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An overview of renewable energy potential in Palestine

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ABSTRACT

The energy sector situation in Palestine is highly different compared to other countries in the Middle East due to many reasons: non-availability of natural resources, unstable political conditions, financial crisis and high density population. Furthermore, Palestine depends on other countries for 100% of its fossil fuel imports and for 87% of its electricity imports. In addition high growth of population, increasing living standards and rapid growth of industrial have led to tremendous energy demand in Palestine in recent years. The total energy consumption per habitant in Palestine is the lowest in the region (0.79 MW h/inhabitant) and costs more than anywhere else in the Middle East countries. The primary goal of this paper is to analyze the current energy sector situation in Palestine and to highlight the status of the potential of renewable energy as an essential future energy source sector in Palestine. Regarding the main possibilities of RE, the wind speed averages (m/s) for main 5 cities were: Tubas 4.97, Salfeet 4.26, Ramallah 3.09, Hebron 2.90 and Jericho 1.32. With these data, Palestine can be considered as a country of moderate wind speeds. By the other hand, Palestine has a high solar energy potential about 3000 sunshine hours per year with a solar radiation (kW h/m^2/day) for year 2013 of 8.27 in Ramallah, 7.51 in Hebron, 6.86 in Salfeet and 6.15 in Tubas. These values are encouraging to exploit the solar energy for different applications. This study highlights that the main renewable energy sources in Palestine are solar energy, wind energy and biomass, thereby the energy dependence on neighbouring countries may significantly decrease, when Palestine uses the available renewable energy sources. The renewable energies in Palestine open new perspectives for energy sector in order to prompt practices for sustainable development.

Contents

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1. Introduction

Energy is a continuous driving force for economic development, sustainable development, social improvements, and improved quality of life [1]. So, energy plays a significant role in economic and social development, and constitutes a major threat to the environment and sustainable development. Rapid technological developments, improvement in standards of living, and increased population density have increased the interests to use the RE resources [2]. The importance of energy for the processes of production and manufacturing is also a key element of sustainable development for this the increasing attention is going to the sources of energy that are renewable in the sense that they can be used without exhausting the source of the energy [3]. In addition, climate change issues and fossil fuel depletion are the main drivers for the recent focus on finding alternative energy resources [4]. It is well known that burning of fossil fuels (Coal, oil, and natural gas) generates pollutant harmful gases (SO_2, CO, NO_X, HC, and CO_2) that causes environmental pollution problems [5]. The reserves of fossil fuels are limited and their large scale use is associated with environmental deterioration [6]. The use of Renewable Energies (RE's) instead of fossil fuels provides many important advantages to the developing countries, including an increase of energy services in remote, rural areas, and is associated with general improvement of economic sector, social sector and environmental issues [7]. The reliance on RE resources around the world is linked with effective approaches to sustainable development: they have a high potential to be cost efficient, not damaging the environment and designed to be suitable for local conditions [8,9]. RE technologies as clean energies continue to grow in the fields of residential, commercial, agriculture and industrial applications [10,11]. RE can help countries to meet their policy goals to secure, reliable and affordable energy, promote development and reduce energy price volatility [12]. The energy sector situation in Palestine is highly different compared to other countries in the Middle East. Palestine is divided into two geographic areas: West Bank (Including East Jerusalem) and Gaza Strip. Nowadays (2014), according to Palestinian Central Bureau of Statistics (PCBS) the population of Palestine is 4,550,368 inhabitants for an area of 6020 km^2, being the population density 756 people/km^2, distributed as follows: West Bank 494 people/km^2 , and Gaza Strip 4822 people/km^2, one of the highest population density in the world. The complex geographical and administrative situation of Palestine can be seen in its administrative divisions made by the Oslo II Accord in 1995, that divided West Bank into three administrative divisions: the Areas A, B and C (See Fig. 1. So, the Areas are not contiguous. Area A indicates that full civil and security control belongs to the Palestine. Area B indicates that Palestine has civil control but security control is joint Israel and Palestine. Area C indicates that full civilian and security control is made by Israel. Approximately 60% of the land regions in the West Bank are classified as Area C. So, Israel control of these divisions therein severely hinders and affects the potential development of a traditional energy sector's infrastructure and regulations and policies, also hinders development initiatives [13]. As shown Fig. 1, there is a complex geographical distribution of these areas, e.g there are 253 different enclosures for area B.

Palestine is facing a critical situation concerning the achievement of sustainable development. Several problems have contributed to the continuous deterioration of the political, economic, social, and environmental conditions and hindered development initiatives. One of the main characteristics of the Palestinian situation is the political instability with direct and indirect consequences for the energy sector and the local economy. In addition, the high electric dependency on Israel can be considered as a major obstacle for economic development in the West Bank. There is no physical continuity between Gaza Strip and West Bank and East Jerusalem. Gaza's isolation presents technical and political challenges for transporting, storing and importing energy [13]. Almost all petroleum products are imported through Israeli companies. So, Israel controls energy imports into Palestine and thus prevents open trade in electricity and petroleum products between Palestine and other countries that hindered the development initiatives [14]. Abu Hamed et al. [13] found that the costs of energy are more expensive than anywhere else in the region. The national and comprehensive energy policy is still not clear, weak and fragmented institutional framework and the incomplete framework of Palestine. RE market is strongly affected by the political stability in the region, and the economic situation of the people rises the demand on energy and availability of indigenous resources. The environment of the political risk and uncertainty has inhibited investors from making large scale energy or industrial investments [13]. So, RE in Palestine can play a key role in the transition to a truly sustainable energy development sector in the long term [15]. Then, Availability, affordability and sustainability of energy supply are interlinked facets of overall energy security in Palestine [16]. The lack and need of stable conditions, reliable and sufficient energy system is one reason that Palestinian community development and economic development are curtailed even before accounting for expected population growth and economic potential [13]. The important conditions such as: economic, political, environmental, geographic, social and infrastructural make clear the necessity and advantages of RE over fossil fuels. Palestine features promising capacities in the potential use of solar, wind and biomass energies. Almost the whole country has high sunshine hours throughout the year; the total annual sunshine hours exceed 3000 h [17]. Global solar radiation is the sum of the beam or direct radiation and the diffuse solar radiation on a surface, where the former is radiation received from the sun without having been scattered by the atmosphere and the latter is radiation received from the sun after its direction has been changed by atmospheric scattering. For Palestine, the average solar resource ranges from 5.4 kW h/m^2/day to6 kW h/m^2/day [18]. Photovoltaic and thermal systems (e.g. solar water heating) without concentrators use the entirety of global solar radiation, that is, both beam and diffuse radiation. However, solar concentrating systems can only use beam solar radiation [19]. This energy is very promising if it is compared to other places in the world like Spain-Madrid (4.88 kW h/m^2/day) [20], USA- Denver CO (4.95 kW h/m^2/day) [21], Australia -Sidney (4.64 kW h/m^2/day) [22], Mexico-Gulf of Mexico (4.78 kW h/m^2/day) [19]. Biomass represents an abundant carbon-neutral renewable resource for the production of bio-energy and biomaterials, and its enhanced use would address several societal needs [23]. Biomass supplies approximately 50 EJ globally, which represents approximately 10% of the global annual primary energy consumption [24]. This percentage is almost the same as the one used in Palestine, where

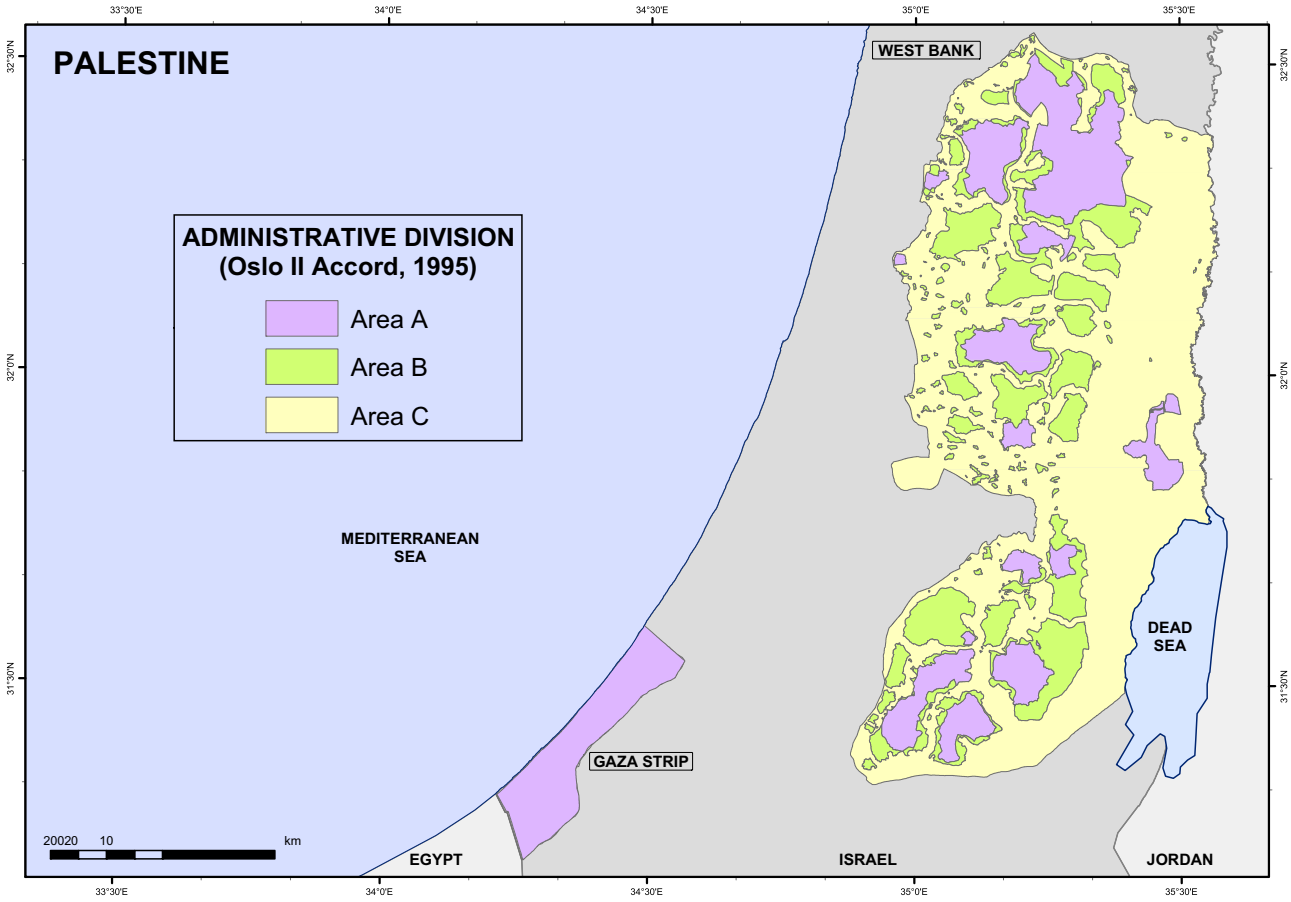

Fig. 1. Map of Palestine, Oslo II Accord (1995). Administrative Divisions: Areas A, B and C.

biomass energy generated by burning wood and agricultural waste is limited to cooking and heating purposes in rural areas and constituted 9% of the total energy consumption [25].

