the power consumed by the world in 1970, based on the total solar radiation power, the average distance between the sun and the earth, and the average diameter of the planet. The atmosphere absorbs 23% of it, reflects around 30% of it into space, and just 47%, or 8.2×1010MW, makes it to the earth's surface, also known as the solar resource on the ground. The oceans receive about 79% of the solar radiation reaching Earth's surface, while the land gets 21% [1]. Of them, only about half, or 8.1×109 MW, are irradiated in places inhabited by humans; the other half, or approximately half, are irradiated in deserted or sparsely populated areas. This is the actual solar energy resource that will be accessible soon. The sunshine conditions around the globe are depicted in Figure 1 around the world [2] while Figure 2 depicts the solar energy map of Egypt [3].

* Marwa M. Ibrahim, National Research Centre, Cairo, Egypt, +201116032559, yara_mh2003@yahoo.com

Renewable and non-renewable energy capacity percentage in Egypt is shown in Figure 3 [4].

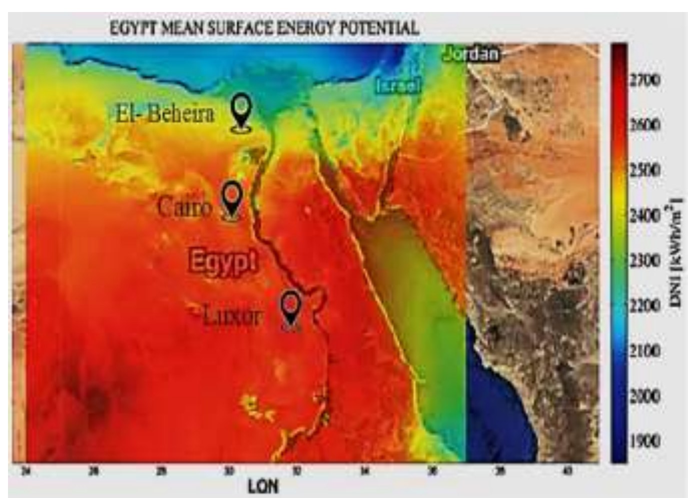

Fig.1: World map of solar energy [2]

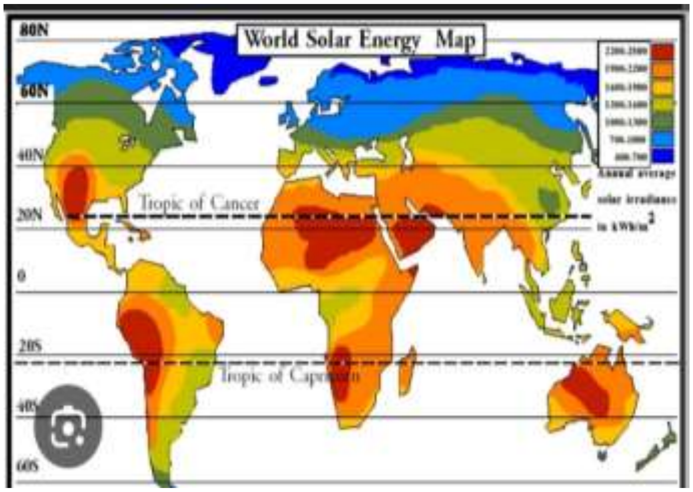

Fig.2: Egypt solar map [3]

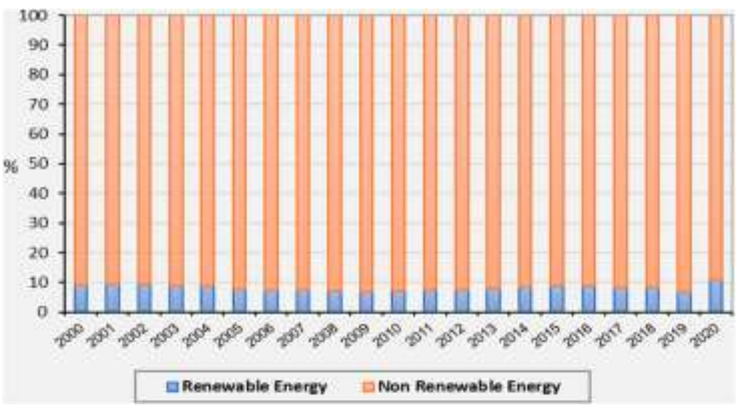

Fig. 3: Relative development of the contribution of renewable energy to Egypt's total energy production [4]

In 2023, the solar power sector saw a record-breaking year. Globally, 447 GW of additional solar capacity was added, a startling 87% increase over the year before as shown in figure 4 [5]. Several significant variables, notably the manufacturing sector's production capacity and the ongoing global oil crisis, contributed to this extraordinary spike. Global manufacturers of solar panels and components have made significant investments in growing their manufacturing sites and modernizing their technologies in recent years. Production capacity for essential components such as polysilicon, wafers, cells, and modules increased significantly in China, the global center for solar manufacturing; by the end of 2023, it is predicted that total module manufacturing capacity will have exceeded 800 GW. Due to the enormous manufacturing scale-up, solar product makers were able to achieve considerable economies of scale, which reduced unit costs and made solar products more accessible than ever. For example, the cost of solar modules fell by almost 50% in 2023 alone, to unthinkable levels only a few years prior.

The rate at which photovoltaics are growing globally is very dynamic and varies greatly per nation. The capacity of solar electricity worldwide hit 1 TW in April 2022 [6]. China topped the world rankings for solar power in 2022 with an installed solar capacity of about 390 GW [7], or about two-fifths of all installed solar capacity worldwide. As of 2022, over 40 countries have a total PV capacity of more than one gigawatt, including Canada, South Africa, Chile, the United Kingdom, South Korea, Austria, Argentina, and the Philippines. The top installers of 2022 included China, the United States, and India [8] Japan, Brazil, the Netherlands, France, Mexico, and Germany were also among the top installers of 2022. While Honduras, Italy, Spain, Germany, and Greece can generate between 9% and 14% of their respective yearly domestic electricity consumption, Australia's existing solar PV capacity is currently enough to supply more than 15% of the country's electrical energy [9]. Solar PV and wind power will account for a record 96% of the increase in capacity added to renewable power sources over the next five years. This is because policies continue to support them because, in the majority of countries, their generating costs are lower than those of both fossil and non-fossil alternatives. It is anticipated that wind and solar PV additions will have more than doubled from 2022 levels by 2028, breaking all previous records to reach over 710 GW. Figure 5 describes yearly solar generation by continent all over the world

Fig. 4: Global Solar Growth 2020-2023 [5]

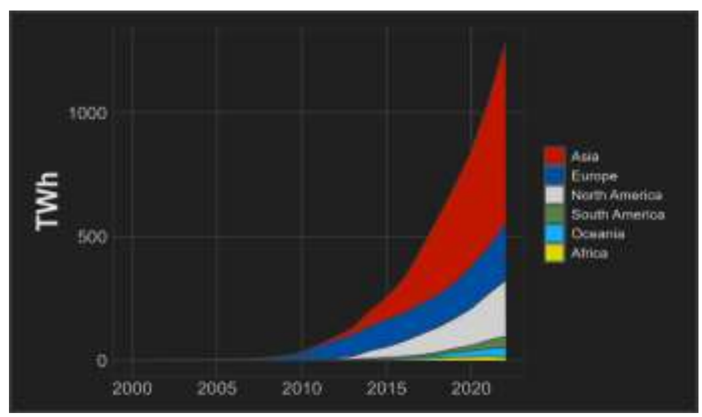

Fig.5: Yearly solar generation by continent over the world [10]

Numerous nations and territories have added significant solar power capacity to their electrical systems as a supplement to or replacement for traditional energy sources. One of two technologies is employed by solar power plants:

- Photovoltaic (PV) systems employ solar panels to directly convert sunlight into electricity, either on rooftops or in solar farms installed in the ground. . Solar photovoltaic (PV) technology uses electronic devices called solar cells to directly convert sunlight into power. It is one of the renewable energy sources that is expanding at the fastest rate and is playing an increasingly important role in the global energy transition. Globally, solar PV will have 710 GW of installed capacity by the end of 2020. The solar PV system's capacity increased by around 125 GW in 2020, the most expansion of any renewable energy source. Solar photovoltaics (PV) converts sunlight directly into electricity through electronic devices known as solar cells. This renewable energy technology is seeing rapid growth and is becoming more significant in the worldwide energy transition. By the end of 2020, the world's installed solar PV capacity had reached 710 GW. 2020 saw the highest capacity growth of any renewable energy source—roughly 125 GW of new solar PV capacity. Because solar PV is so flexible, it may be used for small solar home kits and rooftop installations with capacities ranging from 3 to 20 kW to hundreds of megawatts. It has made producing electricity more democratic. Over the last ten years, there has been a significant decline in the cost of manufacturing solar panels, making them more inexpensive and frequently the most economical source of electricity. Prices for solar modules dropped by as much as 93% between 2010 and 2020. Utility-scale solar PV projects had an 85% decrease in their global weighted average levelized cost of electricity (LCOE) during the same period.

