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Review Article

A Review of Solar Energy Prospects in Palestine

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Abstract: Energy is the main player in the community's development in several aspects. Palestine is an occupied developing country which has a complicated energy sector. Renewable Energy (RE) resources are considered the optimal practical solution to mitigate or resolve the energy crisis in Palestine. Most of Palestine receives solar radiation about 3000 hours annually, and the average solar radiation values range from 5.4 kWh/m^2.day to 6.0 kWh/m^2.day. These results of solar radiation, in addition to the absence of political restrictions on the use of solar energy technology, make solar energy the most viable and feasible choice among other renewable sources. This work objective is to introduce a comprehensive review of the solar energy prospects in Palestine, its geographical data, applications, legislative, and economic potential in contrast to established projects and modules. This review is based on introducing analyzed information about solar energy characteristics in Palestine, Applied solar systems and technology, the policies and legislation, and a recap of strengths, drawbacks, and recommendations. Results showed that best locations for PV solar energy exploitation are Gaza and south West Bank, and worst is Jericho, which leads to resolve many developmental issues in both rural and urban areas.

Keywords: Solar Energy, Irradiance, Photovoltaic Panels, Policies, Development, Palestine

1. Introduction

Energy is the engine of life and the main player in the community's development in several aspects: economically, socially, and its general quality of life. The importance of energy has been historically a cause of nation's conflict. Sufficient energy supply secures community's political and economic stability and provides improved quality of life [1].

In the last century, the world has depended largely on fossil fuels to provide energy [2], due to their vast availability and relatively low cost of mining and extraction. The results were severe on the ecological systems and climate [3]. The consumption of fossil fuel released tremendous amounts of harmful gases (CO_2, SO_2, HC, CO, NO_x, and others), most of them have a proven harmful effect on health and environment and climate [4]. Recently, these resources tend to decay, and their prices became higher as a result of their depletion rate, lack of new discoveries and conflicts [5].

Renewable Energy resources and their technologies have emerged in the last decades as a potential alternative for fossil fuels [6]. In fact, Renewable energy resources have great benefits over fossil fuels, beside the fact that they are a non-exhaustible resource that can provide energy endlessly without the risk of depletion. That means it can be a sole contributor to the sustainable development of communities and states. Also, they release no harmful gases affecting the environment and climate. Even more, they are affordable, clean, and have many applications contributing to developing both urban and rural societies in both developed and developing countries [7].

Palestine is a developing occupied country which has a complicated energy sector, different from other countries in the Middle East. The energy sector is Palestine suffers from the implications of the Israeli occupation. Which is responsible for the severe impacts on all life aspects in Palestine [8]. Gaza Strip and the West Bank are separated from each other. Gaza Strip is under siege since 2007, Israel applies strict bars on energy supplies to Gaza Strip. West Bank is divided into three administrative regions A, B & C as shown in Figure 1: A region with administrative and security control of the Palestinians, and it represents mainly the major cities, B region with administrative authority by Palestinians and security control by the Israelis, and C under the sole sovereignty of Israel, which means that even inside the West Bank, areas lack the administrative geographic continuity which complicates applying a unified plan in the energy sector and almost in most sectors. In fact, about 60% of the West Bank is classified as C areas, which means Palestinians do not have any kind of control over these areas to apply development schemes [9].

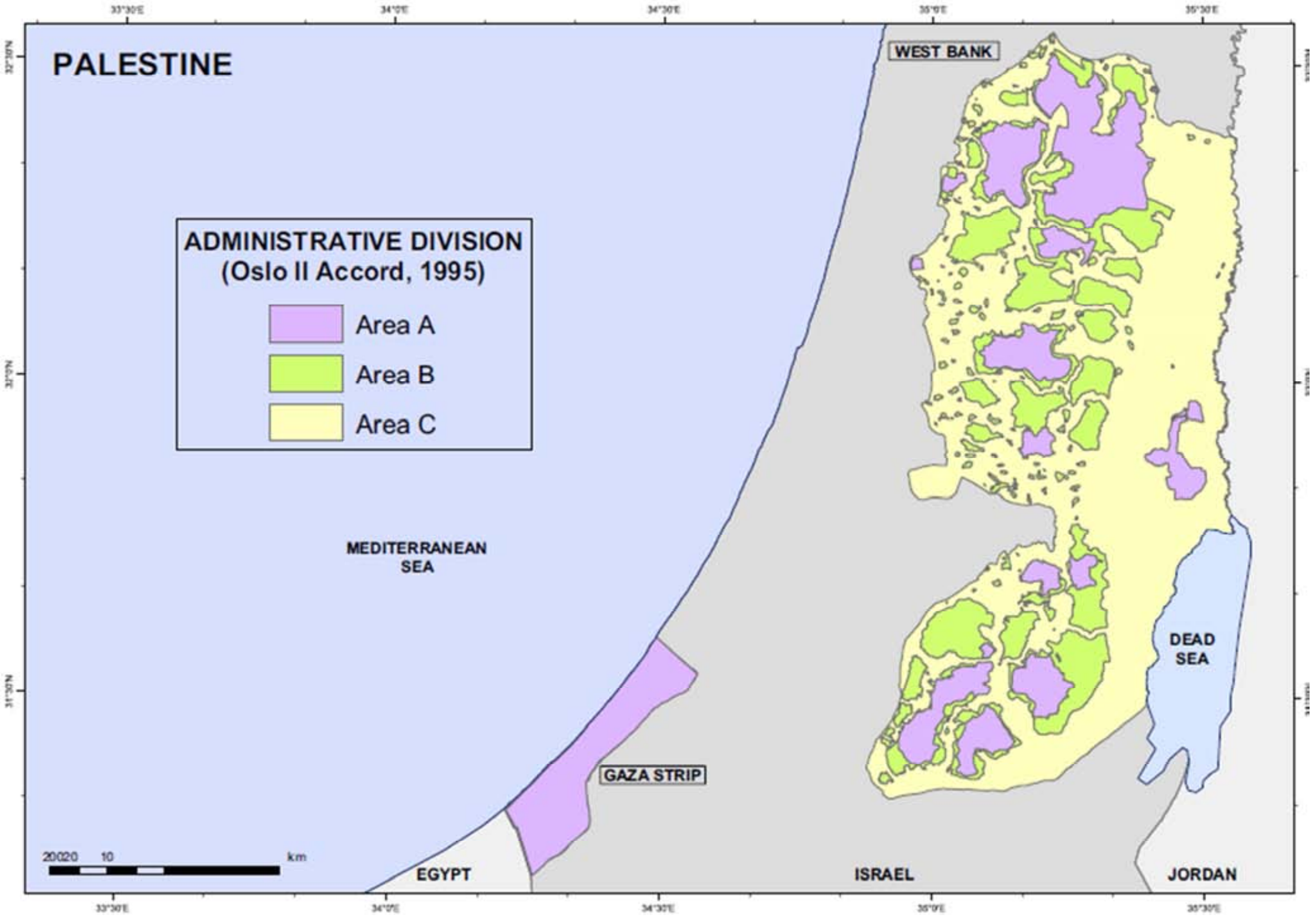

Figure 1. *Administrative Areas in Palestine (West Bank and Gaza) [9].*

Israel controls energy supply to Palestine, about 92% of the electricity and about all oil derivatives and liquid gas are supplied by Israeli companies [10]. The only electricity generation facility is located in Gaza and it works on diesel or gas. While Israel has the sovereignty on Palestinian borders; they prevent energy trade with other countries, which led in turn to unfair energy prices imposed upon Palestinian community. According to Abu Hamed et al [11], energy prices in Palestine are the highest among countries in the region. Gaza strip is not even supplied with enough energy from the Israeli Electricity Company (IEC) and Egyptian Side to fulfill its needs [12], also oil derivatives are barred from Gaza according to the siege applied. With a population of 2,986,714 inhabitants in West Bank and 1,989,970 in Gaza until mid-2019 [13], Poor Electricity infrastructure and the growing demand for energy [14]; the energy sector is in severe condition.