The energy demand increases rapidly in Palestine because of high growth of population. Besides, most of energy is imported from abroad. Therefore, finding alternative of energy recourses is a vital subject for future generation concentrating on the clean energy. As a start, a detailed insight has been pursued to explore the existing energy situation that depends on the non-renewable resources. Several challenges and difficulties face the power generation in Palestine, starting from political situation on ground, economic crisis, shortfall of infrastructure connectivity and ending by lack of supply and demand side management strategies across the country.

Furthermore, from the economic point of view, Palestine experiences big challenges to import the electricity and fuel [26]. And accordingly, it has to start depending on its recourses to generate the power. These circumstances push Palestinian Government to depend on the existing resources to produce energy. These energy sources shall be rely on the sustainability dimensions to improve the environmental quality, economy, and human wellbeing.

In Palestine 100% of the fossil fuels and 89% of the electricity supply are imported from Israel. This condition does not provide a flexible diversity of the energy resources. The aim of this study is to discuss the challenges facing the Palestinian energy sector. On the other side, this paper aims to asses the Renewable Energy potential to be considered in the energy supply contribution, so the main renewable energy sources in Palestine: solar, wind biomass and geothermal, will be evaluated. In summary, this work make a compressive overview in the Energy sector in Palestine and how the contribution of RE can help to solve the situation of the energy demand.

Some previous reviews exist in the specialized literature dealing the energy situation in Palestine. Thus in 2007, Abualkhair [27] evidenced the precarious energy situation in Palestine in 1995, setting the example of there were 65 localities not connected to public electricity network; this author highlighted that for West Bank region, the electricity consumption was estimated at 890 GW h/year, with an average consumption of 496 kW h per capita, while in the Gaza Strip it was 47.91 GW h/year, which was considered to be the lowest in the region. In 2012, Abu Hamed et al. [13], for year 2009, got similar conclusions, although the electricity consumption was increased to 3808 GW h in the West Bank and 1606 GW h in the Gaza Strip, still was the lowest consumption rates in the region and the costs are more expensive than anywhere else in the region and it constitutes a higher proportion of household expenditure [13]. By the other hand, the energy dependence from Israel was shown in previous reviews [27,13] and some literature present the renewable energy as a possibility for reducing the reliance on external energy sources [28,18]. This manuscript aims to follow monitoring the energy situation in Palestine as previous literature was done each 5 years, in order to study whether the situation is improving or not.

2. Geographical and demographic conditions in Palestine

Palestine has two geographical areas separated from each other. Gaza Strip is located on the western side of Palestine adjacent to the Mediterranean Sea. West Bank extends from the Jordan River in the east to Israel in the west. Climatic conditions of Palestine vary widely [29]. Palestine is located between

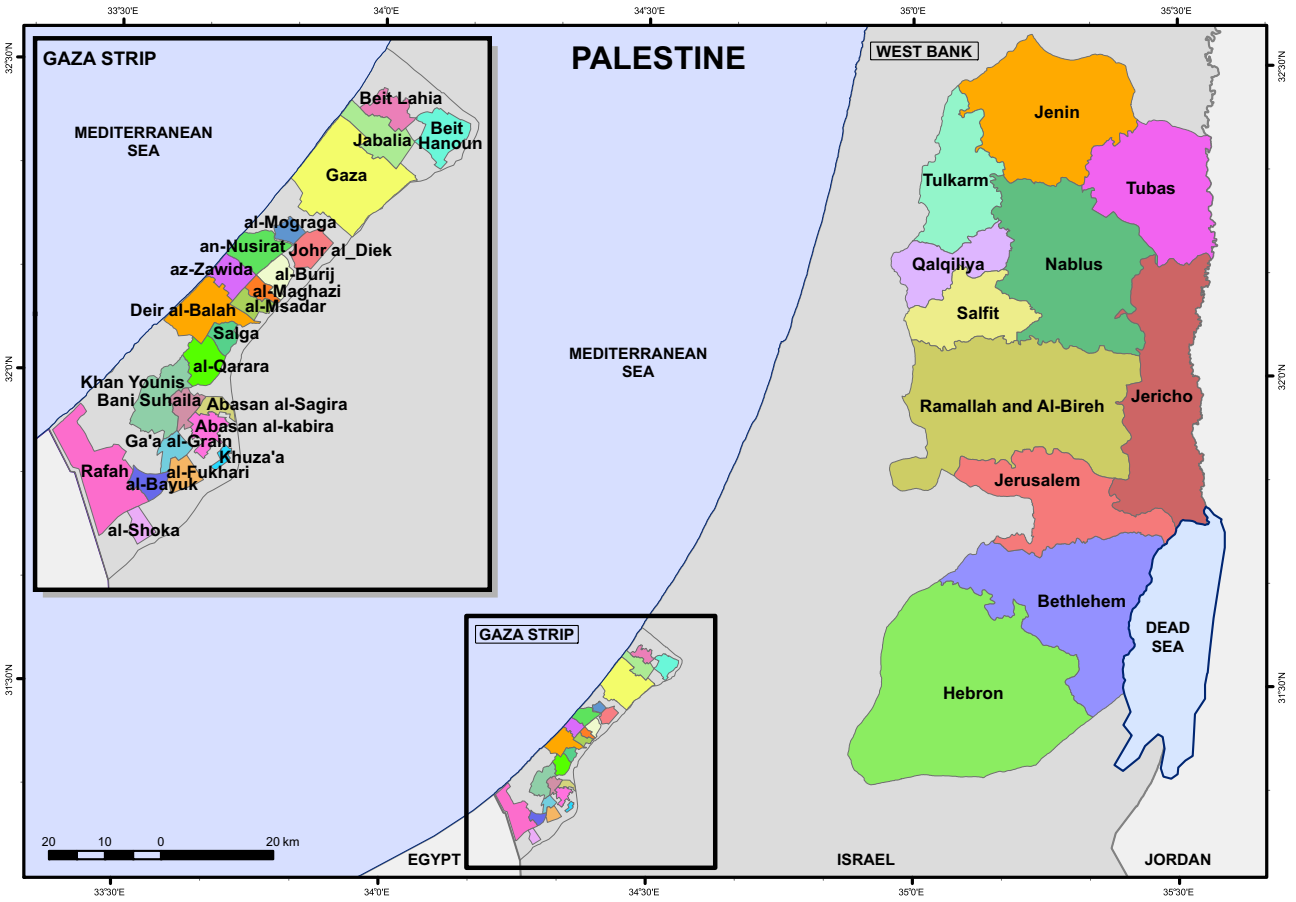

Fig. 2. Regions of Palestine.

34°20′–35°30′ E and 31°10′–32°30′ N (See Fig. 2). Palestine's elevation ranges from 350 m below sea level in the Jordan Valley, to sea level elevation along the Gaza Strip seashore and exceeding 1000 m above sea level in some locations in West Bank. The coastal climate in Gaza Strip is Mediterranean with humid and hot during summer and mild during winter [30]. This area has low heating loads, while cooling is required during summer to achieve thermal comfort. The daily average temperature and relative humidity vary in the ranges of 13.3 °C to 25.4 °C and 67% to 75%, respectively. West Bank areas have cold winter conditions and mild summer weather. The daily average temperatures and relative humidity vary in the ranges of 8 °C to 23 °C and 51% to 83%, respectively. In some areas the temperature declines below 0 °C. Hence, high heating loads are required, while little cooling is needed during summer. In Jericho and the Jordan Valley, due to their special climate conditions almost no heating is needed during winter while high cooling during summer is needed.

2.1. Governorates, localities and demographic conditions

The area under consideration in this paper is Palestine. Its general characteristics and features pertinent are illustrated in Fig. 2, where localities, governorates, population, and geographical coordinates are shown. Palestine is divided into two geographic areas: West Bank (including East Jerusalem) and Gaza Strip. The total area (West Bank and Gaza Strip) is 6020 km^2, the West Bank has 5655 km^2 and Gaza Strip 365 km^2. There are 557 localities, distributed as follows: 524 in West Bank and 33 in Gaza Strip. These are administrated by 379 local authorities, which in turn into 124 municipalities, 10 local councils and 245 village Councils. Palestine has 4,550,358 inhabitants in year 2014, distributed in West Bank (2,790,331,408 inhabitants) and Gaza Strip (1,760,037 inhabitants). These means a population density for the whole Palestine of 756 inhabitants/km^2, and 494 inhabitants/km^2 for West Bank, and 4822 inhabitants/km^2 for Gaza Strip (See Fig. 3). The Fig. 4 presented the Palestinian Population in 2014 by Governorate. Fig. 5 shows the communities inhabitants in Palestine, where the spot size indicates the size of the population.

3. Energy structure

Palestine is a developing country in great need of all types of energy for economic growth. Not all Palestinian people have access to electricity the whole day. However, there are unusual constraints on energy development in West Bank and Gaza Strip. Palestine has not developed domestic energy resources and relies heavily on imports from Israel. Furthermore, energy insecurity is further reinforced by the fact that Israel controls the quantity and condition of energy imported into Palestine. For example, the Israeli control of Palestinian borders prevents open trade in electricity and petroleum products between Palestine and other countries. Israel is therefore able to impose non-competitive energy prices and tariffs on Palestine. Due these socio-political conditions, RE's play special importance for this country [31].