- A turbine transforms the steam produced by concentrated solar power (CSP), commonly referred to as "concentrated solar thermal" plants, into electricity. Mirrors are used in concentrated solar power (CSP) systems to focus sun radiation. By heating the fluid, these rays produce steam, which powers a turbine and produces energy. Large-scale power stations employ CSP to create electricity. The installed capacity of CSP worldwide approached 7 GW by the end of 2020, having increased fivefold between 2010 and 2020. 150 MW were likely put into service in 2020, even if official figures only include 100 MW. The method by which the solar collectors concentrate solar radiation can be used to categorize CSP systems into two types: "linear concentrating" and "point concentrating." The majority of current systems make use of parabolic trough collectors, which are linear concentrating systems. One of a CSP power plant's primary advantages over a solar PV power plant is its ability to store heat in molten salts, enabling electricity generation even after the sun sets. The cost of thermal energy storage has decreased as the market has developed, making 12-hour storage periods viable. As a result, CSP systems now have longer storage durations. Though frequently underestimated, CSP may play an increasingly significant role in the future thanks to its ability to integrate growing shares of variable solar and wind electricity with inexpensive thermal energy storage. Figure 6 shows the Electricity Capacity Trends over the world of 2023 [11]. The development status of solar energy in Egypt is illustrated in figure 7 [12]

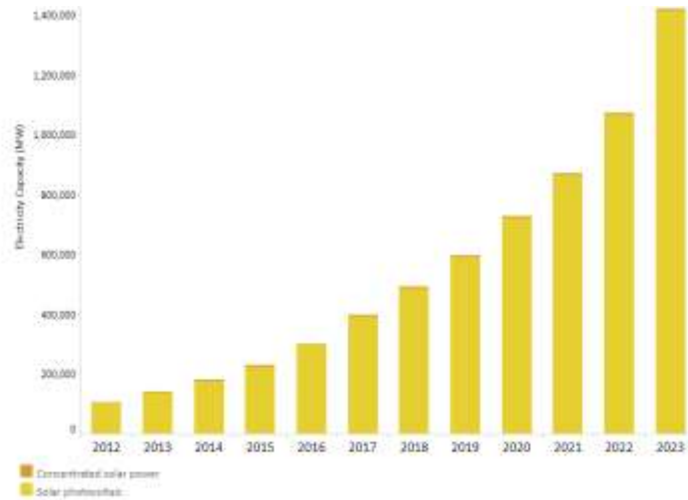

Fig. 6: Electricity Capacity Trends over the World, 2023 [11]

Fig. 7: Development status of solar energy in Egypt in Megawatt, 2023 [12]

Egypt had 1,726 megawatts of solar energy capacity as of 2022. In comparison to the previous year, this constituted a 7.66 percent gain. Additionally, there has been a noticeable increase in solar energy capacity since 2017, although the capacity was comparatively steady between 2010 and 2016.

2. Previous Work

The world's population is growing faster than ever before, and changing consumer behaviors are a few of the primary causes of today's rising energy and electricity usage. The possibility of the world's fossil fuel supply running out shortly has lately come to light. Fuel shortages, rationing and allocation schemes, sharply rising fuel prices, and political and economic instability will follow. In this paper, we focus on solar energy, which shortly has to be the most important source [13]. Over the past few decades, there has been a significant growth in the nation's need for primary energy, and there is currently a severe energy deficit. Oil, gas, and coal are the three conventional energy resources that are finite. The increase in demand is outpacing the rate of domestic production. Solar energy has garnered increased attention due to its very promising potential among various renewable energy sources. Pakistan's [14] energy deficit budget requires a shift from finite fossil fuel reserves to plentiful renewable energy sources. PCSIR and DGNRER focused on solar thermal and photovoltaic systems, with a limited research and development program for solar energy utilization. One use of solar energy that has attracted a lot of interest from experts in this sector is solar water heating systems. This research [15] reviews the three main parts of solar water heater applications: heat transfer fluids, storage tanks, and solar collectors and explores the most recent advancements and innovations in solar water heating. The evolution of solar collector technologies for solar water heaters is also covered, covering non-concentrating (flat plate collectors, evacuated tube collectors) and concentrating (parabolic dish reflectors, parabolic trough collectors) collectors. Uses of the Solar and Wind Energy Resource Assessment (SWERA) database in Brazil include scenario planning and discussion. The study of [16] covers solar power plants for energy production in Brazil, including concentrated solar power plants and solar chimney plants, as well as low-temperature uses, such as small- and large-scale water heating. The outcomes show that solar energy may be used on a wide scale in Brazil to generate power and heat water. If water heating systems were employed to replace home electric shower heads in lower-income families, their payback periods would normally be less than four years. The goal of the study of [17] is to promote the use of industrial solar energy throughout the Arab world, with a focus on Jordan because of its year-round sunny climate. From the perspective of sustainable development, the present prospects of solar energy consumption as a renewable energy option in Nigeria are analyzed and discussed [18]. Being a global producer of natural gas and crude oil, the nation is heavily dependent on these energy sources for the production of power and other energy-related uses. The many uses for solar resources that have been implemented, as well as the level of usage (including specifics of ongoing projects) across the nation, were carefully examined and deliberated.

The conversion of solar energy and the ways used to use it range widely, from passive solar to heating buildings to complicated concentrated form thermos-generate electricity. Understanding these structures in depth and methodically classifying them is essential. We've only touched on the constituent process of main energy sources. The classification of renewable energies, several ways to use solar power, the amount of solar energy that hits the planet, the primary impacts that solar energy creates, and energy conversion techniques—including concentrated solar power—have all been covered in this section [19]. Egypt's freshwater resources are extremely scarce. Drains are also significant non-traditional water resources. This study of [20] aims to accomplish two distinct objectives. Reducing the amount of water that evaporates from the drainage channels is the primary goal. The second goal is to lower CO_2 emissions by using renewable energy in place of the drainage pump station's conventional fuel. Egypt has a large number of outdated drainage pumps, which contribute to tons of estimated CO_2 emissions. For these drainage pumps, solar cell power serves as an alternate fuel source and lowers pollution. The Algharak drain pump station in Egypt was examined as a model for drainage systems. The requirements of the general public and enterprises absorb 80% of conventional energy.

The majority of Indonesia receives sufficient sun radiation, with an average daily exposure of about 4 kWh/m^2 [21]. In essence, solar systems employ solar concentrators and collectors to gather, store, and utilize solar radiation for use in homes, businesses, and industries. sun thermal energy is frequently employed in industry for water desalination, water heating, cooling systems, sun dryers, and space heating. Such technologies are now widely used in energy markets as a stand-in for renewable energy due to a notable drop in cost. This study provides an overview of current developments in photovoltaic applications that have not yet been categorized or analyzed within this framework [22]. Transportation, home applications, street lighting, and water applications are among the fields being studied. Additionally, a summary of the several sub-applications associated with each application family is provided. Greece is a country with a significant solar energy capacity, and this study classifies and discusses the main domains of solar energy exploitation in buildings in Greece. The research examines the effects of the architectural and constructional features of conventional buildings on their corresponding applications, with a focus on systems and technologies applicable to residential and commercial buildings built by accepted design and construction practices [23]. It also looks at pertinent applications in other building categories and in buildings that are designed and constructed with a greater awareness of the environment (green buildings). The study's objective is to enhance buildings' energy and environmental performance in Greece by expanding the use of solar energy and increasing its efficiency.