Regarding this situation, RE energy resources should be considered to mitigate or hopefully resolve the energy crisis in Palestine. RE resources could serve strongly in resolving the increasing demand for energy and contribute to sustainable development [15]. The availability of energy, its affordability and sustainability are the factors that define a reliable energy supply that could help in community development and prosperity. For Palestine case; using indigenous resources as RE give it the chance to overcome the barriers imposed by the Israeli occupation in the face of fulfilling Palestinian needs [12]. Palestine is distinguished by promising capabilities of solar, wind and biomass resources, most of Palestine receives solar radiation about 3000 hours annually, and the average solar radiation values range from 5.4 kWh/m^2.day to 6.0 kWh/m^2.day [16]. These values show a reasonable potential for exploitation feasibility compared to other places worldwide such as Madrid-Spain 4.88 kWh/m^2.day, Sydney-Australia 4.64 kWh/m^2.day [14].

According to the political situation of Palestine, RE resources represents a promising, viable resource that could provide energy in a sustainable way, to fuel the development process and mitigate the Israeli occupational impacts on Palestinian Life. Wind energy has its drawbacks that minimize the opportunities in wide range exploitation, for example; a 700-kW wind turbine has been proposed to support electricity demand of Al Ahli hospital in Hebron, but the proposal has failed to be materialized because of the Israeli rejection claiming that wind turbine could interfere with Israeli military air paths. Biomass energy has potential as well through gasification, combustion and other methods and applications [17]. Solar energy is considered the most viable and reasonable choice regarding the fact that most of Palestine receives plenty of sun ray in terms of duration and radiation intensity [18].

Recent studies have been carried out regarding the solar energy in Palestine, Mai Abu Hafeetha [19] has presented a master thesis in urban planning about the implementation of solar energy as an energy option in Palestine. Nassar et al [12] proposed two scenarios showing that Gaza strip could be supplied with solar energy to fulfill its urgent and full needs of electricity. Dradi [20] presented a complete renewable hybrid solution based on solar and wind energy to power up a small rural village including the economics of utilizing. Al-Arda et al [21] presented a recommended plan for sustainable urban development includes utilizing solar energy at many scales to secure energy supplies. This paper objective is to present a comprehensive review of the solar energy prospects in Palestine, its geographical data, applications, legislative, and economic potential in contrast to established projects and modules. As a modest effort to assess the prospects of utilizing solar energy in Palestine, providing clearer, straight forward information about its different aspects with summarizing, discussion and get a recap helping in managing the field of solar energy in Palestine.

This review is based on introducing analyzed information about solar energy characteristics in Palestine, Applied solar systems and technologies, the policies and legislation, and a recap of strengths, drawbacks, and recommendations.

2. Solar Energy Profile in Palestine

2.1. Solar Irradiance Data

The exploitation of solar energy depends basically on the reliable registered solar irradiance data. Same as any investment plan needs sufficient data to assess the risks and the outcomes of that investment, solar irradiance data is considered the cornerstone of the exploitation process. A potential location for exploiting solar energy should have a reliable measured data of solar irradiance. That could be used to assess the investment process and predict the energy yield of that location [16].

Considered solar irradiance types are [22]:

1. *Global Horizontal Irradiance (GHI)*: the total of both direct and diffused irradiance on a horizontal unit area.
2. *Global Tilted Irradiance (GTI)*: the total of both direct and diffused irradiance on a Tilted unit area. Each tilt angle has a corresponding GTI
3. *Direct Normal Irradiance (DNI)*: the total of direct irradiance on a unit area that is always oriented to be normal to the sun and its position in the sky.

For PV panels investment, the GTI is considered at the proposed tilt angle of the panel, which is mostly considered to be the altitude angle [23]. For solar concertation applications; DNI value has to be considered [24]. So, it's crucial to identify the application that is intended to be employed to select the appropriate data for assessment.

Palestine can be divided into three solar zones based on the global solar irradiance (GHI) as clarified in Figure 2 [25]:

A. *High Irradiance Areas*: those are areas have more than 2300 kWh/m^2.Year, they are colored in red in "Figure 2", and mainly are the hilly regions in Jerusalem, Ramallah, Bethlehem, and Hebron. In addition to the coastal areas of Gaza.
B. *Medium Irradiance Areas*: those areas have GHI values from 2200 – 2300 kWh/m^2.Year, they are colored in brown in Figure 2, and mainly are the Jordan Valley, Jericho, Tubas and other areas in the middle north of West Bank.
C. *Low Irradiance Areas*: those areas have GHI values less than 2200 kWh/m^2.Year, they are colored in brown in "Figure 2", and mainly are Jenin, Qalqilya, Tulkarim and other areas west of the West Bank.

These values are obtained from SOLARGIS [27], which provides irradiance data worldwide via satellites for periods between 1994-2013. It's obvious that GHI values are above 1,900 kWh/m^2.Year for most of Palestine and DNI values are above 2,000 kWh/m^2.Year for most areas. These values set the fact that solar exploitation is feasible in Palestine. It's important to know that the values provided have a margin of error. 4.0 – 9.0% for global horizontal irradiance (GHI), 5.0 – 10.0% for direct global tilted irradiance (GTI) and 10.0 – 15.0% for direct normal radiation (DNI) [27]. However, these values give an overview for solar irradiance in Palestine, but cannot be considered for investment and simulation processes. So, metrological data has to be obtained at the potential site to assess its feasibility for investments in either PV panels or concentrated solar collectors.

Many studies have been conducted investigating solar irradiance data in Palestine, according to a study conducted by Alaydi [28] for solar data in Gaza, solar irradiance data features stable pattern and do not change widely from year to year. This means solar data are stable and energy yield will not change thoroughly annually. Alsamamreh [29] conducted a statistical approach to model solar irradiance data in Hebron to an input function using mathematical regression tools. Resulting in a linear formula that could be used in energy outcome simulation. Qassrawi et al [30] have conducted a study that predicts the future yield of PV panels using previous yield data using neural networks. Hussein et al [31] conducted a study to develop empirical models to estimate global solar irradiance in Gaza strip.