3.1. Energy sector profile

Energy sources consist of: first energy generated by petroleum and natural gas derivatives, second electricity and third RE which (including solar power, wind power, and biofuels [25]. The energy balance in Palestine is highlighted in Fig. 6 by a Sankey diagram. In

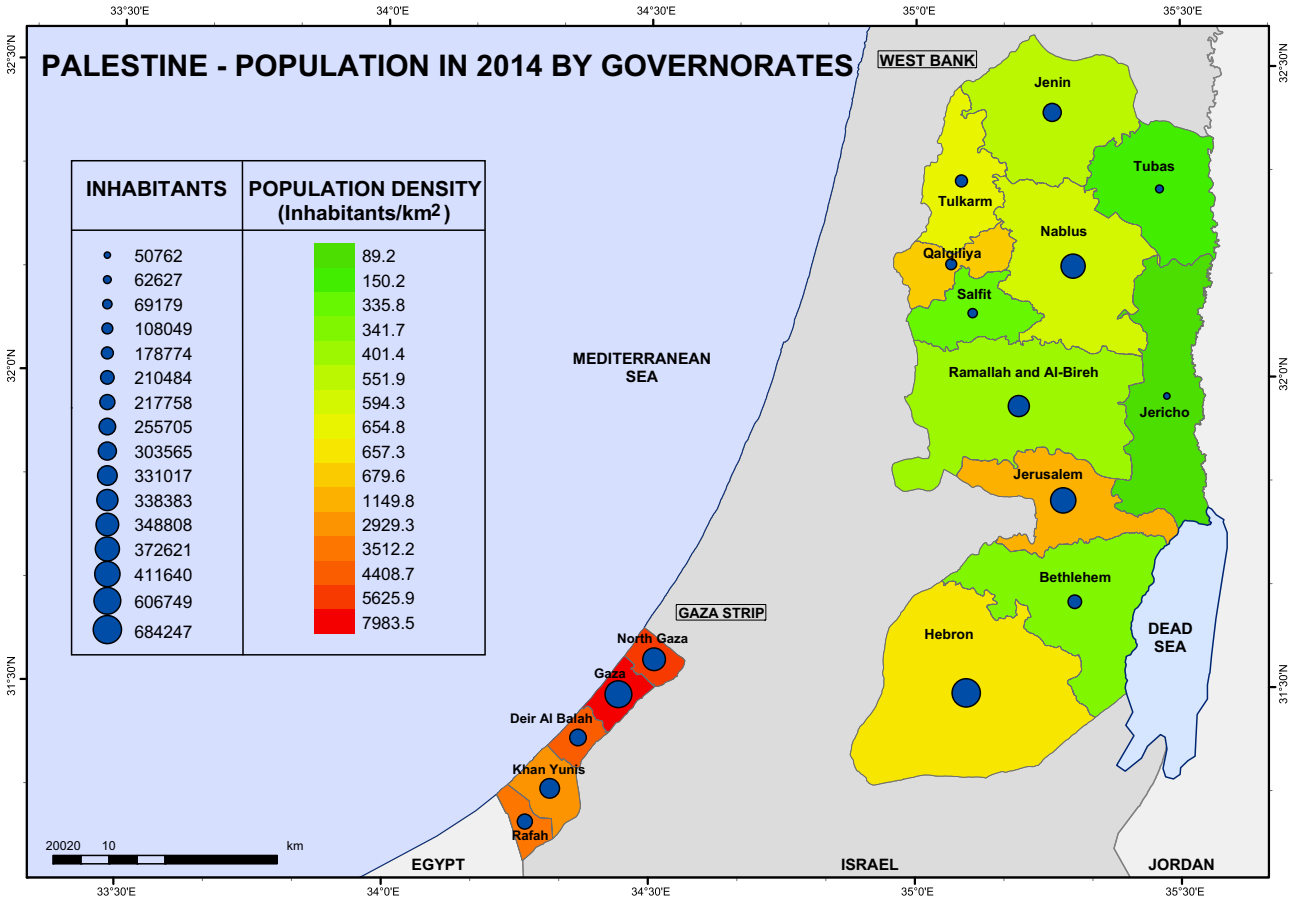

Fig. 3. Population density in Palestine.

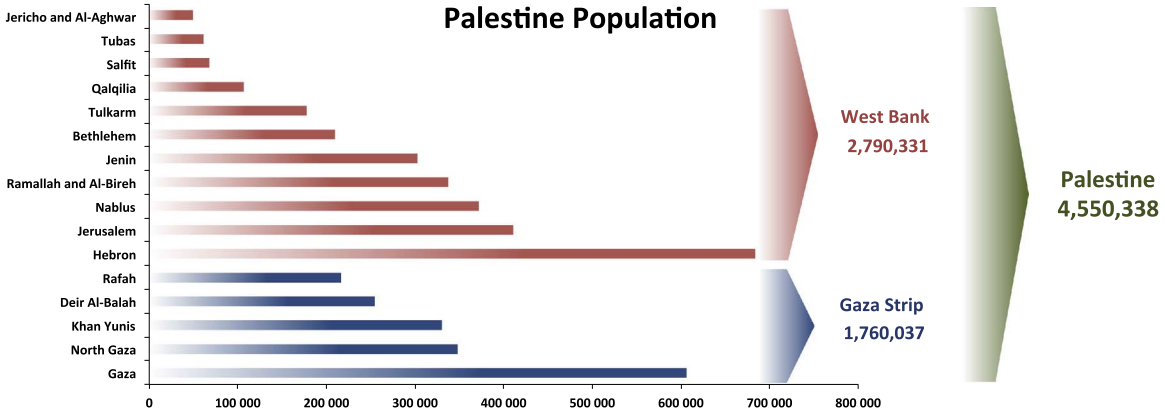

Fig. 4. Palestinian population in 2014 by governorate.

addition, energy conservation in utilities has played a vital role in improving energy efficiency in the industrial, commercial and residential sectors [32]. The objectives of the Palestinian energy sector so far have been to ensure the security of supply and minimizing the dependence upon foreign sources [16]. According to Palestinian National Plan (2011–2013), Energy Sector Strategy has presented that energy sector is distinctive of scarce sources and inability to fully exploit currently available ones, causing it to largely depend on importation from Israel [25], with the exception of RE. Therefore RE strategy sets targets to increase the generation for energy mix and enhance energy independence.

3.2. Energy demand

Palestine is a net importer of oil and petroleum derivatives. The total imported energy in Palestine by type of energy for year 2013 is presented in Table 1. This Table highlights the high dependency for external energy supply in Palestine. It can be noted that almost any type of energy must be imported. Even so, the total energy consumption is considered the lowest in the region. Table 2 shows the average annual prices of different energy types in year 2013 for West Bank and Gaza Strip. The cost of sources of energy are the higher than neighbouring countries. The energy consumption by sectors is illustrated in Fig. 7, where the residential and commercial sector spent the largest energy consumption (71%), here a big

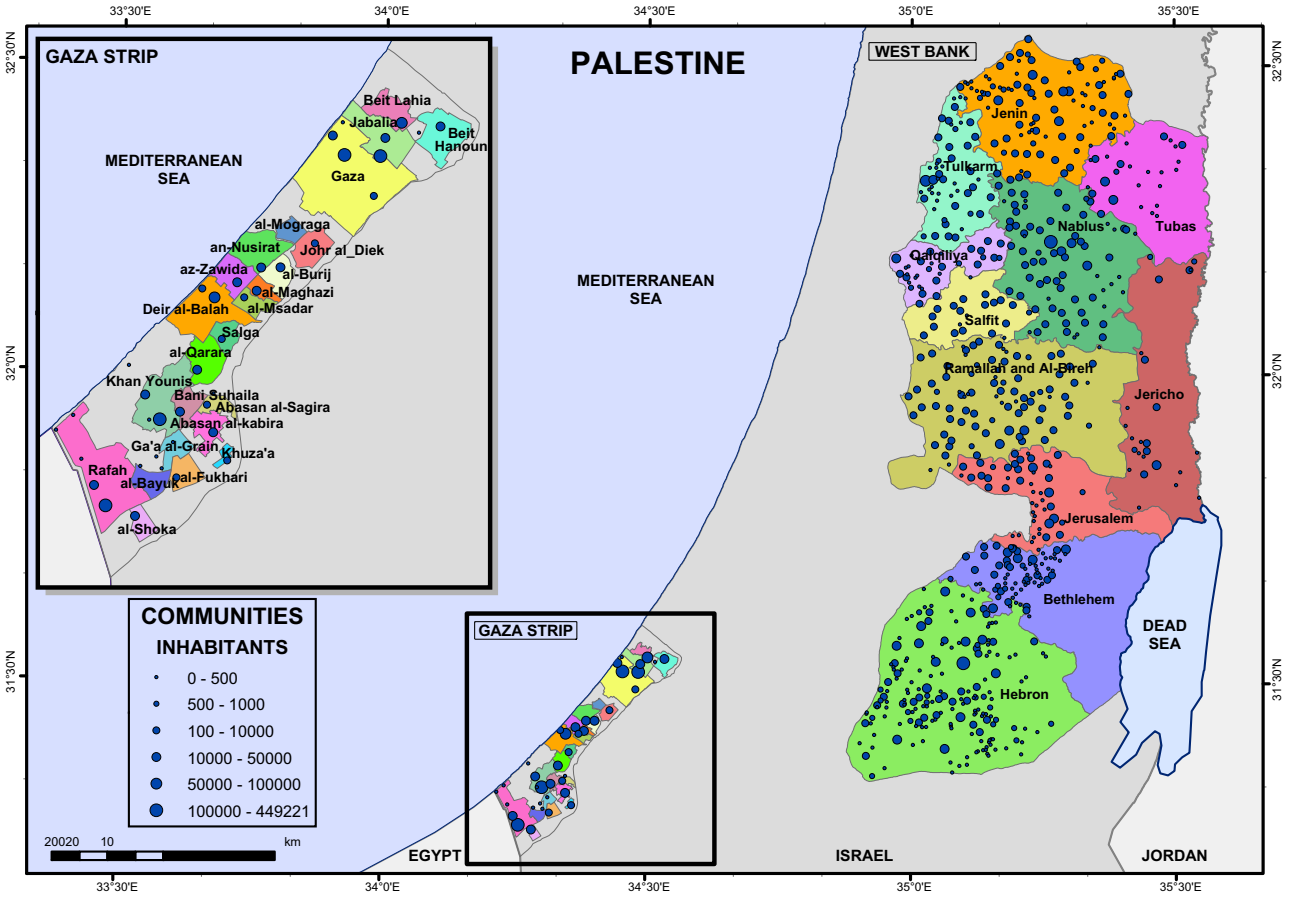

Fig. 5. Communities inhabitants in Palestine.

amount is used for water heating 18% (Fig. 8). Solar energy (solar flat collectors) is used only by an amount of 65% of households (see Fig. 9).