Although solar energy is available all across the world, the nation's nearest to the equator have the highest potential for producing and using it since they get the most solar radiation. Dhofar, which is in Salalah, is one of the Omani cities with consistently high temperatures [24]. Reports state that the city's greatest solar flux in March was approximately 1360 w/m2, and its maximum total solar flux was approximately 12,586,630 W/m2. Therefore, the current assessment concentrated on the achievements reported for the availability of solar energy sources in different Omani cities and the potential of solar energy as an alternative energy source in Dhofar. The essay reviewed different PV methods and operating conditions and concentrated on modern control systems that enhance the PV energy system's efficiency and performance. The Kingdom of Saudi Arabia is planning to create a megacity and business zone called NEOM (KSA). NEOM [25], which is expected to include an area of more than 26,500 square miles, will prioritize cutting-edge technology and sustainability. Both private funding and the Saudi Arabian government are supporting the initiative. Using renewable energy resources in the NEOM region sustainably is KSA's main goal. This study gathers and processes meteorological data, including temperature and wind speed, and assesses the solar energy availability in the NEOM region both quantitatively and qualitatively. Turkey is ideally located in terms of solar energy potential, being in a sunny belt between 36° and 42° N latitudes. This study of [24] intends to investigate many aspects of solar energy applications in Turkey, including the potential and use of solar energy in the nation as well as a brief historical review. Applications include photovoltaics (PVs), solar water heating, steam generation, sun cookery, solar drying, and solar dwellings were investigated. In 2020, Egypt would produce 89.03% of its energy from fossil fuels, compared to only 10.97% from renewable sources [4]. To be more precise, 2.2% of the energy consumed comes from renewable sources, whereas 97.8% of the energy consumed comes from fossil fuels. Consequently, this study suggests that more research be done to investigate "hybrid" energy sources to address Egypt's energy crisis and protect the environment by utilizing clean energy sources like green hydrogen and attempting to lower emissions from fossil fuels. . One of the most promising renewable energy sources that can satisfy the world's expanding need for conventional energy is the solar thermal power plant. With a focus on an integrated solar combined cycle in Egypt with a total capacity of 140 MW of electricity generated using solar power and natural gas, this review of solar thermal power technology, some of the major issues facing it, and a brief economic overview that researchers have studied are stated [26]. It will be simpler for Egyptian developers, researchers, and decision-makers to comprehend problems impacting solar thermal technology and how to fix them once the data has been evaluated.

Concerns about energy security have arisen in developing countries due to rising energy demand. This has made it crucial to leverage the untapped potential of renewable resources. The greatest option for large-scale renewable energy is now photovoltaic panels installed on a grid. This article [27] analyzes the simulated performance of 126 kWp grid-connected solar systems using PVsyst simulation software. This study looked at whether it would be feasible to install a roof-mounted photovoltaic system to provide the necessary electricity to the HIKMA-Pharma pharmaceutical facility in 6th October City, Giza, Egypt. Approximately 81.74% of the total energy is produced annually. The specific output of usable energy is 1797 kWh/kWp/year (4.92 kWh/kWp/day). Another study [28] implements an intelligent smart street light system for remote areas, identifies the key benefits and drawbacks of SSL, and evaluates its feasibility in such areas using a case study of a Cairo University real estate developer located in the Bolak Al Dakrour district of the state of Giza, Egypt. The main objective is to use the DIALUX 4.12 software package to simulate lighting setups and determine the sizing of system components. This paper's goal [29] is to propose a novel thermal research of the parabolic trough solar collector system's absorber/receiver circular pipe for laminar and turbulent (k-ε model) fluid flow. Two-dimensional numerical simulation is carried out using CFD ANSYS FLUENT software. We talk about the effects of raising the heat flux in the direction of the pipe wall. As the Reynolds number rises, the heat transfer coefficient and Nusselt number increase while the drag and skin friction coefficients decrease. When laminar flow conditions are met, the anticipated PTC thermal performance factor is 74%. The desalination sector views a decline in freshwater costs as a major worry.

This study [30] aims to identify the optimal reverse osmosis desalination system in Ras-Gharib City, Egypt, that is powered by a wind turbine or photovoltaic system. The intended output of the system is 0.5 m^3/hr of potable water. The findings indicate that using solar or wind energy leads in a lower electricity bill than using conventional energy systems. The levelized energy cost of the planned photovoltaic system capacity, based on simulation results, is 3.95 cents/kWh, whereas the wind system's levelized energy cost is 9.5 cents/kWh. One cubic meter of filtered water costs 0.08 dollars to produce with a solar photovoltaic system and 0.19 dollars to produce with a wind turbine system. The purpose of this article [31] is to examine the techno-economic viability of SWHS for swimming pools in resorts and hotels for tourists in El Gouna, Egypt. According to the simulation results, the swimming pool's solar energy contribution is 25.831MWh, while the installed collector power of SWHS is 9,980kW. Annually, 2153 kWh of solar energy are generated with a system efficiency of 75.5%. From an economic perspective, COE is 0.0045$/kWh and NPV is 5878.37$.

To lessen the effect of automobile energy demand overloads on the nation's electric grid, a solar PV system can supply the electrical needs of an EV charging station [32]. To deliver electricity to the charging station and office building appliances, this article describes the design, simulation, and economic analysis of a grid-connected solar power system for an electric charging station at a workplace in 6th October City, Egypt. 34% of the power produced by photovoltaic cells is used for electrical appliances and 66% is used to charge electric vehicles. The cost of producing power is 0.0032 $/kWh after applying the financial analysis for 20 years, and the suggested system will pay for itself in roughly five years. After installing the suggested PV system, the annual energy bills decreased by 21%. To meet the water requirements for livestock and irrigation, this study [33] aims to assess the advantages and disadvantages of solar water pumping systems from both a technical and financial standpoint. It also estimates the ideal system size. The chosen location is a remote agricultural area in Fayoum City, Egypt, where 121 m^3/hr supplies demand a maximum power requirement of 443 kW peak. The findings demonstrated that the net present cost of the PV grid extension pumping system is equal to four times that of the diesel system and three times that of the off-grid PV battery system. The off-grid PV battery system costs 0.332 $/kWh, whereas the diesel system costs 0.434 $/kWh. The cost of electricity for the PV grid extension system is 0.07 $/kWh. Another article [13] details the initial design and construction of a solar tree that will supply electricity for mobile and laptop devices in public metropolitan areas as well as lights at Egypt's Grand Egyptian Museum. The Smart Solar Tree is an innovative, eco-friendly piece of urban furniture that can be used as a stylish, tree-shaped public lighting fixture, a six-person public bench, a supply terminal block with six 230V power outlets for laptops and electric bicycles, and a built-in USB charging hub for smartphones and tablets. The overall cost of the 5 kWp solar tree is USD 1700, whereas the flat-mounted PV system costs $2500.

Ten years is estimated to be the payback period for the solar tree. In contrast to normal photovoltaic systems, which cost 0.11 USD per watt, solar trees only cost 0.07 USD. This year-long research aims to simulate the first dynamic solar heating system to supply sanitary hot water (SHW) and the hot water required to heat 756 villages in the Palm Hilis compound in New Cairo, Egypt [34]. The solar energy contribution to DHW is 14.27 MWh, and the installed collector power of SWHS is 732 kW. Of the system, 97% is powered by solar energy. COE and NPV are, in terms of economics, 0.00083$/kWh and 57072$, respectively. Furthermore, the recommended system costs 0.223 dollars for 1 m^3 of hot water and has a 4.4-year payback period.

The main obstacles to the widespread use of thermal solar energy are the absence of precise data on resource changes and uncertainties, discontinuity throughout the night, and low energy density when compared to the use of fossil fuels, firewood, and electricity. Egypt's electrical and thermal use of solar energy is still relatively small in comparison to the energy generated by burning biomass and fossil fuels, which have higher energy densities and are easier to store. This paper seeks to increase awareness of the application of solar electricity and heating in Egypt while taking into account both the economic and environmental aspects since it presents the first study and approach of this solar application in Egypt. The return period is brief despite the large initial investment, as will be covered in more depth later. The purpose of this work is to (i) give a summary of the state of solar energy development in Egypt, and (ii) talk about potential applications for this resource's development as well as the present barriers to the large-scale development of solar energy conversion systems (SECs) in Egypt. In light of this, this study presents a few uses for solar photovoltaics as the primary energy source. Transportation, residential, agricultural, and desalination applications are among these uses. The surprisingly extensive body of research on these applications demonstrates how versatile PVs are in covering a broad range of applications in critical applications where other conventional or renewable resources cannot match their efficiency and suitability for the job. This paper consists of five parts: introduction of the topic with some statists data is presented in first part. second part introduce pervious work with paper goal while third part illustrates solar energy cells with more fundamental concepts. And electric, thermal applications of solar energy is shown in fourth part while conclusions and future work are exhibited in fifth part.