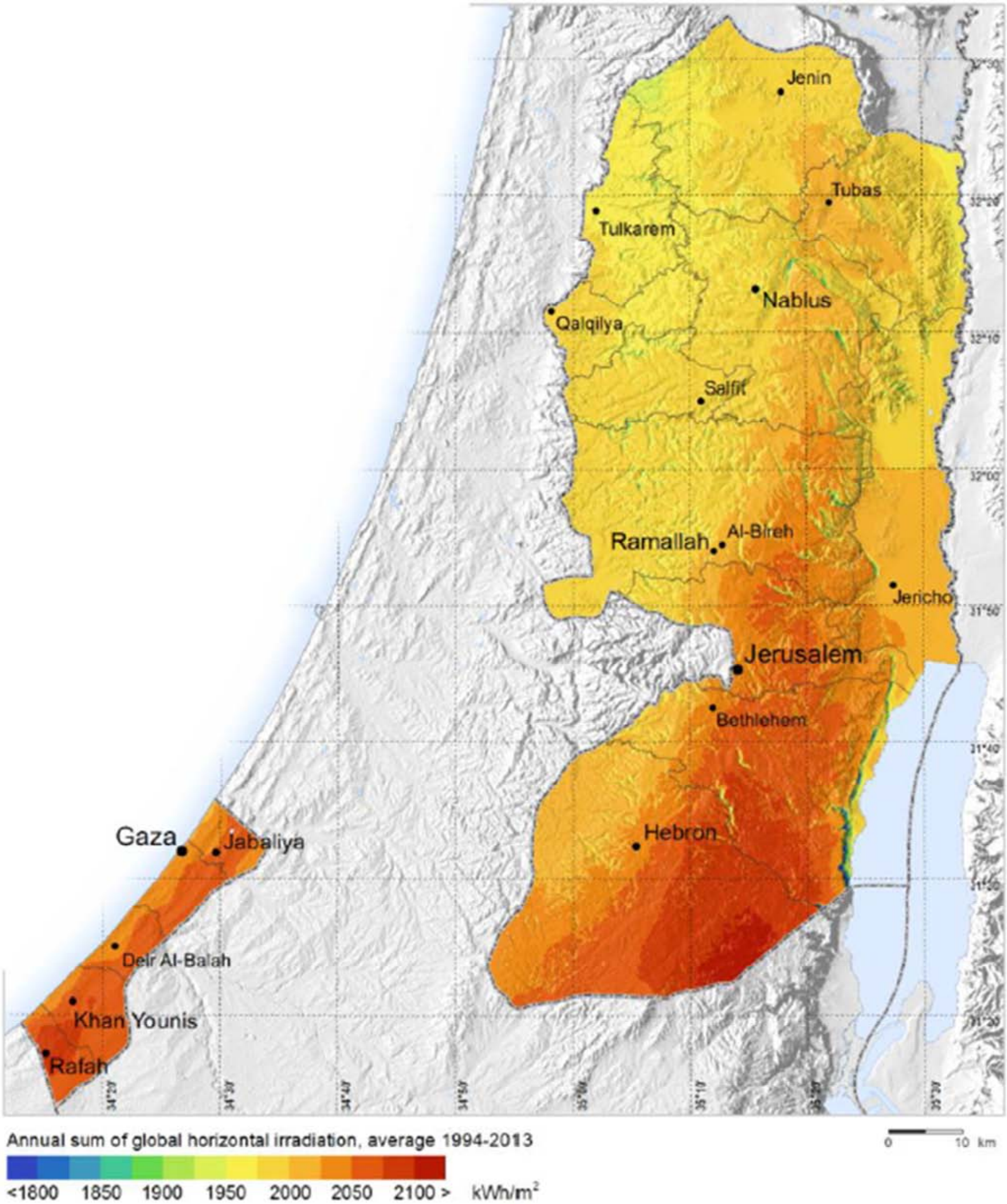

Figure 2. *Annual sum of irradiance for surface inclined to the south with 27^0 degree, period 1994-2013 [26].*

As per the Palestinian Energy and Natural Resources Authority (PENRA), the average GHI in Palestine is 5.4 kWh/m^2.day. it varies from region to another and around the year reaching a minimum average value of 2.63 kWh/m^2.day in December to 8.4 kWh/m^2.day in June, with about 3000 hours of sunshine yearly [25]. “Figure 3” and figure 4 shows the average values of GHI for some Palestinian cities:

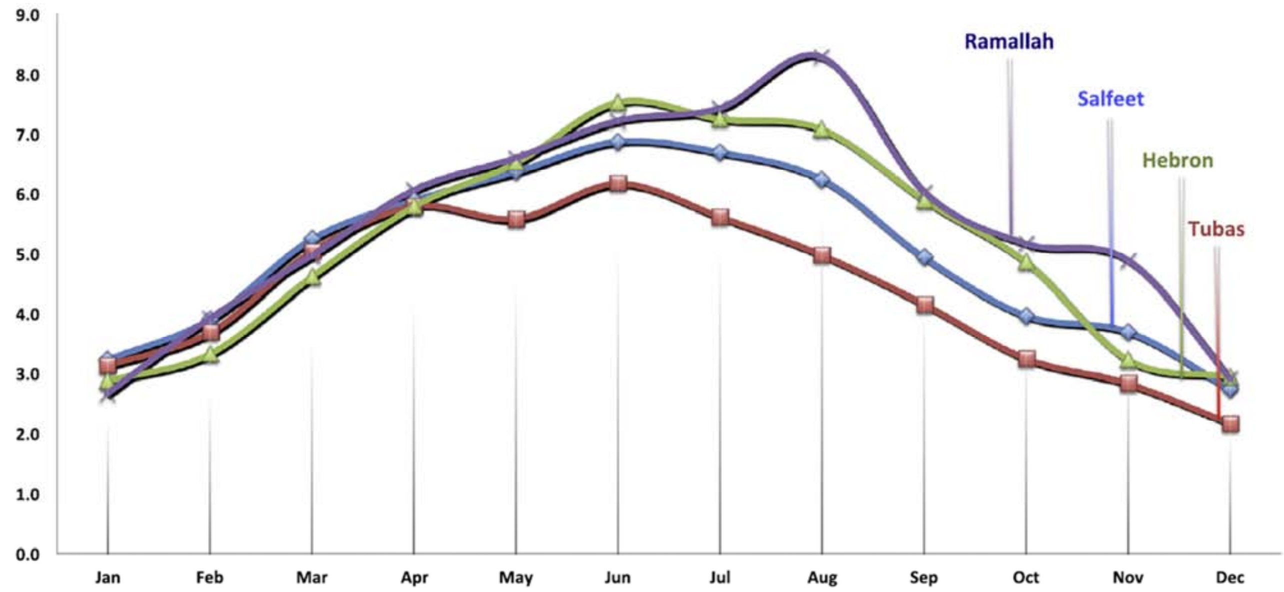

Figure 3. *Monthly average of solar radiation in different cities in West Bank 2010 [14].*