3.3. Electric power sector

This section summarizes an overview of Palestinian electric power sector, which depends on importation. Palestinian Energy Authority plays the role of regulator in Palestine in zones under their control (areas A and B). The electricity imported in Palestine by country in year 2013 is shown in Table 3, with a total amount of 4,484,808 MW h, distributed in 3,365,597 MW h for West Bank and 1,119,211 MW h for Gaza Strip. The total consumption is 5,136,861, so these mean that more than 87% is imported from Israel, while less than 8% is from Palestine Electric Company. Egypt supplies some electricity for Gaza Strip and Jordan for West Bank. Fig. 10 summarizes the electrical energy overview by a Sankey Diagram. West Bank depends almost entirely on Israel Electrical Corporation (IEC) for electricity supply; it is mainly supplied by three substation (161/33 KV): one in the south in Area C close to Hebron, a second in the north in the Ariel settlement Area C close to Nablus, and a third in Atarot industrial Area C near Jerusalem. Electricity is supplied to the centre of West Bank largely through Jerusalem Distribution Electrical Company (JDECO) via 33 KV and 11 KV distribution power lines at several connection points with the IEC including, Ramallah, Jericho, Bethlehem and the eastern part of Jerusalem. The maximum capacity of electricity supply to the West Bank is 600 MVA; 40% directly by IEC which supplies electricity to 215 towns and villages, and 60% indirectly by IEC through JDECO which supplies electricity to East Jerusalem [27] and 165 towns and villages in West Bank. At the end of 2006, two agreements were done, one with Egypt to supply Rafah (South of Gaza) by 33 KV power line 17 MW, and with Jordan to connect Jericho through a 33 KV power line power line 20 MW via King Husein Bridge, JDECO submitted a new request to upgrade the power line to 132 KV, which is compatible with the voltage supplied by the Jordanian electricity company.

The number of localities in Palestine with availability of electricity network by governorates in year 2013 is shown in Fig. 11. Hebron and Tubas are governorates with problems for availability of electricity network. Fig. 12 shows the amount of electricity supplied in Palestine by governorate in this year. The Table 4 presents the distribution of localities related to electricity source by governorate in 2013; this highlights the complex situation in the electricity supplied in Palestine, where more than 7 companies are involved. But not all the localities have electricity network, and have to supply it with generators. Table 5 presented that distribution of localities by governorate in 2013, which need to be supplied by generators. On the other hand there are some few RE resources for electricity generation. It exists only 1 wind farm and 10 facilities of solar energy in whole Palestine.

Table 6 presents the distribution the connected localities to electricity in Palestine by average hours of electricity availability per day and governorate. Figs. 13 and 14 show the distribution of connected localities to electricity in Palestine by average hours of electricity availability per day by governorates in 2013 at summer and winter. There are 557 localities in whole Palestine. As it is shown in Table 6, 118 localities are classified as “Not Stated” and 24 localities without Electricity Network, being the main problems for the governorates of Tubas and Jericho. This last governorate, Jericho, has also the main problems derivate to this not Electricity Network, and most of the localities have not access to electricity

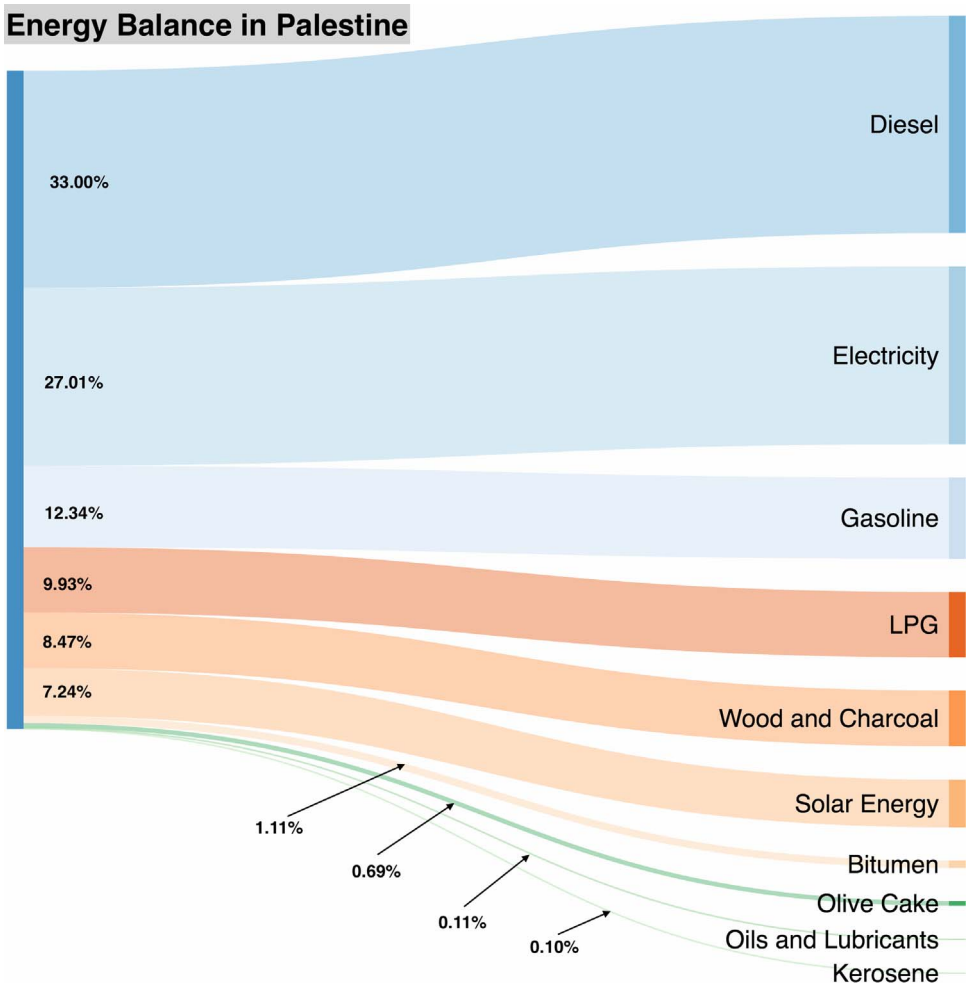

Fig. 6. Sankey Diagram of Energy Balance in Palestine.

Table 1
Imported energy in Palestine by type of energy in year 2013 (Source: Palestinian Central Bureau of Statistics, 2014).

Region	Type of Energy							
	Electricity (MWh)	Gasoline (1000 Liter)	Diesel (1000 Liter)	Kerosene (1000 Liter)	LPG (Ton)	Bitumen (Ton)	Oils and Lubricants (Ton)	Wood & Coal (Ton)
Palestinian Territory	4,734,254	237,545	556,780	1648	132,464	17,507	2110	10,150
West Bank	3,406,998	217,409	437,316	1577	93,432	17,441	2078	10,073
Gaza Strip	1,327,256	20,136	119,464	71	39,032	66	32	77

the whole day. The Fig. 15 summarizes the main electricity problems in Palestine, being classified as: Electrical current weakness (28%) Electrical current disconnection (26%), Old Electricity Network (24%), Non served areas (17%), and others (5%).

The only Palestinian electricity production is from the Gaza power plant; with 140 MW of production total capacity installed which covers a part of Gaza city and other surrounding areas. The Palestinian Electric Company was established in 1999, with 33% of its assets for public shareholders and 67% for private shareholders and with cost of USD 60 million. The IEC is considered the monopoly of electricity production in West Bank with a main production capacity of more 10 GW. In fact, Palestine is completely dependent on the IEC for their electricity needs. The consumption for Palestine is equal to 0.79 MW h/inhabitant. If we compare this data with neighbouring countries in year 2011: Kuwait 16.12, Qatar 15.75, Bahrain 10.02, United Arab Emirates 9.39, Israel 6.93, Oman 6.29, Lebanon 3.50, Jordan 2.29. It is concluded that Palestine has the lowest value, in an order of 5 times lowest than Lebanon or 10 times to Israel. Furthermore, the cost of electricity is very high; Table 7 illustrates the electricity tariffs for residential, commercial and industry sectors in West Bank. Table 8 illustrates electricity residential tariffs in West Bank and Gaza Strip in year (2014).

Table 2
Average of annual prices of energy for year 2013 in Palestine (Source: Palestinian Central Bureau of Statistics, 2014).

	Liquefied Petroleum Gas (LPG) ($/Kg)	Kerosene ($/*l*)	Coal ($/Kg)	Gasoline (Israeli 95 gasoline) ($/*l*)	Diesel ($/*l*)
West Bank	1.42	1.56	1.82	1.75	1.56
Gaza Strip	1.32	1.56	1.94	1.75	1.56

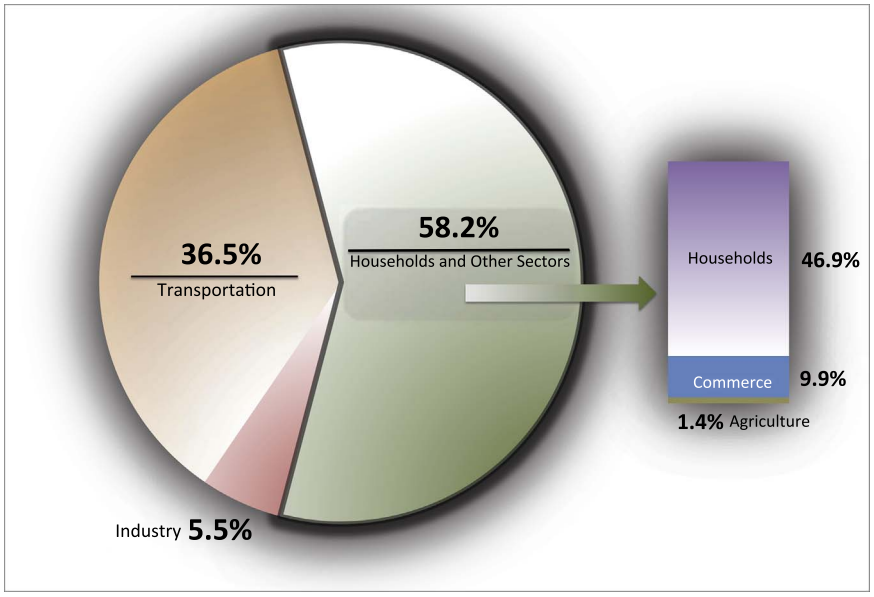

Fig. 7. Energy consumption by sectors, 2013.