3. Solar Energy Fundamentals

3.1 Solar cell working principle

A photovoltaic (PV) cell, sometimes referred to as a solar cell, can absorb, reflect, or let light flow straight through it. Since semiconductor material makes up the PV cell, it can conduct electricity more effectively than an insulator but not as effectively as a metal, which is a superior conductor of electricity. Light photons form electron-hole pairs at the p-n junction in solar cells as shown in figure 8, which produces a voltage that can drive current across a connected load. The conversion process is started when light photons enter the p-n junction through the thin p-type layer. They provide enough energy to form many electron-hole pairs. The junction's state of thermal equilibrium is broken by the incident light. The n-type side of the junction can be rapidly reached by the free electrons in the depletion zone. Likewise, the p-type side of the junction might rapidly experience holes in the depletion. The barrier potential of the junction prevents the freshly formed free electrons from continuing to cross it once they reach the n-type side. The barrier potential prevents the freshly formed holes from crossing back over the junction once they get to the p-type side. The p-n junction's ability to separate electrons and holes permits it to operate similarly to a tiny battery cell. PV cells are made of a variety of semiconductor materials. The semiconductor absorbs light energy and transfers it to electrons, which are negatively charged particles found in the material. The electrons can go through the material as an electrical current thanks to this additional energy. The grid-like lines on solar cells, or conductive metal contacts, are where this electricity is extracted and used to power the rest of the electric grid and your house. A photovoltaic cell's efficiency can be defined as the difference between the electrical power it produces and the energy it receives from the light it receives. This ratio shows how well the cell converts energy from one form to another. PV cell production capacity is determined by a number of cell performance parameters as well as the properties (such as wavelengths and intensity) of the available light.

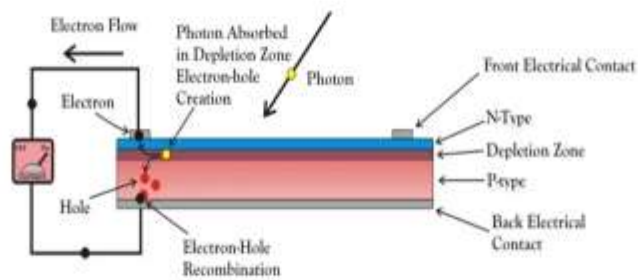

Fig. 8: Solar PV cell working principal scheme

3.2 Solar cell material classification

First-, second-, and third-generation solar cells are distinguished from one another by their active materials and power conversion efficiency (PCE). Silicon is the basis for about 90% of photovoltaic systems used worldwide, and crystalline silicon cells are used in about the same proportion of home solar panel systems. Mono and polycrystalline cells are also derived from crystalline silicon cells. Solar cells can contain silicon in a variety of ways. The quality of the silicon is what counts most, though. This is due to the direct impact on its effectiveness. In this instance, purity refers to the orientation of the silicon molecules. The resulting silicon is purer the better the alignment. This results in higher rates of solar conversion into electrical power. As was already established, efficiency levels depend on how pure the silicon molecules are, and improving purity can be somewhat expensive. To be surprised, though, efficiency isn't the main reason people want to invest in solar energy. For most prospective customers, the price and the amount of room it takes up are the most essential factors. The classification of PV solar cells according to materials is shown in Figure 9.

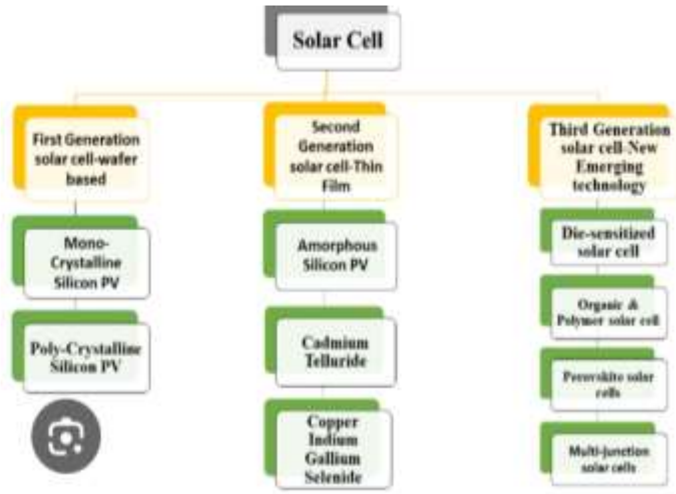

Fig. 9: PV solar cells classification according to materials

3.3 Solar energy power formula

A solar panel's capacity to generate power is contingent upon various aspects, such as its dimensions, effectiveness, positioning, and meteorological circumstances. The purpose of this segment is to provide a thorough method for determining the energy output of a solar photovoltaic array while taking the following variables into account:

- Area of photovoltaic arrays
- Efficiency of the solar modules' conversion
- Place of origin
- Tilt angle of the solar array
- Temperature of operation

Numerous setups for photovoltaic systems are feasible. The following features of a system make this procedure valid:

- Fixed system with no monitoring
- oriented exactly north or south

$$\text{Energy Output (kWh/month)} = \text{Solar Array Area } (m^2) \times \text{Conversion Efficiency} \times \text{Solar Radiation for The Month } (kWh/m^2/day) \quad (1)$$

When estimating solar panel output manually, there are a lot of variables to take into account, which might lead to calculation errors like: solar pane efficiency, solar panel type, power rating, location, orientation of solar panels and maintenance of solar panels. The solar panel output per year is given according to next equation:

$$E = A \times r \times H \times PR \quad (2)$$

Since; E: Energy (kWh)
A: Total solar panel area (m^2)
r: Solar panel efficiency
H: Annual average solar radiation on tilted panels
PR: Performance ratio

4. Solar Energy Applications

4.1 On-Grid BENBAN Solar Park

The project was started in September 2014 as part of the Sustainable Energy Strategy 2035 of the Egyptian government. At first, NASA had helped determine the ideal site for the solar park. With a nominal output capacity of 1650 MW, Benban Solar Park is a photovoltaic power plant that can produce about 3.8 TWh annually. It is situated in the western desert of the Benban (Aswan Governorate), about 40 kilometers northwest of Aswan and 650 kilometers south of Cairo. At the moment, Benban ranks as the fourth-biggest solar power facility globally. The 37.2 km^2 Benban Solar Park is divided into 41 distinct plots in 4 rows, each ranging in size from 0.3 km^2 to 1 km^2. Different enterprises will be able to develop 41 plants on each plot. The Egyptian Electricity Transmission Company (EETC) will build four new substations on the property to connect the 41 plants in the Benban Solar Park to the high-voltage network. These substations will then be connected to a current 220 kV line that is around 12 km away from the Benban Site. In the future, EETC might also build a second connection to the nearby 500 kV line. Part of Egypt's Nubian Suns Feed-in Tariff program, the Benban Solar Park is a significant endeavor to influence private sector funding and expertise to support the target of producing 20% of power from renewable resources by 2022. The map of Benban Solar Park is located in Figure 10. The solar radiation data of Benban Solar Park is described in Figure 11. The scheme of Benban Solar Park is shown in Figure 12. The 4-dollar billion Benban Solar Park in Egypt is mostly financed by the London-based European Bank for Reconstruction & Development (EBRD), which declared on October 24 that the project is now operational. An overview of Benban Solar Park is illustrated in Table 1. Specifications of solar PV module used in this project are exhibited in Table 2. 32 sub-systems scheme of Benban Solar Park is shown in Figure 13.

Fig.10: Location of Benban Solar Park

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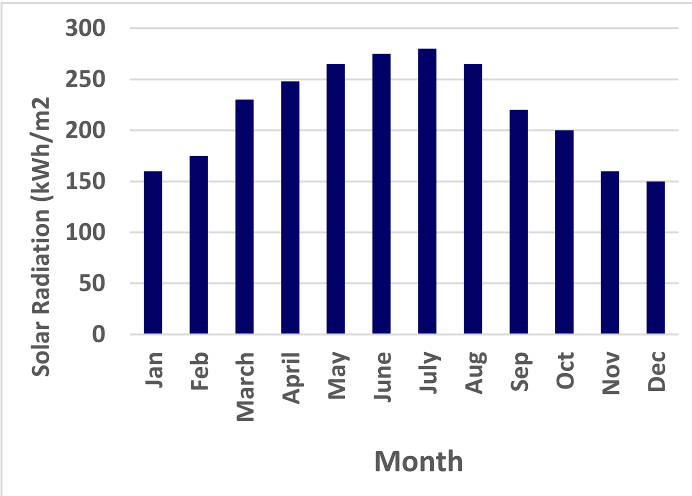

Fig.11: Solar radiation of Benban solar Park

Fig.12: Scheme of Benban Solar Park.