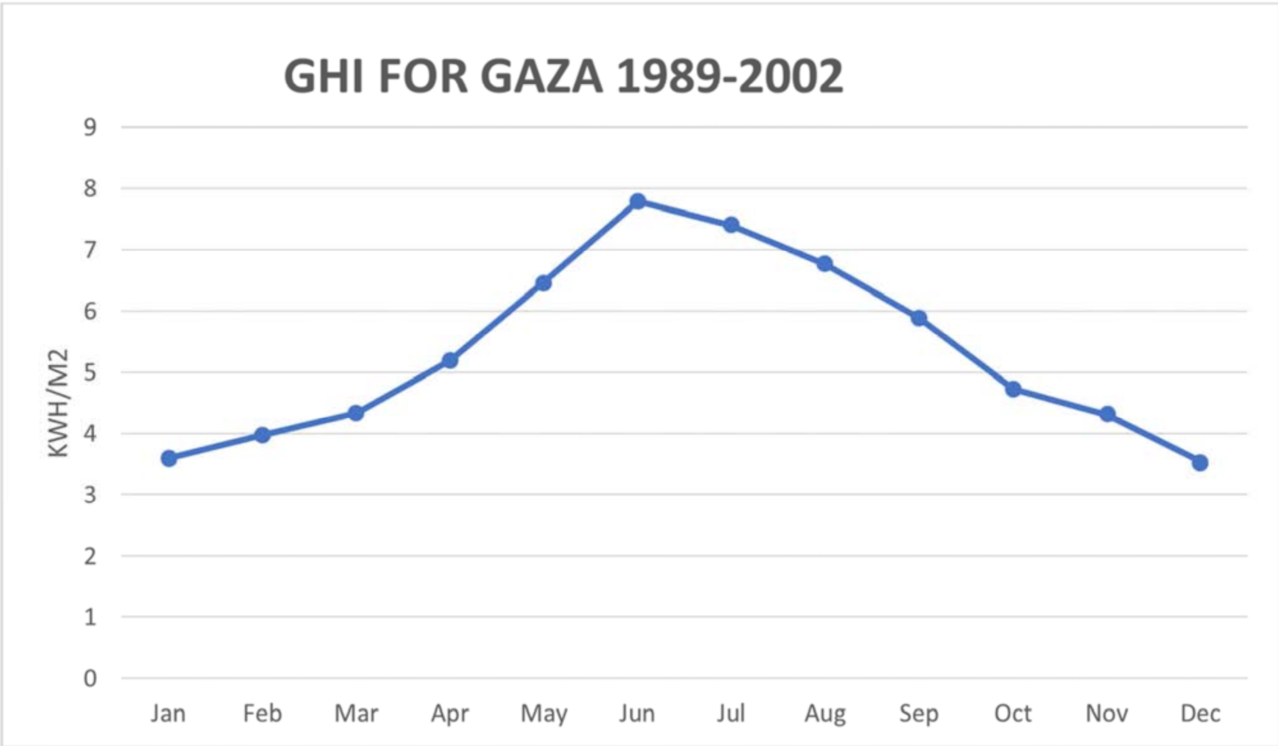

Figure 4. *Monthly average of solar radiation in Gaza 1989-2002 [28].*

2.2. Temperature Effect

One of the variables that should be recognized when utilizing solar energy is air temperature. It affects both photovoltaic panels and thermal solar panels and concentrators. Higher air temperatures lead to reduce the efficiency of the PV panels whereas it enhances the output of the thermal solar systems. However, PV panels efficiency decay for temperatures above 40 C^o [32]. Table 1 and Figure 5 shows the monthly averages of maximum temperature for Palestinian areas.

Table 1. *Monthly averages of maximum temperature for Palestinian areas [25].*

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hilly Areas	14	15.3	18.7	23.8	28.1	30.7	32.5	32.5	30.6	27.1	21.3	16
Jordan Valley	18.2	19.2	23.5	28.3	32.7	35	36.3	36.3	35	31.8	24.7	20.3
North West Bank	14.8	15.7	18.7	23.3	27.8	30.6	32.5	32.9	31.2	28	22.2	16.8

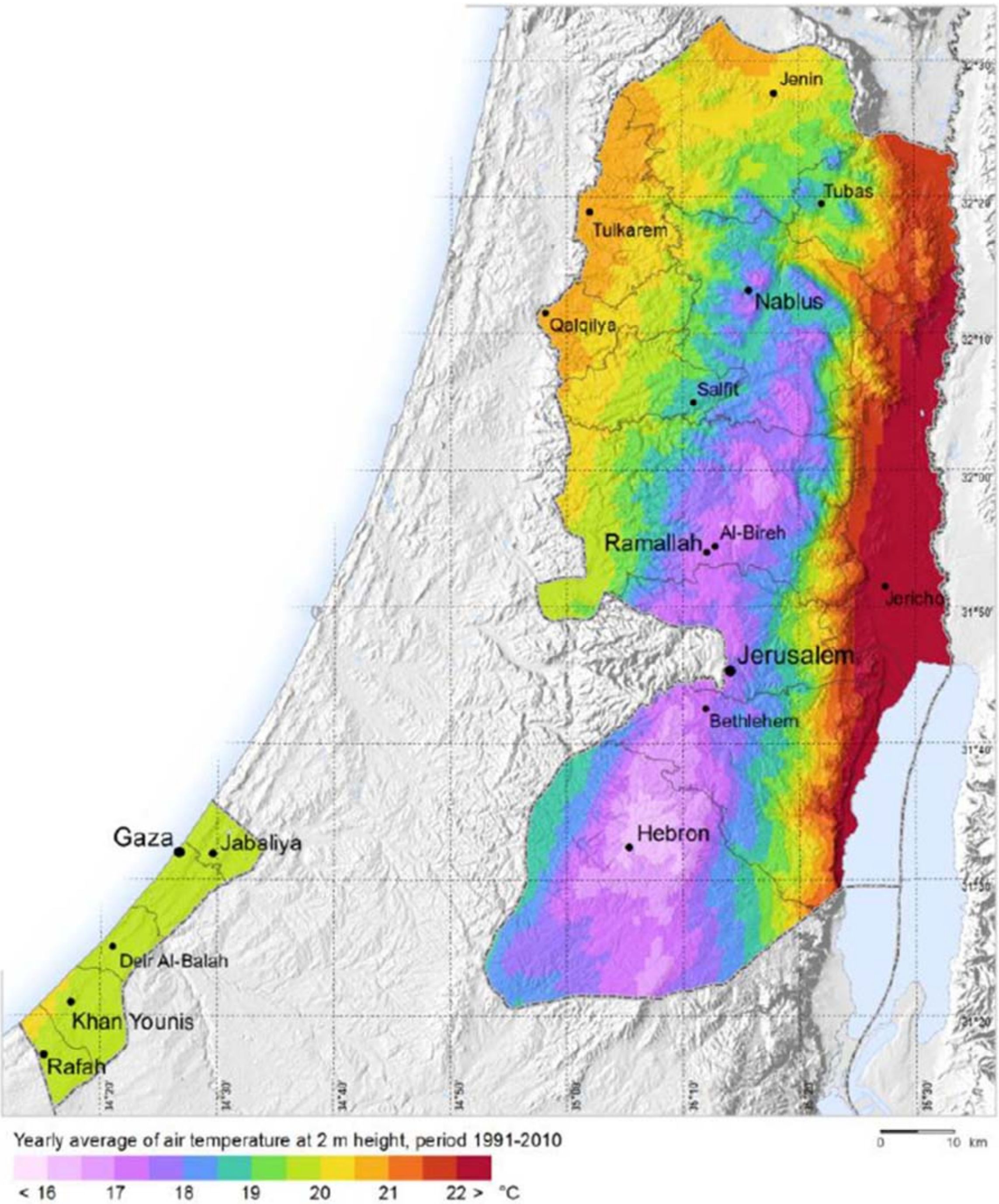

Figure 5. *Annual average air temperature at 2 m height, period 1991-2010 [26].*

Careful examination for the values above leads to the following inferences:

1. Since all average temperatures are below 40 C^{o}, then all solar energy systems work properly.
2. Solar PV panels operate best in Jan, Feb, Mar, Nov & Dec good in Apr, May, Jun, Sep and Oct. Less efficient in Jul and Aug. nevertheless, PV panels still produce much energy in hot months due to the high solar irradiance in summer.

All these observations should be taken into consideration during the assessment of solar PV plants feasibility. Referring to temperature data for Palestine from PENRA 1975-2005. They show that the annual average temperature is moderated all around the years, which means that solar PV panels could be utilized without restraints. The only exception is for Jordan Valley areas, where the temperature exceeds 40 C^{o} for a portion of the summer season. In that case, it's recommended to use monocrystalline PV panels due to their resistance to high temperatures [25].