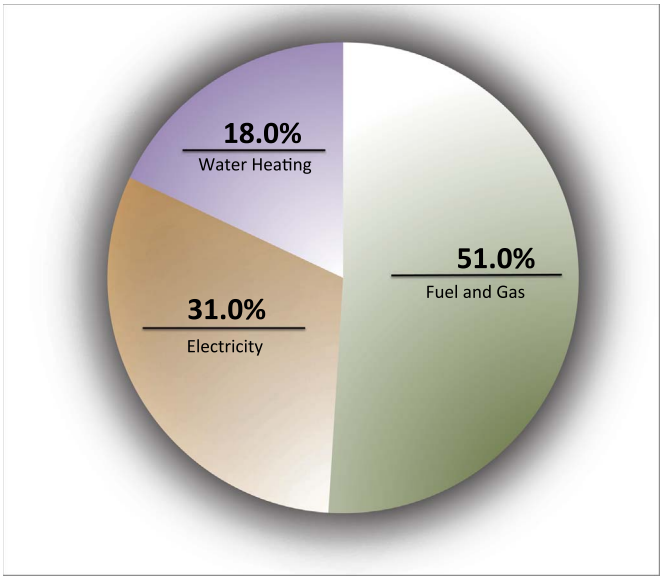

Fig. 8. Total primary energy consumption in Palestine, 2013.

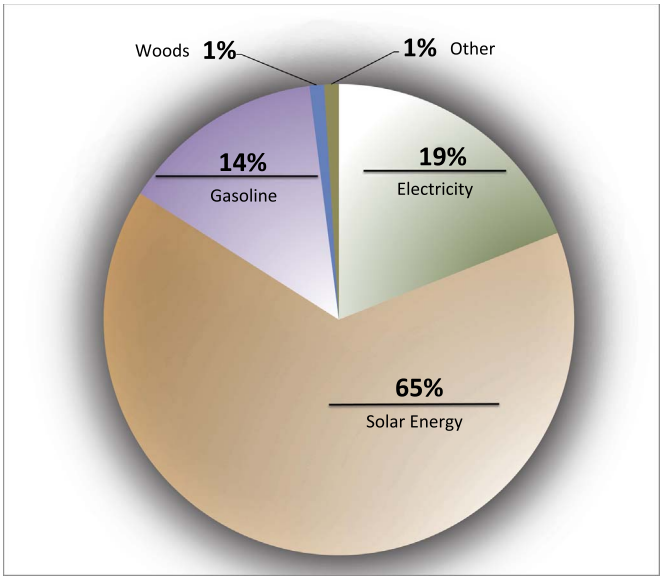

Fig. 9. Distribution of energy consumption for water heating, 2013.

4. Renewable energy sources

The interest in Renewable Energies (specially in solar energy), are motivated to give flexibility to the system power supply, reduce external dependence and reduce problems caused mainly by the environmental impact of using fossil fuels and depletion of its reserves. Also RE can play an important role in energy supply in remote and isolated areas of Palestine where no electricity is available during 24 h a day.

4.1. Solar energy

Palestine has high solar energy potential about 3000 sunshine hours per year and high annual average of solar radiation amounting to 5.4 kW h/m^2/day on horizontal surface. The solar radiation on horizontal surface varies from 2.63 kW h/m^2/day in December to 8.4 kW h/m^2/day in June. Fig. 16 presents the monthly average of solar radiation in four cities in Palestine: Salfeet and Tubas in the north part of West Bank, Ramallah in the middle part of the West Bank and Hebron in south part of the West Bank in year 2010. The highest solar radiation average for year 2010 in Salfeet is 5.65 kW h/m^2/day, then Ramallah is 5.5 kW h/m^2/day, Hebron is 5.14 kW h/m^2/day, and Tubas is kW h/m^2/day. For Ramallah the highest solar radiation is 8.27 kW h/m^2/day in August, Hebron is 7.51 kW h/m^2/day in June, Salfeet is 6.86 kWh/m^2/day in June and Tubas is 6.15 kW h/m^2/day in June. These values are encouraging to exploit the solar energy for

Table 3
Electricity distribution (MW h) in Palestine by country in year 2013 (Source: Palestinian Energy and Natural Resources Authority, 2013).

	Israel Electric Company (IEC)	Jordan	Egypt	Gaza Electricity Distribution Co.	Total
West Bank	3,365,597	41,401	0	0	3,406,998
Gaza Strip	1,119,211	0	208,045	402,607	1,729,863
Palestine (Total)	4,484,808	41,401	208,045	402,607	5,136,861

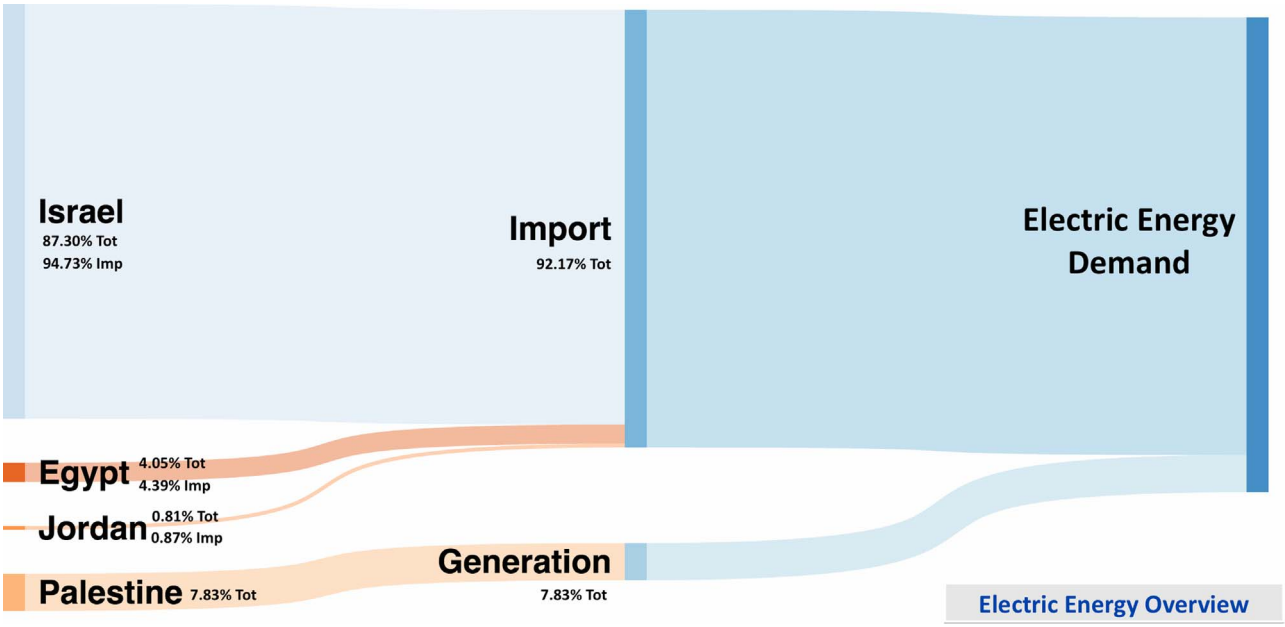

Fig. 10. Sankey Diagram of the Electric Energy Overview.

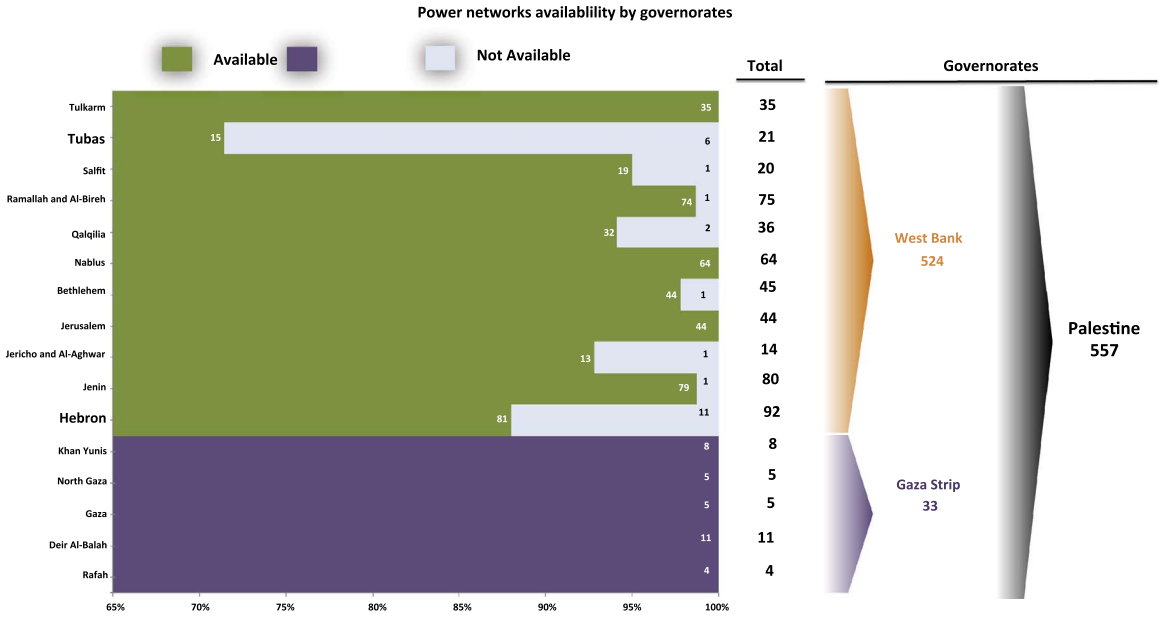

Fig. 11. Availability of electricity network by governorate in Palestine (2013).

different applications such as water heating, drying of crops vegetables and fruits, water desalination, water pumping [33–35] and electrification of remote locations isolated from the electrical networks. On the other hand, the yearly evolution of solar radiation is very promising. Fig. 17 presents the monthly and yearly averages of solar radiation in Salfeet in 4 years, from 2010 to 2013. The highest solar radiation average is 5.65 kW h/m^2/day for 2010, then year 2011 is 4.51 kW h/m^2/day, year 2012 is 4.38 kW h/m^2/day, and the lowest value in year 2013 is 3.52 kW h/m^2/day. Fig. 18 presents the monthly and yearly averages of solar radiation in Tubas in these years 2010–2013. The highest solar radiation average is 4.81 kW h/m^2/day for year 2010, then year 2011 is 4.23 kW h/m^2/day, year 2013 is 4.15 kW h/m^2/day, and the lowest solar radiation value is 3.74 kW h/m^2/day in year 2012.