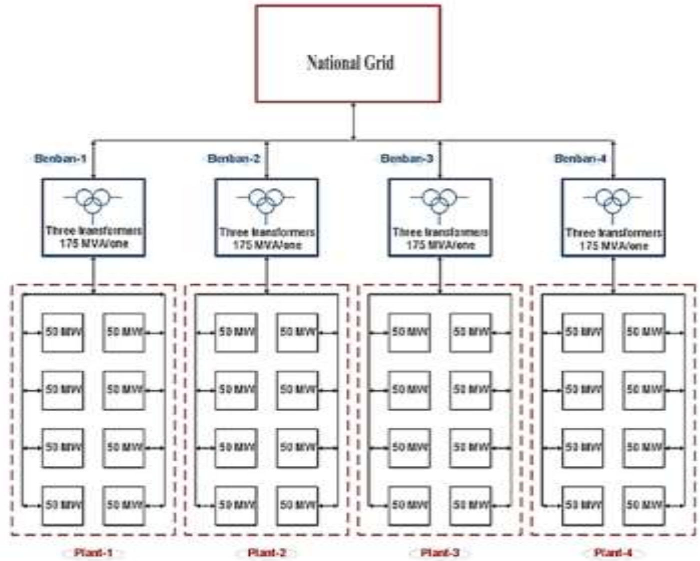

Table 1: Overview of Benban Solar Park

No of projects	Capacity (MW)	Total (MW)
27	50	1350
3	20	60
1	25	25
1	30	30

Table 2: Specification of solar PV module used in Benban Solar Park

Solar module type	JKM330PP-72-V
Maximum power (W)	330
Maximum power voltage (V)	37.8
Maximum power current (A)	8.74
Open circuit voltage (V)	46.9
Short circuit current (A)	9.14
Operating temperature (o C)	from 40 to +85

4.2 Solar thermal power plant

Concentrated Solar Power (CSP) is the most potent and appropriate option among solar technologies due to its capacity to provide both heat and electricity. The most advanced and dependable CSP technology is found in parabolic trough field plants. Since CSP facilities generate electricity using steam, they function similarly to traditional steam power plants. The main distinction is that CSP facilities generate heat using clean, emission-free solar radiation rather than nuclear or fossil sources. The receiver, a crucial part of a CSP plant, has a significant impact on the plant's total effectiveness. It must exhibit both low thermal emittance and high solar absorptance. Solar thermal power plants based on parabolic troughs are the only solar power plant technology that has undergone commercial testing to far. They are therefore great choices for drastically lowering carbon dioxide emissions. At current rates, CSP plants need at least 2000 kWh/m2/y of direct normal irradiance to be profitable. Integrated Solar Combined Cycles (ISCCs) could be an interesting alternative since integrated designs could lead to a highly efficient use of both solar and fossil resources. Using coupled cycles is one way to boost power plant efficiency because they recover exhaust gas heat. The factory is situated in Kuraymat, some 87 kilometers south of Egypt's capital, Cairo. The location is at 29° 16' north latitude and 31° 15' east longitude on the eastern bank of the Nile River. The ISCC Kuraymat project went into commercial operation in June 2011. The first integrated solar combined cycle power plant in Egypt is called Kuraymat. With a 20 MW solar contribution, the plant has a 140 MW capacity. An illustration of an ISCCS featuring a heat recovery steam generator (HRSG) and double-pressure steam turbine is provided in Figure 14. After being extracted from the high-pressure pre-heater, the preheated feed water is evaporated and gently heated in the solar steam generator before being brought back to the HRSG and superheated to the live steam temperature alongside the steam from the conventional evaporator. The steam turbine, preheater, super-heater, and condenser of an ISCCS must be larger than the equivalent parts of

a standard combined cycle (CC) plant using the same gas turbine type due to the increased steam mass flow for the integrated plant. Table 1 is a compilation of the solar field design parameters. The design thermal power of the Solar Island is attained at DNI values between 700 and 800 W/m2, depending on the incident angle and solar field condition. Table 3 indicates specifications of this station.

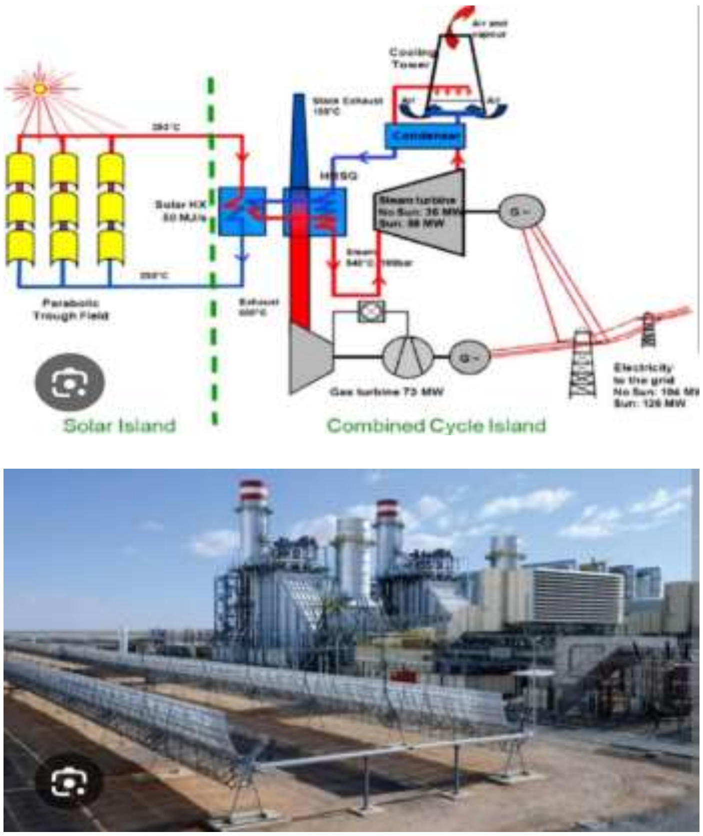

Fig. 14: ISCC Alkuraymat power plant Schematic.

Egypt is working on the 100 MW Kom-Ombo plant in Upper Egypt, which will be its second CSP project. NREA is spearheading the project's development, with assistance from the World Bank, African Development Bank.

4.3 Solar thermal Desalination system

The increasing demand for water in the industrial and urban sectors in arid and semiarid coastal zones has spurred the quest for new nonconventional water resources. Due to Egypt's limited supply of water from the Nile River, the impending drought caused by climate change, and the construction of upstream dams, desalination facilities are the most realistic solution to the massive demand for water in desert areas. The Nile River provides 97% (55.5–109 m3/year) of Egypt's annual renewable water resources [35]. Unconventional water sources include saltwater desalination, wastewater reuse, brackish groundwater desalination, and rainwater collection. Over the past 20 years, groundwater use has dramatically expanded in Egypt. The Egyptian Ministry of Water Resources established a groundwater management department to coordinate groundwater use.

All of Egypt's major aquifer systems, including the fissured basement complex aquifers, the Moghra aquifer, the tertiary aquifer, the carbonate rock complex aquifers, and the Nubian sandstone aquifer, contain significant volumes of brackish nonrenewable groundwater aquifers. More than a century ago, the main objective of desalination in Egypt was to supply drinking water to workers in rural and coastal areas who worked for energy and petroleum businesses. Most desalination facilities are built using thermal techniques. Thermal and membrane technologies are among the many desalination processes used. Thermal desalination includes vapor compression desalination, multistage flash desalination, and multi-effect desalination. Membrane desalination uses forward osmosis, RO, and electro-dialysis.