2.3. Wind and Relative Humidity Effects

Relative humidity and wind data for three major cities in each radiance area are provided as a model [25]:

Table 2. *Relative humidity, evaporation, and rate of wind speed [25].*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A- Hebron Site Representing Hilly Areas (Irradiance Level A)												
Relative Humidity %	76.5	75.6	71.0	62.3	59.9	64.3	66.2	68.9	69.0	67.4	64.4	71.3
Wind Speed Average km/h	13.8	13.6	10.8	13.5	12.0	11.6	12.0	11.7	12.1	11.3	11.5	11.6
B- Jericho Site Representing Jordan Valley (Irradiance Level B)												
Relative Humidity %	53.9	54.0	46.8	40.8	38.8	40.3	43.5	45.5	44.1	4.8	45.2	48.9
Wind Speed Average km/h	58.0	67.0	156.0	217.0	259.0	286.0	309.0	282.0	233.0	148.0	102.0	76.0
C- Nablus Site Representing North West Bank (Irradiance Level C)												
Relative Humidity %	76.3	76.7	73.0	65.4	62.3	66.0	67.8	69.1	67.5	63.5	61.3	69.8
Wind Speed Average km/h	8.2	8.1	8.1	9.5	9.4	10.0	10.6	10.2	8.9	8.5	7.1	7.1

Palestine is considered a humid country. In fact, it's a coastal strip on the Mediterranean Sea. Gaza is the most humid and Jericho is the lowest humid city. West Bank generally is 50 km from coasts of the Mediterranean. Wind blow and direction affect the vapor concentration. So that, relative humidity doesn't follow a certain profile in some region.

Wind and water vapor in the air, both affect radiation in different ways, water vapor absorbs part of the spectrum energy of the irradiance in the invisible infrared band [33]. Wind causes small particles of dust in the desert like areas and sandy particles high sky. So that they become consistent in the atmosphere called (aerosols). The increase of aerosols in the sky increases irradiance scattering "diffusing" in the atmosphere. This takes place on the visible and ultraviolet band of the radiation spectrum. This occurs in Jericho area in the Jordan Valley when the south wind blows. Also, middle Palestinian territories are affected by southern and eastern winds. Hilly areas with more than 700 m height have the lowest aerosol content. Western wind blowing from the Mediterranean is clean, which is the most common wind in most of Palestine, compared to southern and eastern wind coming from deserts [25].

Generally, radiation depends on the value of Aerosol Optical Depth (AOD) [25]. There is no measurement, report or publication represents this factor. However, long term metrological radiation data could include this effect within. But it still has another use, which is more cost on operation and maintenance of PV panels in the desert surrounding or coastal regions.

2.4. Sky Clearance Effect

Cloud formation obscure portion of the solar radiation from reaching the ground, preventing useful exploitation of sunbeams. So, having a sky clearance factor could help in better planning and assessment for a potential location [25].

According to the last report, issued by Palestinian Central Bureau of Statistics (PCBS) 2009 "Climatic Report for Palestinian areas", Table 3 is filled:

Table 3. *Daily shining hours in Palestinian areas [25].*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shining hours in Jordan Valley	5.8	6.8	8.0	9.4	11.2	11.9	11.9	10.9	9.8	7.8	7.5	5.7
Shining hours in West Bank Middle Areas	6.0	7.0	8.0	9.5	11.5	12.3	12.5	11.5	9.9	8.1	7.8	5.3
Shining hours in West Bank Southern Areas	5.4	6.1	8.0	9.1	11.2	11.4	11.5	11.5	9.2	7.6	7.2	5.5
Annual Rate of Shining Hours at Which PV Systems Work at Full Capacity												5.5

Based on these data, the clearance index could be generated using sunshine averages and solar time data as represented in Figure 6.

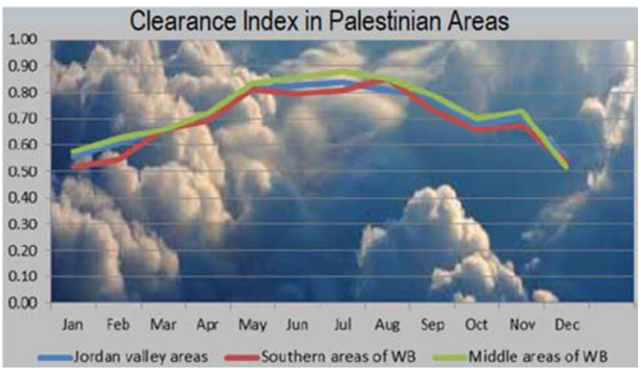

Figure 6. *Clearness index % in Palestinian areas [25].*

This index shows that Palestine has a clear sky most time of the year. Maximum values obtained in summer. It helps to represent the deviation of solar data that obtained theoretically and the operational production based on it. To produce more accurate solar irradiance data profile for further assessment [25].

2.5. Solar Energy Potential Map

Solar data can be represented usefully by summarizing all its parameters on a map, to show cooperatively the solar data at each location. Defining the main areas of better potential.

West Bank and Gaza strip have many potential locations to consider building solar energy harnessing plants. But it's useful to benefit from suitable circumstances in an area to get the best project outcomes. Namely, the best locations for using photovoltaic panels is where the temperature is moderate, low natural pollution (dust, sand…etc.). such areas can be found in eastern parts, western parts of West Bank, and in eastern parts of Gaza Strip [25].

Figure 7 represents the annual electricity product of solar PV panel of 1.0 kW peak output [26]. By investigating the color index of the map, more red areas hold better electricity output ignoring other factors of deficiency such as air temperature or aerosol content. Geographic location determines the potential outcome of the solar PV plant.