The previous study results present that utilizing of PV systems for electrification of rural and remote villages in Palestine is economically profitable, and more feasible than using diesel generators or extension of high voltage electric grid [36]. These results are helpful to encourage energy sector planers and decision makers in Palestine to use PV systems to reduce the impact to the environment by reducing CO_2 emissions to the atmosphere when comparing with diesel generators. Then, a considerable potential for PV applications in Palestine is available that relies on the following facts:

- High average of solar radiation intensity and sunshine hours of about 3000 h per year.
- Availability of a large number of rural villages, settlements and public utilities isolated from the electric grid that will not be connected to it in the near future.
- High fuel cost in Palestine makes PV more feasible than diesel powered electric generators in supplying power to different applications in rural areas.

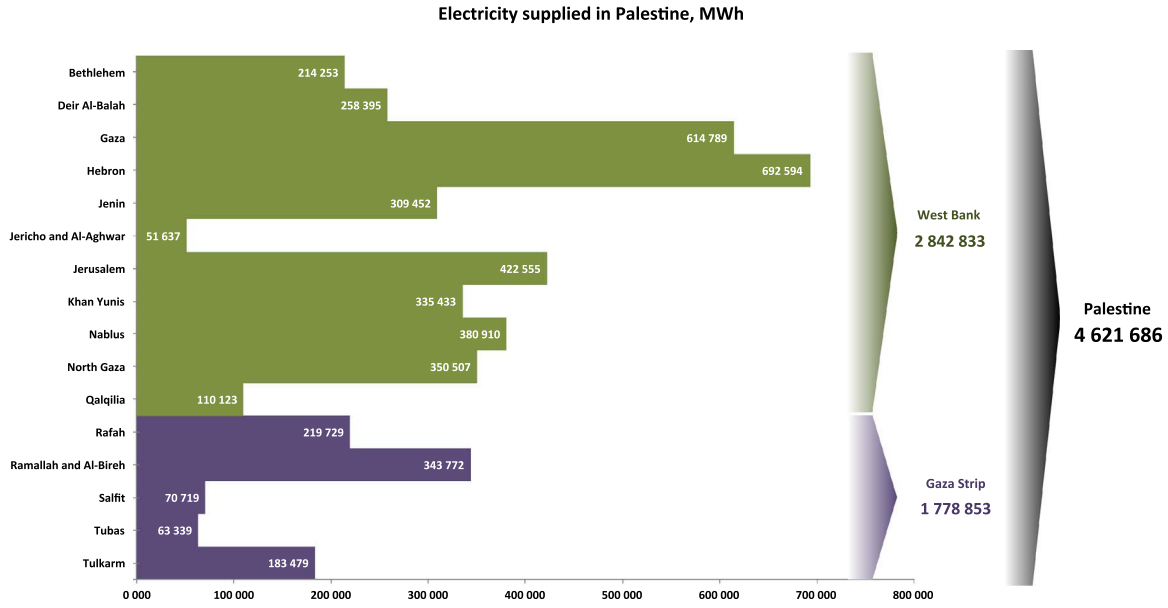

Fig. 12. Amount of electricity supplied in Palestine by governorate (2013).

Table 4
Distribution of localities in Palestine by the main source of electricity and governorate, 2013.

Governorate	There is No Electricity Network	Main Electricity Source						
		Jerusalem District Electricity Co.	An Israeli Source (Israeli National Company)	Local Authority	Southern Electricity Company	Another Local Authority	Gaza Electricity Distribution Co.	Others
Jenin	1	0	37	16	0	4	0	22
Tubas	6	0	6	4	0	0	0	5
Tulkarm	0	0	15	15	0	1	0	4
Nablus	0	0	40	8	0	0	0	16
Qalqilia	2	0	19	7	0	4	0	2
Salfit	1	0	15	4	0	0	0	0
Ramallah and Al-Bireh	1	62	7	5	0	0	0	0
Jericho and Al-Aghwar	1	3	5	5	0	0	0	0
Jerusalem	0	31	2	11	0	0	0	0
Bethlehem	1	39	2	3	0	0	0	0
Hebron	11	0	29	33	15	2	0	2
North Gaza	0	0	3	1	0	0	0	1
Gaza	0	0	1	1	0	0	0	3
Deir Al-Balah	0	0	4	3	0	0	1	3
Khan Yunis	0	0	6	1	0	0	0	1
Rafah	0	0	2	1	0	0	0	1
West Bank (Total)	24	135	177	111	15	11	0	51
Gaza Strip (Total)	0	0	16	7	0	0	1	9
Palestine (Total)	24	135	193	118	15	11	1	60

4.2. Wind energy

The renewable wind power type offers a feasible and cheap solution to distribute power generators over wide areas worldwide [37]. So, it became one of the most convenient and environmental friendly path of electricity generation [38]. Previous study showed that the worldwide capacity of wind power generators was 94 GW (About 1% of worldwide electricity use) [29], not only for large scale energy production but also for stand-alone systems [39] so; wind power has the potential to satisfy both types of systems [40]. In addition, some agencies (European Wind Energy Association and the German Aerospace Centre) have proposed scenarios that have RE sources, including wind farms, supplying 80% of Europe's entire electricity demand by 2050. The National Renewable Energy Laboratory in the USA (NREL) assessed how wind could supply 20% of the entire US electricity demand by 2030, being actually the wind power installed capacity in USA 47 GW. In the same way, another study demonstrated that the wind electricity potential in Canada is many times the current total electricity demand [41], being actually the wind power installed capacity in Canada 5.27 GW. In other countries like Spain, at the end of 2012, the wind had generated approximately 22,622 MW, with an electrical output more than 48,212 GWh and met approximately 18% of the total national electricity demands, having occasionally surpassed 21% of monthly demands [42]. Kitaneh showed that the shortage of natural energy resources is strongly requiring Palestinian to search for renewable, green and sustainable energy sources like wind energy [29]. Recent studies show the wind energy resource mapping of Palestine, where the main conclusion was that wind potential all over Gaza is

Table 5
Distribution of localities in Palestine by existence of subscribers needs to be supplied with electricity by generators and governorate, 2013.

Governorate	Existence of subscribers need to be supplied with Electricity by Generators		Not Stated	Total
	No	Yes		
Jenin	71	4	5	80
Tubas	12	1	8	21
Tulkarm	28	1	6	35
Nablus	57	2	5	64
Qalqilia	30	0	4	34
Salfit	15	2	3	20
Ramallah and Al-Bireh	55	11	9	75
Jericho and Al-Aghwar	8	1	5	14
Jerusalem	28	2	14	44
Bethlehem	36	1	8	45
Hebron	51	4	37	92
North Gaza	4	0	1	5
Gaza	4	0	1	5
Deir Al-Balah	7	0	4	11
Khan Yunis	6	1	1	8
Rafah	2	1	1	4
West Bank (Total)	391	29	104	524
Gaza Strip (Total)	23	2	8	33
Palestine (Total)	414	31	112	557

unfortunately not enough to be considered at any level [43], but Basel and Yaseen showed the utilization of wind energy could be feasible in many locations in Palestine for cutting-off electricity production by Petroleum [14]. Electricity generation by using wind energy requires studying wind speed based on the available data and topographical features of the land in different locations. The coastal strip region (Gaza Strip) is characterised by a very low wind speed throughout the year, with an annual average of about 2.5–3.5 m/s. Related to West Bank, the hilly regions are Nablus, Ramallah, Jerusalem, and Hebron, which have an annual average wind speeds varying in the range of 4–8 m/s. The Jordan Valley, represented in Jericho, has very low wind speeds of an annual average of about 2–3 m/s. So, the wind energy potential seems to be limited to the mountains with heights about 1000 m above sea level. This would include regions of Nablus, Ramallah and Hebron where the speed reaches 5 m/s, which is suitable for operating a wind turbine [29]. E.g. Al-Ahli hospital is located in the south western part of Hebron at 1000 m above the sea level, where an average wind speed at 10 m above the ground level reaches 6.2 m/s, based on the previous values the proposed and required wind turbines to be installed at Al-Ahli hospital are expected to be around 700 kW total power production capacity [29]. Energy Research Centre (ERC) at An Najah National University has been carrying out measurements of wind speed and direction using modern meteorological stations equipped with automatic data loggers. Fig. 19 illustrates the monthly averages of wind speed in year 2013 at different cities in West Bank. Tubas, Jericho, and Ramallah have the maximum of wind speed in summer months: June, July and August, instead Salfeet has its maximum in winter: December, January, February and March. Table 9 summarizes the wind speed averages in years 2011 and 2013 for these cities. It can be seen that the behaviour is quite similar in these years. Tubas is 4.80 m/s and Salfeet is 4.18 m/s, Ramallah is 3.08 m/s, Hebron is 2.68 m/s and Jericho is 1.41 m/s. With these data, Palestine can be considered as a country of moderate wind speeds, these conclusions were also reached by other authors for Palestine [29] where the hilly regions had annual average speed of 4–6 m/s. The values of wind speed are encouraging to use small wind turbines to electrify sites located far from the grid and have high potential of wind speeds. In addition another feasible application for small wind turbines is to use them for water pumping, especially for rural areas where diesel generators are used for this purpose.

4.3. Biomass

The technical potential from available annual supplies of residues and wastes has been estimated in energy terms at over 100 EJ per year at delivered costs of two to three U.S. Dollars per

Table 6
Distribution the connected localities to electricity in Palestine by average hours of electricity availability per day by governorate in 2013 at summer and winter.