Table 3: Specifications data of AlKurymat system

Solar Field Aperture Area (m^2)	130800
No of Solar Collector Assemblies (SCAs)	160
No of Loops	40
No of SCAs per Loop	4
No of Modules per SCA	12
Total Collectors Modules	1920
Collector/Heliostat Model	SKAL ET-150
Mirror Model	RP3
Design Irradiation	700 W/m^2
Maximum Solar Field Thermal Power Output	61 MW
HTF Input Temperature	293 °C
HTF Output Temperature	393 °C
Maximum Solar Field Thermal Energy Output	61MWt
Nominal Turbine or Power Cycle Capacity	20 MW
Turbine Model	SST-900
Power Cycle	Steam Rankine

The most significant technique for creating desalinated water in Egypt is RO desalination plants. Over the past ten years, the number and capacity of desalination units have increased, especially in the Gulf countries, where they now make up 42% of global capacity and 45% of Multi-Stage Flash (MSF). The production of desalinated water rose from 850–103 m3/day in 2020 to 1.3–106 m3/day and then to 6.4–106 m3/day in 2050. In many applications, the cost of saltwater desalination has dropped from high to competitive due to notable developments in seawater desalination technology. Tourist communities on the north coast and the Red Sea can use modern technologies because they are far from conventional water sources, which makes transportation more expensive and vulnerable to pollution problems. Egypt's renewable water resources, including desalination, are derived from large brackish water aquifers and over 2,400 km of Mediterranean and Red Sea coastline. Seawater desalination is now being carried out along the coastal districts of the Red Sea to provide enough domestic water for towns and resorts since the economic value of each unit of water in these areas is high enough to offset the cost of desalination. More than a century ago, Egypt began desalination to supply fresh water for domestic consumption in remote areas of public water distribution networks. In the Helwan region, this procedure first took the form of a large distillation tank. But in the mid-1970s, Egypt began implementing advanced desalination technology due to the country's expanding urbanization and population growth in both coastal and rural regions. Between 1975 and 1982, Egypt installed three types of electrodialysis (ED) technology. The salinity of the influent water was between 2000 and 10,000 ppm, and the equipment's capacity varied from 50 to 1000 m3/day. Egypt presently produces between 475 and 106 m^3/year of desalinated water. The current cost of desalinating one cubic meter of saltwater is between 0.7 and 0.9 USD. In 2019, the International Desalination and Water Treatment group (IDWT) and Military Production in Egypt signed an agreement to establish a company that specializes in the production of desalination and water treatment plants, including a large-capacity device like that in Hurgada.

Furthermore, in February 2019, Egypt completed the construction of the largest desalination plant in the world in the Ain Sokhna region, which purifies 136,000 cubic meters of water daily and supplies the Suez Gulf's northwest economic zone. This is on top of three other massive factories in El Galala, East Port Said, and New Alamein, each of which has a daily capacity of 150,000 cubic meters. At a total cost of 9.71 billion EGP, 14 seawater desalination facilities with a daily capacity of 476,000 cubic meters have been completed in the governorates of Matrouh, Red Sea, North Sinai, South Sinai, Port Said, Dakahlia, Suez, and Alexandria. Furthermore, there are 76 seawater desalination facilities with a combined capacity of 831.69 thousand cubic meters per day spread across the governorates of North Sinai, South Sinai, Red Sea, Matrouh, Ismailia, and Suez. This makes a total of 90 desalination plants with a daily capacity of 1.307.69 million cubic meters. According to the investigation's findings, El Alamein has emerged as a highly sought-after location for solar-powered desalination experimental projects. The coastal aquifer system, which offers a possible alternative, is responsible for this appropriateness. This choice was motivated by the growing water needs along the northern coast as well as worries about the salinity of the groundwater. Its allure as a prime location for solar-powered desalination is further enhanced by the region's high levels of sun radiation and consistent temperature. A 1000 m3/day solar-powered RO desalination plant was designed and constructed in the Northern Western Desert (El Alamein area) to use brackish groundwater from two dug wells that draw from the coastal aquifer system, which has a salinity of about 21,150 mg/L. Figure 15 displays the schematic structure of the solar-powered RO desalination plant. The productivity of the RO membrane increases as the temperature of the feed rises, despite a modest drop in salt rejection. The ideal temperature range for the RO membrane's feed is between 5 and 45 °C. The brackish groundwater's feed water temperature is approximately 32 °C and is rather constant throughout the year due to its location approximately 35 meters below the surface of the earth. Figure 16 shows how feed water temperature, output, and salt rejection are related [36]. Predicted future desalination capacities in Egypt (2018–2037) are described in figure 17.

Fig.15: Typical design scheme of solar powered RO desalination plant

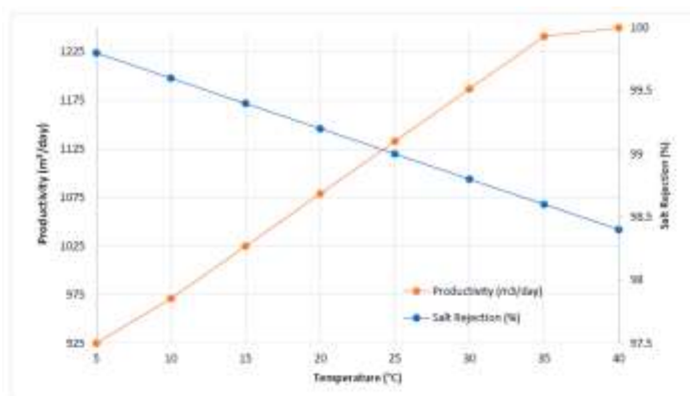

Fig.16: Relation between feed water temperature, productivity and salt rejection [36]

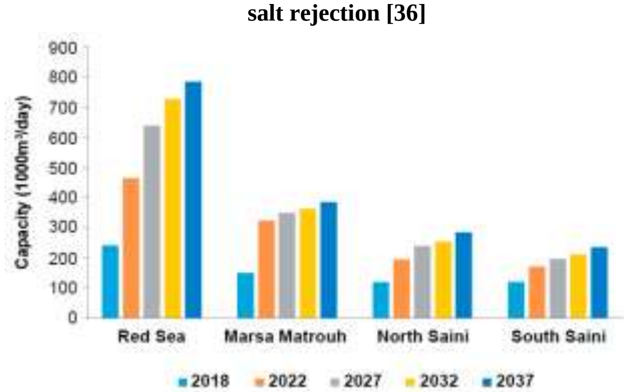

Fig.17: Predicted future desalination capacities in Egypt (2018–2037)

4.4 Solar pumping system

Due to water pollution, inadequate river flow, growing demand from expanding populations, and the rapid development of new rural and urban areas, water has become a more limited resource and a significant issue in many nations worldwide. The agricultural sector employs 25% of the workforce and accounts for around 12% of Egypt's GDP overall. Since pumping water uses a lot of energy, the majority of plants in the world are now fueled by conventional power generating. Fossil fuel prices rise, making their operations even more expensive due to the additional expenses of pollution and greenhouse gas emissions. Since there is a shortage of diesel on the market and diesel fuel is more expensive due to its remoteness when used in abandoned lands, solar photovoltaic modules are viewed as a viable alternative for producing electricity in remote agricultural areas where electricity is required to supply water pumping plants. Solar power for water pumping is a good substitute and an alluring option for traditional diesel-based pumping systems because of the shortage of electricity, high diesel prices, and CO_2 emissions. The capacity of the system components, which may satisfy the demands of plant autonomy and the volume of water required for irrigation, is the primary determinant of the efficiency of photovoltaic water pumping systems. Egypt is one of the most promising countries in the MENA region for solar energy because of its 96% desert territory, high frequency of clear sky days, and solar radiation that ranges from 2000 kW/h in the north to 2600 kW/h (m²/year) in the south. There is a chance to move away from unreliable and unsustainable fossil fuel-powered generators with the advent of solar-powered pumps. Additionally, using solar-powered irrigation reduces the risk of fuel and supply price fluctuations and ensures a steady and dependable on-farm energy source. Crop losses brought on by inadequate irrigation are therefore prevented. With a direct connection between the pump and a solar inverter, standalone solar pump systems for direct irrigation provide an extremely straightforward solution. Nevertheless, there is no backup power source offered by this system. Additionally, inadequate water conservation infrastructure prevents 50% of farms from receiving adequate irrigation. Because diesel prices are rising so quickly these days, maintaining a diesel generator pump system is highly expensive. Finding a sustainable method of irrigation for agriculture is crucial and essential.160kW Solar Water Pump Inverter in Egypt is established in Aswan on May 2022 to develop a new series of solar pumps with the help of VEICHI solar pump drives for agricultural irrigation, fruit tree irrigation of 145m^3/h water for irrigation. The specifications of this system is shown in table 4. Solar water pumping system scheme is presented in figure18.

4.5 Solar water heating system for swimming pool

Using solar energy to heat a swimming pool has always been a smart concept because free solar heat is always better than hefty gas or electric bills. Adding a solar pool heater may drastically lower your swimming pool heating expenses. Maintaining a pleasant and comfortable pool water temperature during warm weather is the aim of solar pool heating. Solar pool heaters have meager yearly operating expenses and are reasonably priced compared to gas and heat pump pool heaters. To maintain a desired temperature throughout the swimming season, bring the pool up to temperature in the spring, or prolong the swimming season, most swimming pools need to be heated in some way.