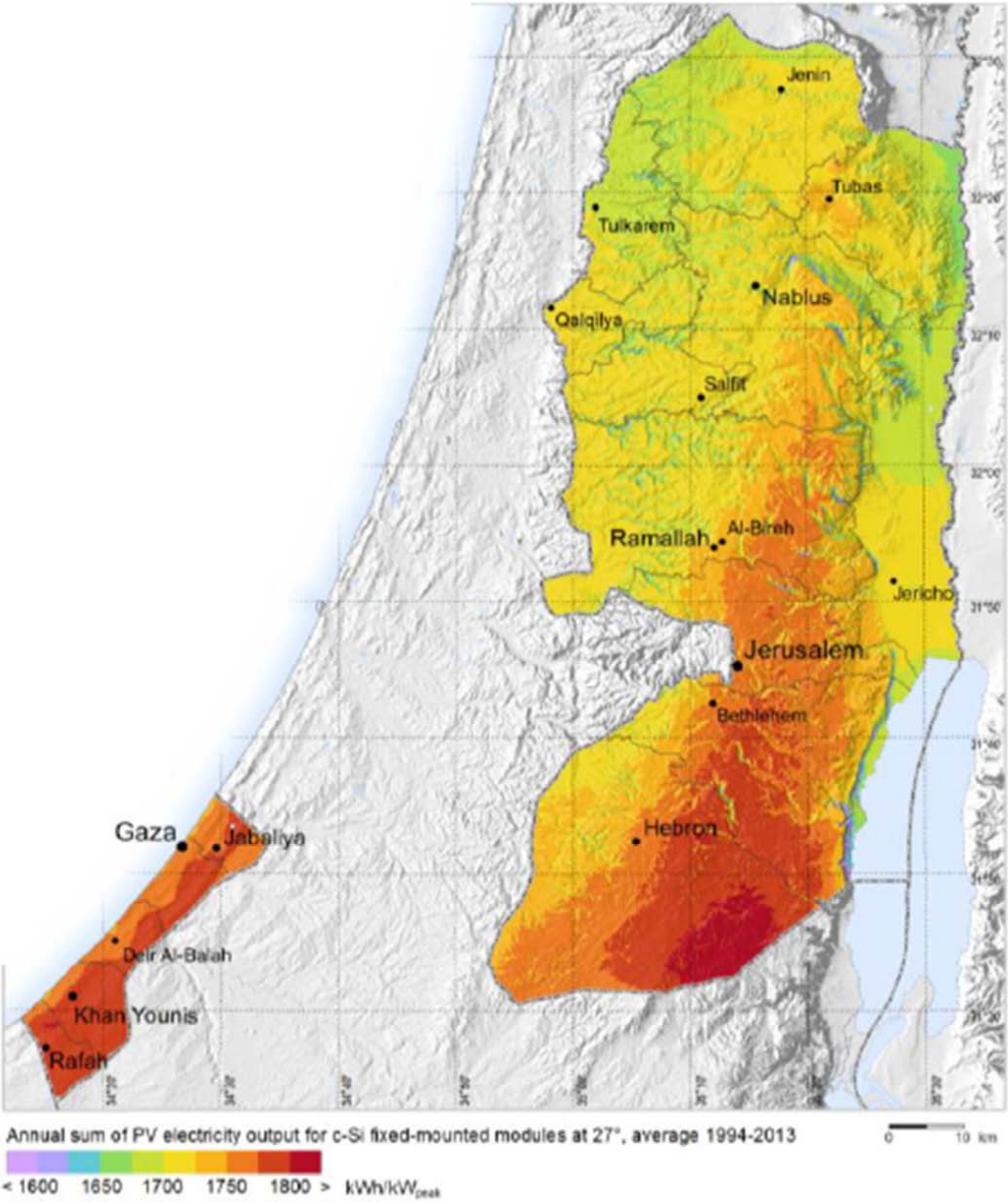

Figure 7. *Annual PV electricity output from an open space tilted due south with 27^0 with a nominal peak of 1 kW [26].*

Table 4 also, predicts the energy output considering also the climatic conditions in each area band. It varies between 1,700 kWh/m^2.Year to 1,765 kWh/m^2.Year. maximum outcomes could be obtained in Gaza and far south of the West Bank higher as 1,800 kWh/m^2.Year [25].

***Table 4.** Annual average of electricity yield of 1 kW PV panel tilted due south with 27^0 [26].*

Palestinian Areas with Different Irradiance Levels			
	Level A	**Level B**	**Level C**
PV Electricity yield for fixed-mounted modules at optimum angle "kWh/kWp"	1765.0	1715.0	1703.0
Optimum Angle "Degree"	27	27	27

Due to the geographic and climatic circumstances in Palestine. Gaza Strip is considered the best for power generation via PV panels, and Jericho is worst due to its high temperatures and aerosol air content [25].

On the other hand, solar thermal systems are less sensitive than PV panels for temperature and aerosol contents. That's related to the fact that solar heating panels take advantage from the whole frequency's spectrum of solar radiation, unlike PV panels which exploit high frequencies only. Solar water heaters have the potential to be employed increasingly in residential, commercial and industrial scales. Their abundant infrastructure and existing long experience. Makes the investment in solar water heaters less expensive and profitable with relatively low payback periods [34].

According to collected data, many feasibility studies have been proposed for solar energy utilizing. Leading to establish many pilot projects.

3. Solar Energy Applications in Palestine

Solar energy viability in Palestine has encouraged not only researchers but also organizations to establish solar energy-based projects and industries [35]. Due to the availability of the irradiance and the high prices of energy [5], people and organizations started to employ solar energy to fulfill needs.

Solar energy projects in Palestine has two main themes: electrification and hot water production [25]. Electrification for general domestic use, power up remote rural societies, water pumping and desalination. Hot water production for domestic water heating for homes, commercial buildings, hospitals, factories. And for heating purposes such as greenhouse heating, swimming pools heating, space heating.

3.1. Solar Energy PV System for Direct Electrification

As a country with 92% of its electricity imports from Israel [14]. Electricity generation using photovoltaic panels has emerged strongly in the local market, taking advantage of the reduced prices of the PV panels and encouraging governmental policies [35, 36]. Many types of research have been conducted to assess the potential outcome of utilizing PV panels and their potential contribution to the gross electricity demand. A study conducted regarding solar exploitation in Gaza concluded that PV utilizing has the capacity to fulfill the urgent needs of electricity to fulfill Gaza strip electricity requirements. Even more, in the better scenario; it could fulfill the full needs of Gaza Strip electricity by using rooftops of buildings and available areas for PV electrification [12]. Also, in a step to encourage the utilizing of PV panels in Gaza for electrification, PENRA has launched with the cooperation of Gaza Electricity Distribution Company (GEDCO) the "Rotating Box Project" [37]. Which is directed to domestic homes and small utilities, to install PV panels of different capacities with payback plan with no interests. Jerusalem Electricity Distribution Company (JEDCO) also provides the option of purchasing the generated electricity via solar PV panels with the same purchase rate from the Israeli Electricity Company (IEC) [25]. These circumstances have encouraged more customers to emerge in utilizing solar energy to reduce the financial burden of high energy prices and revenue in the future.

Solar PV electrification also proved to be more feasible to use against diesel generators for electrification of remote areas. A study was conducted to investigate the feasibility of solar energy to power a remote village in Tubas area of the West Bank (Atouf), concluded that rural areas can be powered via PV panels for electrification in a more feasible way in terms of erection and production scopes, better than diesel generation or extension of the local grid [38]. Many projects have been also established to electrify remote villages and utilities such as Imneizil Village South of Hebron. It's widely used for electrification for Bedouin's assemblies in southern areas [39].

Also, PV electrification emerged in utility systems, such as universities, hospitals, clinics. Taking advantage of their available roof areas, many have started installing PV panels to secure a part of the utility energy bill. Many examples such as Birzeit University campus [40], Al Ahli Hospital [41] and many others, a Project now is intended to implement PV electrification for 500 schools between the ministry of education and Palestinian Investment Fund (PFI) [42].

Due to the successful emerging of PV panels electrification. The specialized power plant has been established and under construction for continuous electricity generation on the grid. An agreement between Palestine and Japan has been signed to establish a PV power generation plant of a total capacity of 300 to 500 kW [43]. Another has been made with Chez Republic for Tubas Agricultural Industrial Plan of 120 kW [21]. But the most distinguished project is the solar power plant in Jericho of a total capacity of 100 MW. This project will be executed through a multistage procedure [21]. And according to Palestinian energy national plan [43], the total energy production constructed by 2013 will be 200 MW in West Bank and 280 MW in Gaza. In Gaza Strip, two main projects are under construction: one with a total capacity of 7 MW, and the other is 40 MW under the project "Turn on the Lights in Gaza" [12].

3.2. Solar Energy for Well Water Pumping and Irrigation

As energy is a crucial factor in supporting living standards in a society, the availability of water also is important for providing a decent living standard. In Palestinian remote rural communities; water availability is a problem. Most of these societies depend on tankers to provide their water requirements [44].

For such applications, water could be pumped either via a diesel-powered pump, or solar powered pump. According to SELF [45], Solar powered pumping is more reliable and feasible than diesel-powered pumps. Also, Naim mentioned that solar-powered pumping is more feasible than diesel-powered pumping in flowrates below 2000 m^3/day and cheaper in flowrates below 1,200 m^3/day [46].

Solar pumping projects have been carried out in many remote rural areas in Palestine, such as Yanoon Village [39], many studies and proposal have been made for this application. It's considered useful exploitation for solar energy that helps remote areas to stand and support their life needs in the seize threatened regions by Israel. In Gaza strip, many regions have shallow water under several meters below but due to the absence of electricity, people depend on diesel pumps to pump out and irrigation [46]. A study has been proposed by Alsayid et al [47] for automatic irrigation system powered by solar 2 axis tracking PV panels. The study illustrated the validity of this option and considered a step forward in agriculture sector reinforcement in case of application. Especially knowing the problems facing remote agricultural areas with electricity and operational costs.