Governorate	Average Hours of Electricity Availability Per Day									
	Average Hours of Electricity Availability per Day During Winter				Average Hours of Electricity Availability per Day During Summer				There is No Electricity Network	Not Stated
	All Day	(16–23) Hours	(6–15) Hours	Less than (5 h)	(All Day)	(16–23) Hours	(6–15) Hours2	Less than (5 h)		
Jenin	66	4	4	1	67	3	4	1	1	4
Tubas	13	0	0	0	13	0	0	0	6	2
Tulkarm	28	1	0	0	28	1	0	0	0	6
Nablus	51	5	0	3	51	5	0	3	0	5
Qalqilia	26	1	1	1	28	0	1	0	2	3
Salfit	15	1	0	1	15	1	0	1	1	2
Ramallah and Al-Bireh	47	10	1	9	54	3	1	9	1	7
Jericho and Al-Aghwar	1	7	0	0	1	7	0	0	1	5
Jerusalem	19	5	2	5	23	2	1	5	0	13
Bethlehem	29	2	1	3	31	0	1	3	1	9
Hebron	41	4	0	4	43	1	0	5	11	32
North Gaza	0	0	0	0	0	0	0	0	0	5
Gaza	0	0	0	0	0	0	0	0	0	5
Deir Al-Balah	0	0	1	0	0	0	1	0	0	10
Khan Yunis	0	0	1	0	0	0	1	0	0	7
Rafah	0	1	0	0	0	1	0	0	0	3
West Bank	336	40	9	27	354	23	8	27	24	88
Gaza Strip	0	1	2	0	0	1	2	0	0	30
Palestine	336	41	11	27	354	24	10	27	24	118

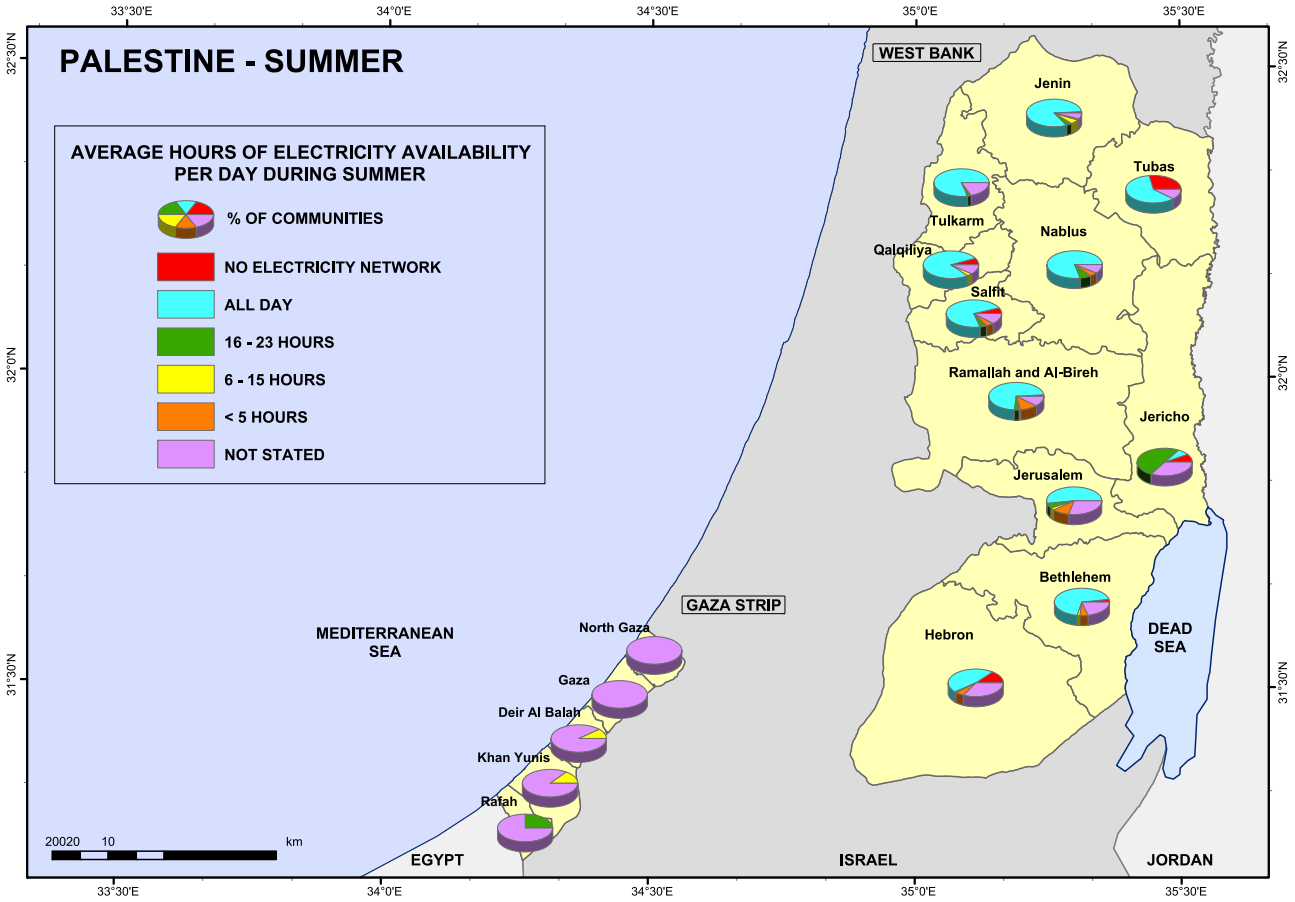

Fig. 13. Average Hours of Electricity Availability per day in summer (2013).

1GJ in the world [44]. Palestine can be considered as an agricultural country. In addition, the Agricultural Sector is a pillar of the Palestinian national economy, and a principal driver of economic growth, yielding large contributions to GDP, including dividends from commodity exports, and employing thousands of Palestinian. Palestine has different types of plant products that can be used as energy sources. Due to evapotranspiration conditions [45,46], there are 49 major crops planted in West Bank and Gaza Strip. These can be classified as fields' crops (wheat and Barley), vegetables, and fruit trees [47]. Agricultural residue and food processing wastes from Agro-Industry represent an important source of biomass with widespread availability. The main vegetables are: broad beans, parsley, cabbage, peas, carrot, pepper, cauliflower, potatoes, corn (sweet), pumpkins, cowpeas, radish, cucumber, snake cucumber, eggplant, spinach, garlic, squash, jews mellow, sugar beet, lettuce, thyme, musk melon, tomato, okra, turnip, onion, water melon, beans. There are some studies that provided energy potential and models for the prediction of the higher heating value of vegetables residues [48], and others that show that this type of energy can be extracted for electricity production through biomass gasification [49]. Besides the gasification process, the production of biofuels from agricultural residue (Lingo-Cellulosic-Feedstock) can be achieved through a biochemical process to produce ethanol or through a biomass to liquid by thermo-chemical process to generate biodiesel. Typically, the biomass to liquid route yields up to 2001 of synthetic diesel per dry ton of residue, which means 22,800 tons of diesel can be generated for the agricultural residues [50]. This could account for nearly 5% of the national diesel consumption [50]. Regarding to fruit trees, they can be used as lignocellulosic feedstocks. In Palestine these are: almond, apple, apricot, avocado, banana, citrus, date palm, figs, guava, loquat, nuts, olives, peach, pear, plum. There are also works that predicting the heating value of these kind of biomass [51]. Also waste and the organic portion of municipal waste can be used possible to produce biofuel from them with negligible additional land requirements or impacts on food and fibber crop production [3]. Recently, studies show that about 1.3% of all electricity consumption in Palestine can be produced by combustion of olive cake, referred to year 2009 [26].

4.4. Geothermal

Geothermal energy is considered as a clean source of energy, when compared with other energy sources due to reduction in greenhouse gas emissions [52]. It is a renewable, green, reliable, and a cheap domestic energy resource that needs development studies and investments in the geothermal sector which should be encouraged and supported [53]. Geothermal resources offer energy that is constant, and available on demand, providing an important alternative to fossil fuels [54]. So, the main advantages for Geothermal system essentially uses the stable temperature of the ground at specific depth for heating in winter and cooling in summer, providing clean energy and reduction in energy costs. The use of geothermal energy and its associated technologies has been increasing worldwide, eg. Australia [55], China [56], or Turkey [57]. There is little information mentioned in literature about geothermal energy potential in Palestine compared to other RE sources, it has been shown that geothermal has enormous potential as a source of energy for cooling and heating [58]. It has been found that the Palestinian land is attractive for geothermal energy utilization, mainly there are two of the very high sources, these are Gaza strip and north of Palestine [59]. The only known