Table 4: Specification of 160kW solar water pump system

	Pump
Rated power	160 kW
Rated Voltage	380VAC 3 Phase
Rated Current	310A
Rated Frequency	50Hz
Rated RPM	2920RPM
Solar Pump Controller:	
Drive Brand /Model	VEICHI / SI23-D5-160G-A
Rated Output	380VAC 3 Phase
Rated Power/Current	160kW/310A
Input Voltage Range	250VDC –780VDC
Solar Array	
Solar Array	420Pcs
Total Power	226000W
Total Voc	720VDC

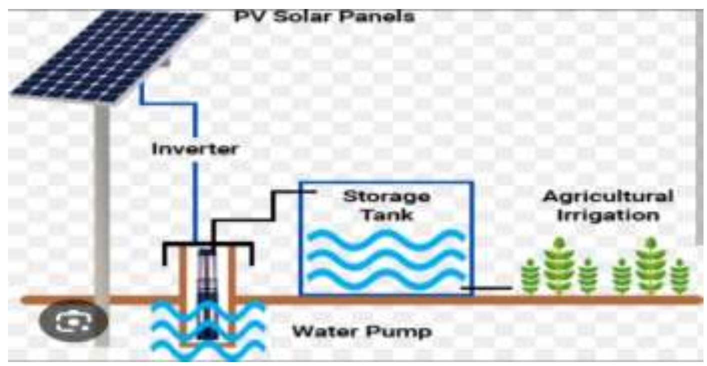

Fig.18: Solar water pumping system scheme

Although you can use electric or conventional gas heaters, your local utility provider may charge you high monthly bills. In certain climates, solar pool heating is one of the most economical uses of solar energy. Before being put back into the pool, the water is heated in the solar collector or collectors after passing through the filter. By running the water through the collector(s) at night, the pool can be cooled in hotter climes throughout the hottest summer months. Even though September through March is the swimming pool season in Egypt, there are still days when it's too cold to swim, and the early morning hours are frequently too chilly to dive in. Maintaining a pleasant and comfortable pool water temperature during warm weather is the aim of solar pool heating. In these cases, the most economical and effective solar collectors are those with open absorber plates. Solar pool heating systems can cover up to 100% of your pool's heating requirements. The size of the system depends on a number of factors, including the amount of solar insulation that is available, wind speed, local temperatures, and collector orientation and angle. El-Gouna, Hurgada, Egypt's tourist resort's outdoor pool serves as the scene. El Gouna, an amazing resort in Egypt created by Orascom Hotels and Development, is well-known for its water sports, which include scuba diving, snorkeling, windsurfing, and water skiing, among many other exhilarating pursuits. This is because it has a wealth of beaches that offer visitors all the activities they need. It is located on the Red Sea in the Red Sea Governorate of Egypt, 20 kilometers north of Hurghada and 25 kilometers from Hurghada International Airport. The El Gouna Film Festival is held at El Gouna, a city on the Red Sea Riviera. El Gouna is 17.73 meters above sea level and can be found at latitude 27.402484 N and longitude 33.6511438 E. the scheme of solar heating system for swimming pool is shown in figure 19.

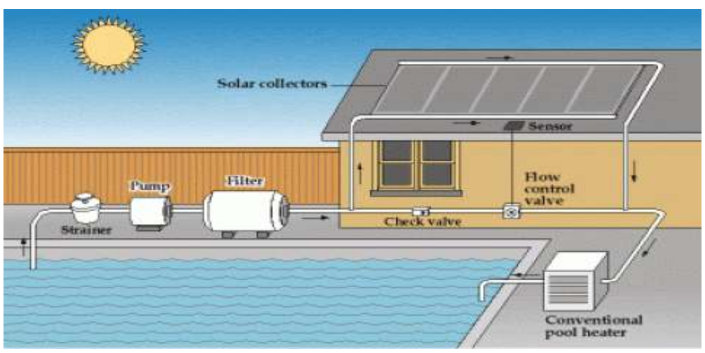

Fig.19: solar water heating system for swimming pool

When the temperature of the collector is sufficiently higher than the pool temperature, some systems use sensors and a manual or automatic valve to redirect water via the collector or collectors. Filtered water just skips the collection or collectors and returns to the pool when the collector and pool temperatures are comparable. Typically, the goal of solar pool heating is to maintain a pleasant and comfortable pool water temperature in moderate weather. Systems with open absorber plate solar collectors are the most economical and efficient in these circumstances. If the system is made to return to the pool while not in use, these unglazed systems can even be used for indoor pools in colder areas. It might be less expensive than building a more costly glazed collector system, even if you have to turn the system off during cold weather. The available solar insolation, wind factors, local average temperatures, and collector orientation and angle all affect the system's size. For an accurate sizing calculation, get in touch with your local supplier. Low water temperatures and less expensive collectors make solar pool heating an economical use of solar energy. The typical cost of purchasing and installing a solar pool heating system is between $2,500 and $4,000. This offers a payback period ranging from one to seven years, contingent on local fuel prices and solar resource availability. Additionally, they usually outlast heat pumps and gas pool heaters. The collector's monthly mean and output temperatures are shown in Figure 20.

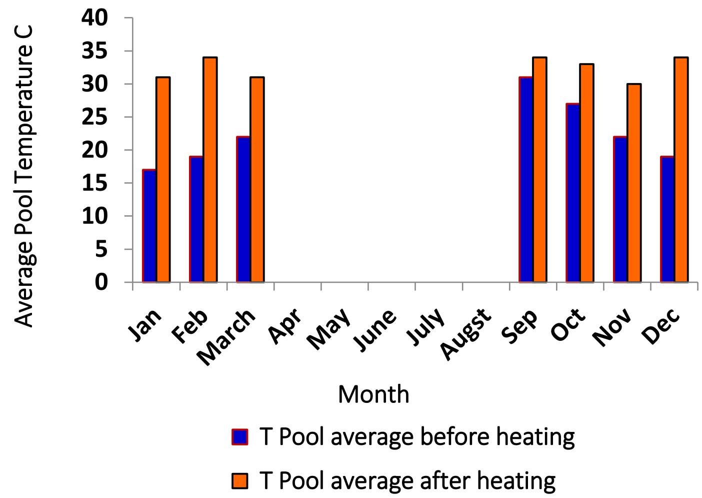

Fig.20: Monthly average temperatures of the pool of SWHS proposed

The net present value of this system is 5878.37 $ and Cost of electric solar energy is 0.0045 $/kWh while Cost of 1 liter of water heated is 0.403 $. Payback period is about 1.5 year and Profit (surplus) is 7824.173 $.

4.6 Solar street lighting

Typically installed on the lighting structure or built into the pole itself, solar street lights are elevated light sources that are powered by solar panels. At night, a fluorescent or LED lamp is powered by a rechargeable battery that is charged by the solar panels. The majority of solar lights use solar panel voltage to sense outdoor light and automatically turn on and off. Solar streetlights are made to function all night long. If the sun is absent from the sky for a long time, many can remain lighted for multiple nights. Lamps from older models weren't LED or fluorescent. To better withstand wind, solar lights placed in windy areas typically have flat panels. Fuzzy control theory and wireless technology are used in modern designs to manage batteries. With the use of this technology, the street lights can function as a network, with each light having the capacity to turn the network on and off. The location is Bolak Al Dakrour, Cairo University's Real Estate Developer's entrance street in Giza, Egypt. With latitude 30° 02' N and longitude 31° 19' E, it is situated at an elevation of 143.6 m. The chosen site's roadway is 32 meters long, 10 meters wide, and has two lanes. It is a residential area with grass (trees) and a sidewalk. Table 5 shows the dimensions and component specifications of the suggested solo solar system illumination. Table 6 shows the components of the bill of quantities BOQ sheet and the approximate cost of solar LED lights [28].