3.3. Solar Energy for Water Desalination

Water resources in Palestine come majorly from underground water. Generally, Palestine faces an ongoing water crisis all the time as a result of the Israeli control of water resources [48]. Water is being sold to the Palestinians by Mekorot (Israel Water Company) at high prices. But the problem becomes more severe in Gaza strip and Jordan Valley. Where there is a high shortage of water supply from the Israeli company, but the common character of both is containing shallow brackish water that cannot be used for human consumption.

Utilizing solar energy to desalinate these water resources is a solution that mitigates the problem of water supply. Studies and researches have been conducted to test the feasibility of using solar energy in desalination of seawater or brackish water. According to Abu-Jabal [49], desalination using evaporative distillation with triple effect evaporators is feasible for our region. While evaporative desalination is considered large energy consuming procedure with best desalination results; and it is feasible to implement, this means that less consuming energy procedures are feasible too.

The most popular way to desalinate water is using Reversed Osmosis (RO) membranes. These membranes reduce the salinity of water to the limits that qualify to be potable water. A practical study has been conducted by Imad Khatib [50] based on the model shown in Figure 8:

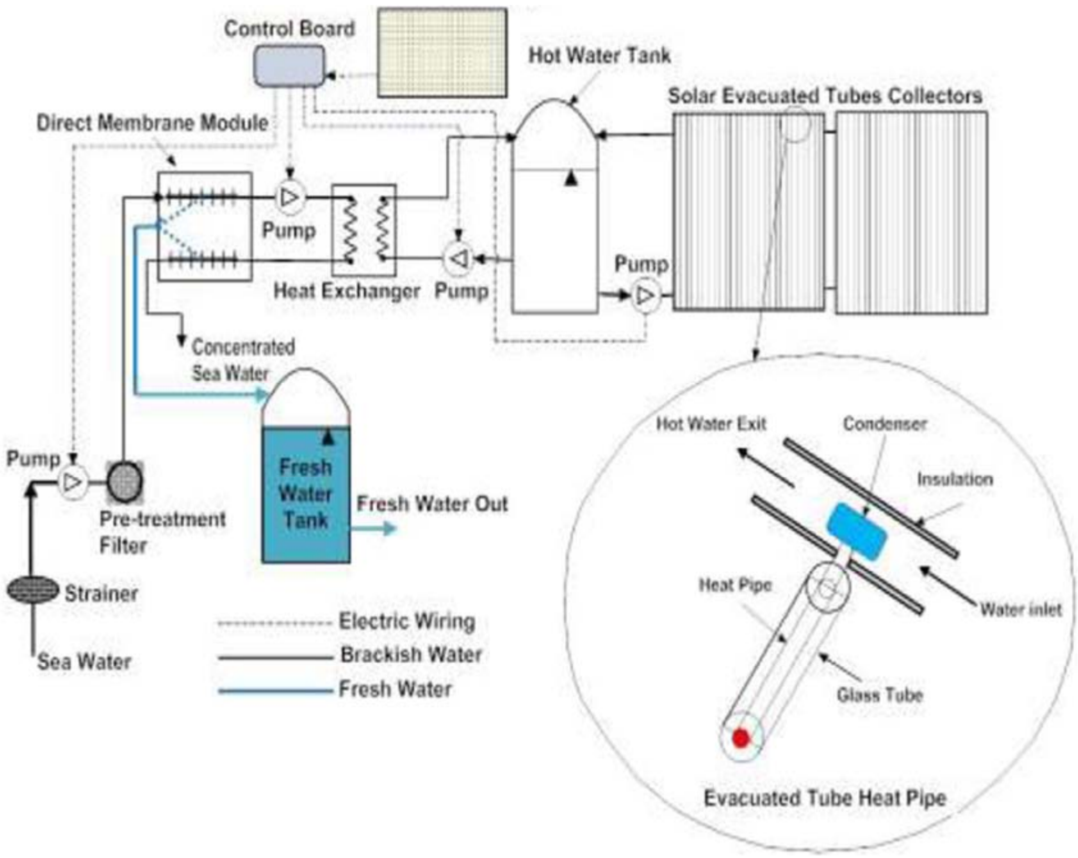

Figure 8. *A Schematic draw of solar-powered desalination system [50].*

Referring to Khatib study, the proposed system above utilizes both PV panels and solar water heaters, occupies 30 m^2 and produces 30 – 50 Lt/Hr.

In Jordan Valley, water is brackish in some areas. Water solar desalination project has been established as a pilot project in Zubeidat Village, which has three wells with brackish water. According to the outcomes, for a salinity of 2681 mg/l. a 435 W plant is required to extract one cubic meter of fresh water a day. The energy needed to obtain fresh water is 2.35 kWh/m^3. A schematic layout for the plant is shown in Figure 9 [44].

These values give a useful overview of how much feasible is the exploitation of solar energy in water desalination. This field can improve the lives of people in Jordan Valley and Gaza Strip, and provide them with continuous potable water.

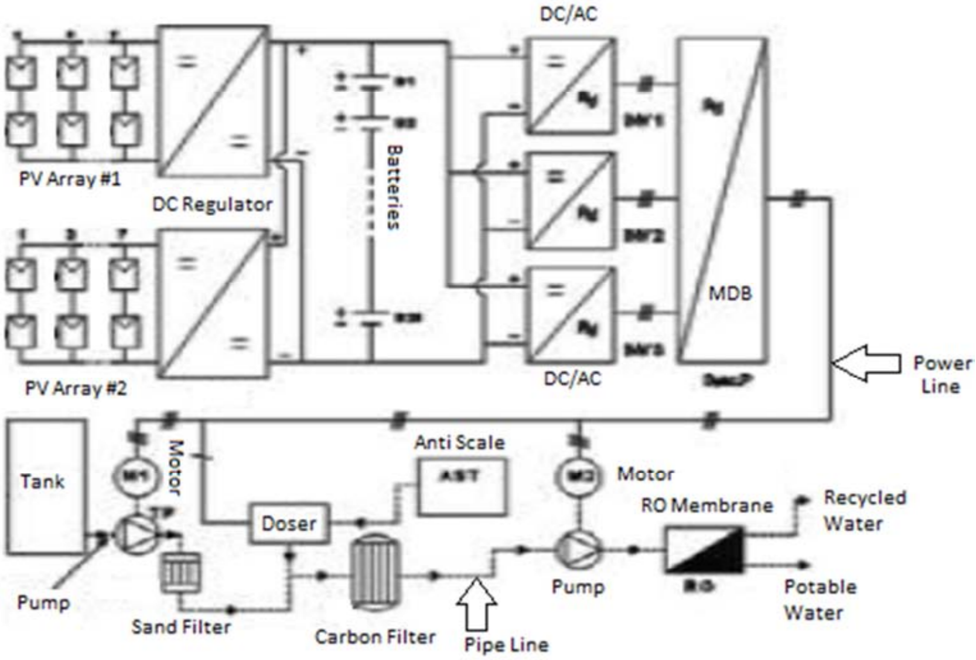

Figure 9. *Photovoltaic powered RO desalination system [44].*

3.4. Solar Energy for Heating Applications

Utilizing solar energy is widely used in Palestine in domestic water heating. As per A. Juaidi [14], Palestinians consumed 18% of the gross energy consumption on water heating. 65% of that consumed energy was solar generated (Figure 10). Due to the high rates of electricity and fuel in Palestine due to the Israeli occupation, solar water heaters (flat panel type) and its accessories have emerged earlier than PV Panels, Palestine has many companies for manufacturing and utilizing solar water heaters. Although 75% of the Palestinian residences have solar water heaters [51], further growth is occurring on solar water heating in the utilities. Such as hospitals, factories, and commercial buildings.

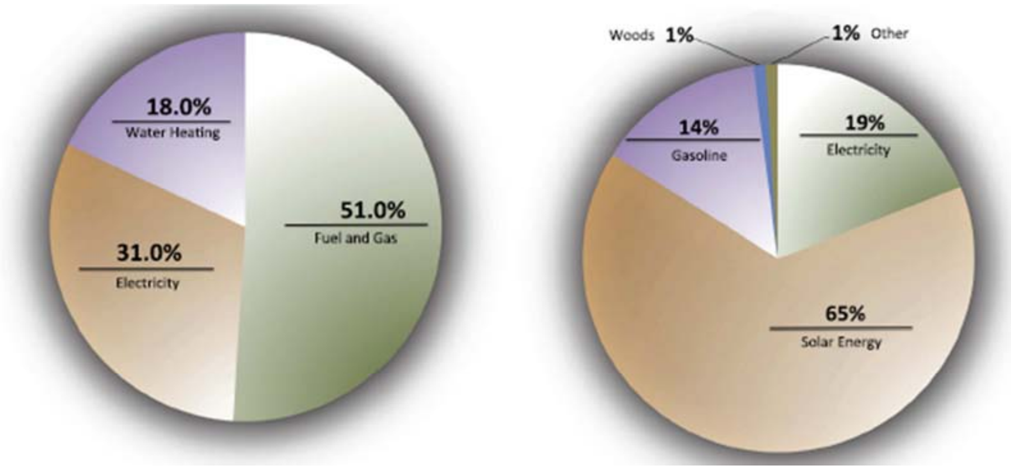

Figure 10. *Left: Palestine energy consumption (18% water heating), Right: 65% of water heating came from solar energy.*

Water heating requirements represent a considerable portion of the energy needs of facilities. Al-Ahli hospital, for example, spent about have of its energy needs on heating water for space heating, domestic hot water and steam generation [52]. This amount differs from facility to another depending on the nature of its activities. However, solar energy for heating purposes emerged to secure a great portion of water heating energy demand. Many projects on a considerable scale have been established in Al-Ahli hospital for domestic hot water application [41], Birzeit pharmaceutical Company (BPC) for industrial hot water use. Birzeit University for domestic hot water use, Grand Park Hotel for domestic water heating and pool heating. The total metric area of the installed solar water heaters as per PCBS 2007 amounted 1,500,000 m^2. These values already generate 940 GWh annually and save the Palestinian economy 85 M€ [53].

4. Policies, Strategies, and Initiatives

Proper utilizing of resources cannot occur proficiently unless suitable legislation and law are made to organize and secure that utilizing. Although solar energy in Palestine has great potential, only 8% of that potential is utilized [14], proper legislation, that organizes the field of renewable resources exploitation, will foster the investment in this field. Which in turn will affect reducing more and more the outsourcing energy supply.

Palestine has made many steps in encouraging the exploitation of renewable energy resources in Palestine. According to Palestinian National Plan 2011-2013 [43], a list of published policies and their interventions considers building a solar-powered plant of 10 MW capacity in West Bank, following to the pilot projects implemented before such as Jericho Industrial Agricultural Zone Electrification. funds are being secured to proceed in the 100 MW solar plant project in Jericho [21]. Also, Palestinian Energy Authority (PEA) launched a PV solar project initiative in 2013 for building generation capacity of 5 MW by installing 5 kW on-grid PV arrays onto the rooftop of 1,000 building [21].

Another strategy plan for energy has been issued to 2020, states that 130 MW of power generation will be sourced by renewable resource project, where the most implemented renewable projects are solar energy projects. This strategy is based on carrying out feasibility studies and bidding process, up to 2015. And installing projects based on that studies of 25 MW from renewable resources [25].

Legal laws have been also issued to support the process of utilizing renewable resources in general. i.e. Decree-Law. Which is objectified to encourage exploitation of renewable resources and their application. This law, even with some conservations on its contents, is an important step in legalizing the exploitation of renewable energy and the relation with between power distribution companies and the investors in this field [25].

5. Discussion and Conclusions

Referring to the gathered data and related analysis; Palestine has plenty of sunshine days of 3000 hours yearly and Global irradiance greater than 2200 kWh/m^2.Year, After analyzing drawback factors of the solar energy exploitation, Palestine still has an excellent potential to exploit solar energy in many applications. Best locations for PV solar energy exploitation are Gaza and south West Bank, and worst is Jericho. Which leads to resolve many developmental issues in both rural and urban areas. Many strengths and drawbacks can be outlined to illustrate the status of solar energy prospects in Palestine.

5.1. Strengths

The foreseeable strengths for exploiting solar energy in Palestine can be summarized but not limited to as follows:

1. The abundance of plenty of solar irradiance at a considerable and feasible amount for exploitation.
2. The absence of Israeli bars on importing solar energy systems and equipment
3. The high energy prices of electricity and fuel, which fosters the implementation of alternative abundant resources.
4. The emergence of many private sector companies in the solar energy business as manufacturers and integrators.
5. The availability of trained engineers and technicians in the field of solar energy.
6. The existence of governmental awareness of the energy situation in Palestine, which has led to adopt strategies fostering renewable energy solutions. Through initiatives, laws and tax exemptions.
7. Available donors in the field of renewable energy such as the European Union and Japan. Which could serve to fund for some projects.
8. Cooperation of power distribution companies and their promoting integration services

5.2. Drawbacks

1. The political status of West Bank and Gaza, Israeli repetitive bombing of infrastructure in Gaza Strip and its sovereign over B and C areas in west bank hinders the implementation of large-scale solar plants for electricity production.
2. The fragmented efforts in solar energy field make data seems to be not integrated with each other all the time, which affects inversely on the efforts of studies and investments.
3. Absence of a unified, clear, and reliable resource of solar data for Palestine.
4. Absence of building laws that make utilizing solar energy obligatory.
5. Poor electricity grid infrastructure.

5.3. Recommendations

Regarding the introduced information about solar energy status in Palestine, weaknesses have been pinpointed to be considered for more research and organizing as follows:

1. Verifying solar irradiance data provided by SOLARGIS. Leading to construct a national comprehensive solar map data for all locations in Palestine. Including modeling these statistically long term gathered data into reliable regressed representation for simulation and feasibility studies input.

2. Mapping the Aerosol Optical Depth (AOD) for better and more accurate irradiance data representation and more reliable simulations output.
3. Introducing more researches regarding the thermal solar plants aimed for power generation. To exploit solar energy in hot areas such as Jericho in a more efficient way, far from PV negative temperature sensitivity.
4. Introducing more researches in utilizing solar energy for space cooling purposes, using the advantage of thermal driven heat pump machines (absorption chillers).
5. Introducing more studies to investigate the side effects of on-grid solar systems on the quality of electrical power and assess its effects.
6. Proposing more solar solutions for agricultural remote areas. Resolving issues regarding water and monitoring.
7. Propose more solar solutions for industrial utilities. To help in reducing operation energy requirements.
8. Issuing a unified set of laws and legislation. Define all the aspects regarding renewable energy exploitation, organizing the relation between the investor and the electricity companies. In such way that fosters further investment in this field.
9. Establishing a national center for solar energy. To be the unified resource for all solar data in Palestine. Also, to lead the sector and organize its aspects. And train professional technicians to secure workmanship and entrepreneurs in the solar energy industry. [9]

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