Table 6: BOQ sheet of solar LED luminaries [28]

Electrical BOQ	Quantity	Unit Price (EGP)	Total Price (EGP)
Components			
Solar Street Light 30 W	10	3,200.00	32,000.00
Poles 7m	10	3,200.00	32,000.00
Installing Team			
Installation	1	6,000.00	6,000.00
Team Transportation	1	2,000.00	2,000.00
Total Cost			
Total (Supply + Apply)	1		72,000.00

Here, the cost of systems that generate power is contrasted with the cost of resources. When determining fundamental payback periods, the monthly cost of grid electricity was also considered. It has been reported that the capital cost of an LED roadway powered by an electrical grid distribution system would be $7,250 USD. The estimated capital expenditure for ten light poles equipped with LED street lights powered by solar photovoltaics is $4,500 USD. The cost of the installation is not included in the monthly energy usage charges, which are calculated using the Egyptian power distribution company's tariff rates. According to the Egyptian electricity distribution company, the tariff rate for street lighting is 0.01 USD [40] per unit of energy use (kWh). The annual e-bill that must be paid is approximately $2,400 USD, and the average monthly cost of energy use is $200 USD. The cost of construction is higher than that of a solar panel when compared to the other technologies. Grid construction payback periods of four years were calculated without taking operating costs into consideration. On the other hand, solar-powered systems are nearly cost-free to operate and have a 25-year lifespan. A solar system with a two-year payback period can save e-bills for an extra 4.46 years, or about 60,000 USD, which can be used for other purposes, considering that solar PV systems have a 25-year lifespan.

4.8 Electric vehicle (EV) transportation application

The relationship between solar panels and electric automobiles has grown in importance among homeowners as EVs and sustainable energy solutions have gained popularity. We'll go over the fundamentals of solar panels for EVs in this tutorial, giving you the information you need to decide whether to use solar energy to power your EV. Understanding the dynamics of solar-powered electric vehicles is essential, regardless of whether you're an existing EV owner thinking about solar integration or someone who is exploring both purchases at the same time. A variety of factors influence the precise quantity of solar panels that are advised for an electric car. These variables include your daily mileage, the capacity of your EV battery, and the ability of your solar panels to generate electricity. In general, homeowners may require five to twelve solar panels in order to fully charge their electric vehicle. The majority of EV owners do not, however, charge their batteries from zero every day. A number of variables determine how many solar panels are required to charge an electric vehicle:

- Energy Consumption of the EV: The amount of electricity you need to produce from solar panels depends on how much energy your EV uses. The size of the EV's battery, its efficiency, and your driving style are some of the variables that affect this.
- Efficiency and Output of Solar Panels: A number of variables, including the technology, size, tilt angle, direction, and local weather, affect the efficiency and output of solar panels. Larger arrays or more efficient panels will generate more electricity, meaning you'll need fewer panels to charge your EV.
- Available Sunlight: The energy output of solar panels is influenced by the quantity of sunlight that reaches your area. Areas with less sunlight might need larger solar arrays to make up for it, whereas homes with more sunlight will produce more electricity.
- Charging Patterns: The size and arrangement of your solar panel system will be influenced by your EV charging habits, such as how frequently you charge, when you charge, and how much energy storage you require.

By 2019, the Egyptian government hopes to cut petroleum imports by 10%, and electric cars will help the nation use less petroleum. At a state-owned Wataniya gas station on the Cairo-Suez highway, the country's first EV charging station was inaugurated. Two months later, BMW dealer Bavarian Auto presented the BMWi, Egypt's first electric vehicle. The Wataniya charging station is owned by Revolta Egypt, an electric vehicle technology business. There are already 17 charging stations across the country, according to Badawi (Issue, 2019). Revolta Egypt aims to cover nearly every region of the country in the upcoming two years. A 5.9 kWp solar power system with a charging station is installed on the roof of an office building. This solar power system powers both the charging station and the office building. Electricity generated by photovoltaic power plants can be used to directly charge an electric vehicle during the day. If more electricity is generated than the car requires, a two-way meter can be used to sell excess energy to the grid. Electricity from the national grid is delivered to the charging station and office space at night by the two-way meter. The project, which is located in one of the most affluent areas in the city, is close to the Al Hosary Mosque, the most famous mosque in the city, and the 6th of October Club, the largest gathering spot in the city. The Family Mall may be found at latitude 29.9 N and longitude 30.9 E. Table 7 includes the specs of electric automobiles and charging stations [32]. The PV Generator System Energy (AC grid) is 10,463 kWh/year while Energy from Grid is 80,798 kWh/year. Annual Yield is 1,786.69 kWh/kWp. The Performance Ratio is 84.8 % while Solar Fraction is 11.5 %. Electricity Production Cost is about 0.0032 $/kWh and Payback period of this system is 5.1 year. CO_2 Emissions Avoided is 4,912 kg/year. 31,261 kWh from electric vehicle stations and 60,000 kWh from eclectic appliances for the business buildings make up the system study's total yearly consumption of 91,261 kWh.

The office building consumes 5,199 kWh of electricity directly, the PV generator produces 5.9 kWp, the solar power system produces 10,463 kWh of electricity annually, and the charging auto station receives 5,264 kWh of electricity annually.
The monthly electricity cost savings before and after PV installation are displayed in Figure 21. Electric vehicles have a maximum SOC of 24%.

Table 7: Electric vehicle Parameters & Charging station specifications [32]

Electric vehicle	
Model	e-niro 136 (AC charging 10.5 kW)
Manufacturer	Kia
Range in accordance with WLT	289 km
Consumption	15.3 kWh/100km
Battery capacity	39.2 kWh
No of seats	5
Empty weight	1667 kg
Top speed	155 km/h
Engine power	100 kW/136PS
Discharge power	10.5 kW
Charging station	
Charging station technology	AC type 2
Charging power	10×10.5 kW
Charging mode	PV optimized
Desired range per week	350 km
Time at charging station	8h (from 9 am to 5 pm)
No of trips per week & per vehi	12 (29.2 km per journey)
Mileage per year	10×18250 km (27923 kWh/a)

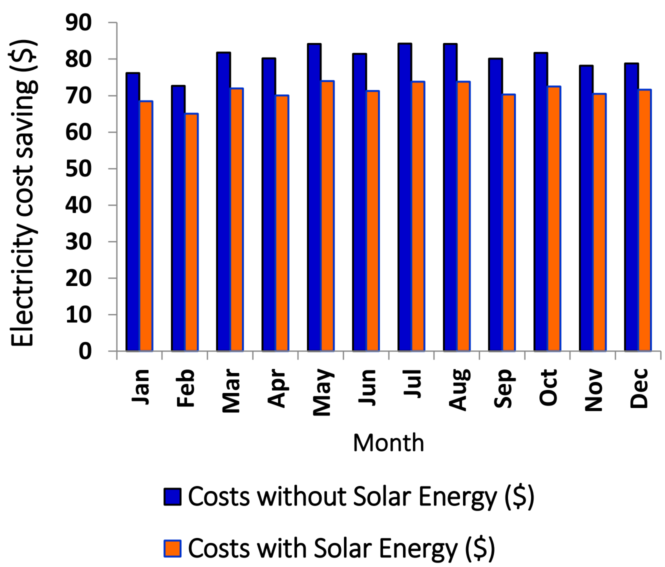

Fig. 21: Electricity cost saving of this proposed system whole the year

5. Conclusions

Buildings in Egypt, a nation abundant in solar energy resources, can benefit to some extent from these resources by (i) integrating suitable systems and (ii) using acceptable design and construction techniques. One of the most important determinants of a country's economic progress is thought to be energy. An amazing and limitless source of energy is the Sun. The power generated by the PV module and the solar potential of the site are related to the conversion and application efficiency of photovoltaic (PV) systems. This study aims to present all current applications of solar energy in Egypt in the forms of electric and thermal systems which wasn't mentioned before. Street lighting, water desalination applications, electric community systems, electric vehicle transportation, residential water pumping applications, and swimming pool heating are among the fields being studied. Therefore, a region's solar parameters are important for solar energy feasibility assessments. Egypt, which is in the Sun Belt, is one of the Omani places with consistently high temperatures. Reports state that the city receives about 250 kWh/m2 of solar radiation on average. The region's fascinating solar potential prompted the need for solar energy investment in the area as a replacement for other non-renewable energy sources like fossil fuel-powered generators. Therefore, the current study concentrated on the potential of solar energy as a substitute energy source as well as the proven successes in having solar energy sources available in different Egyptian towns. It was considered how to generate and consume power in Egypt using both solo and hybrid energy systems. It also emphasized how important global radiation data is for Egypt's PV systems to operate as efficiently as possible. Future research was suggested, and the region's potential for whole solar system application was highlighted. According to the reports, state regulations and initiatives have a significant influence on advancements in the field of solar energy applications in Egypt structures. Beyond all else, the nation benefits greatly from solar radiation, and any initiative to harness it for the sake of the nation's energy balance is worthwhile. Naturally, structures can play a big role in maintaining that equilibrium.

Conflict of Interest

The authors declare no conflict of interest.

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