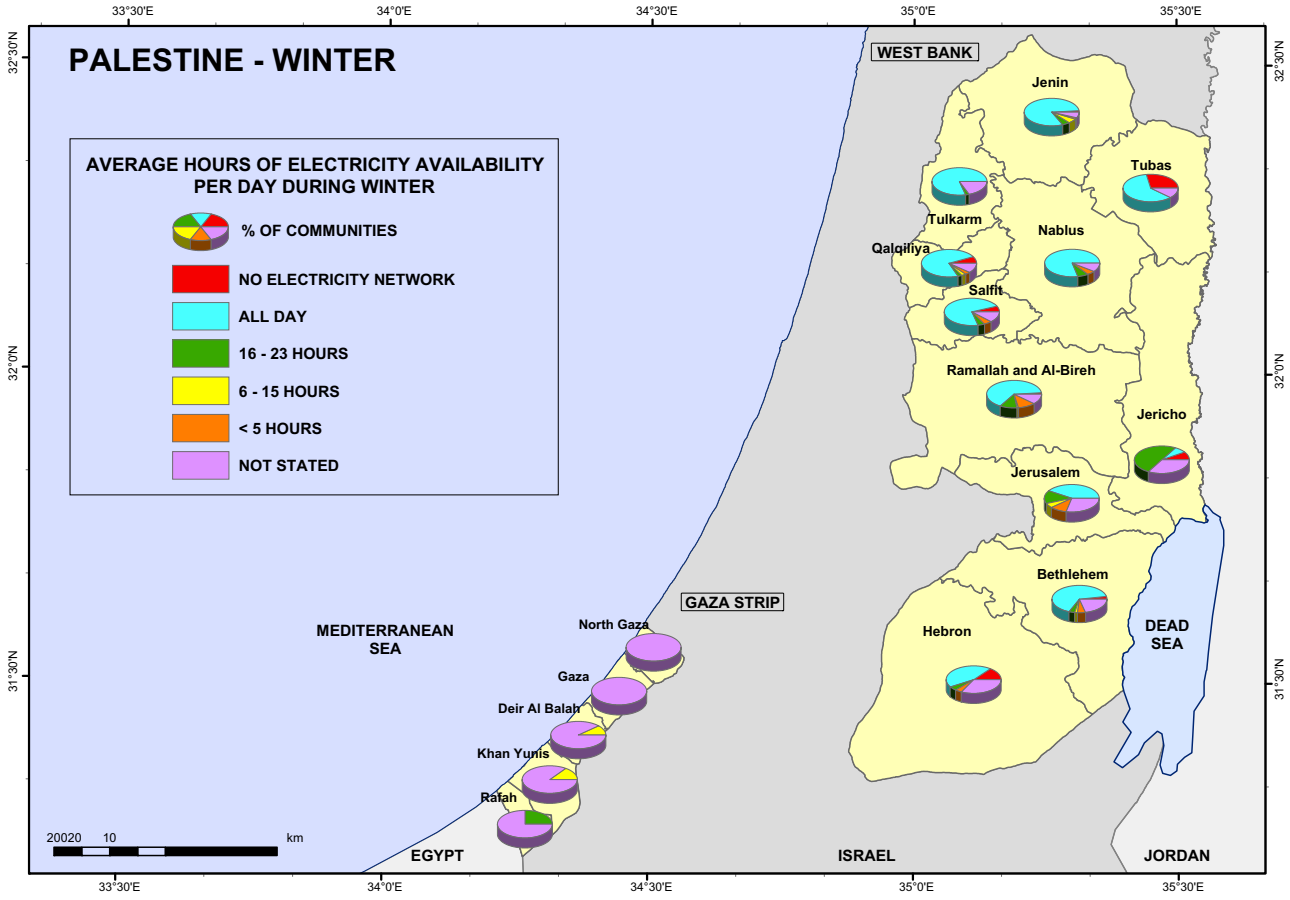

Fig. 14. Average Hours of Electricity Availability per day in winter (2013).

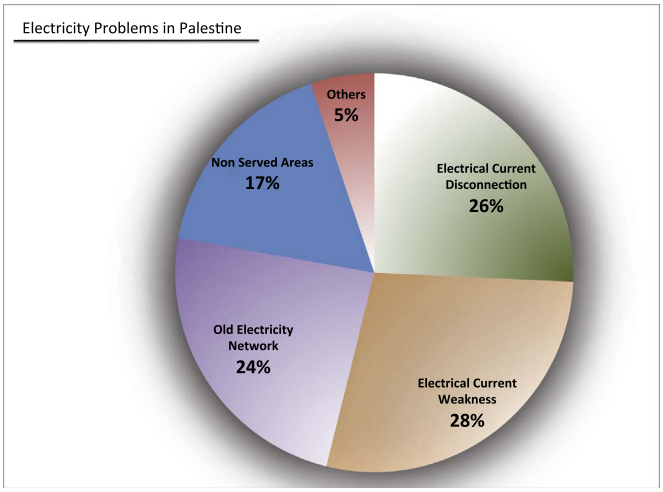

Fig. 15. Main electricity problems in Palestine (2013).

Table 7
Electricity tariffs in West Bank (2011).

Electricity Tariffs	Currency Exchange	2011
Description	Prices (NIS/kW h)	($/kW h)
Residential	0.55–0.7	0.141–0.179
Commercial	0.55–0.68	0.141–0.174
Industry	0.55–0.65	0.141–0.167

Table 8
Electricity residential tariffs in West Bank and Gaza Strip (2014).

Range (kW)	Gaza Strip ($/kW h)	West Bank ($/kW h)
1.0–160	0.126	0.151
161–250	0.128	0.159
251–400	0.128	0.179

project in Palestine is related to a residential building at Ramallah in West Bank executed by (MENA Geothermal) company that provided evidence of the major reduction in energy costs which paid for heating and cooling by more than 70% with a payback period of 4.5 years [14].

4.5. RE projects in Palestine

The Palestinian National Energy Plan (2011–2013) [25] presents that in addition to wood, coal and peat, RE is used for heating water in residential buildings. Exploitation of RE sources comprises approximately 18% of the total energy consumption in Palestine. So, the annual growth of the solar power use is almost 1%. However, this Plan highlights that the use of solar energy is very low in comparison to available capacities of the total energy consumption, only 8% of solar power is used. It should be noted that this percentage have declined over the past years. Furthermore, it has not kept pace with the general growth and expansion of other sectors, nor has it met the energy demand. The previous report has shown that the projects which were implemented in West Bank are small scale pilot solar power for generating and supply electricity to outpatient clinics, schools and Bedouin residential areas or small villages, which were remote from public

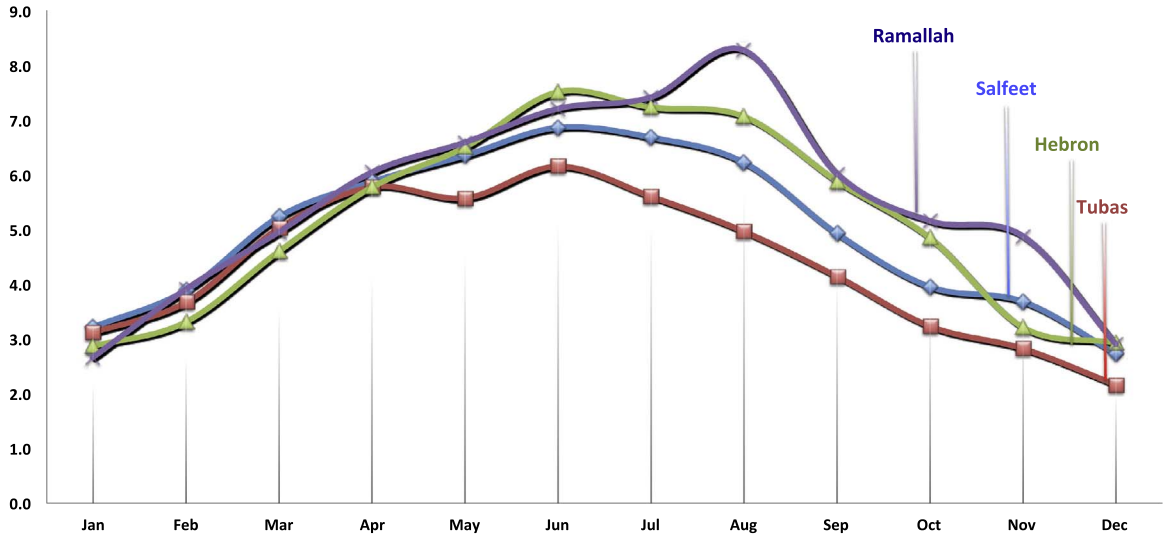

Fig. 16. Monthly averages of solar radiation in different cities in West Bank in year 2010.

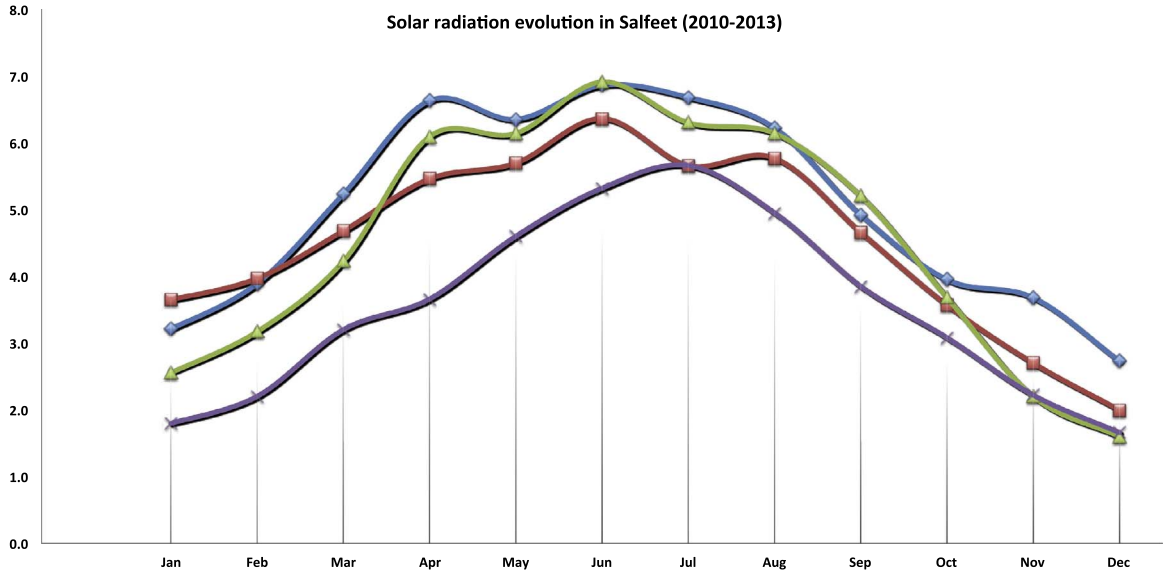

Fig. 17. Solar Radiation (kW h/m^2/day) for Salfeet, years (2010–2013).

electricity networks, these are stand alone systems. E.g the projects of Imneizil village in the southern Hebron governorate and Atuf village in northern West Bank. Total capacity of solar power projects is close to 50 kW. Another project is based on an initial agreement reached between Palestine and Japan to implement a solar tender based electricity generation project with a 300–500 kW capacity to supply the Industrial-Agricultural zone in the Jericho area. The most important project is a solar facility of 100 MW for electricity generation in Jericho. This plant will be built over several stages, the first stage will provide 10–20 MW [25]. Palestine has quite small remote communities that are far from the grid. People living in these remote communities use diesel generators to power their homes for a limited period of time, mainly after sunset. Furthermore, about 34.7% of Palestinian households experience interrupted power supply [60]. To electrify these remote communities will help to solve the problem of power supply shortage. The implementation of a hybrid system that is based upon Photovoltaic (PV) to supply power to remote and isolated locations is considered a viable option. This is especially true for areas that receive sufficient amounts of annual solar radiation [61]. RE has not reached yet a satisfactory level of utilization. The main barriers for investment in RE in Palestine are presented are:

a) High initial investment, weak capacity of local assembly and manufacturing, distribution, installation and maintenance of RE technologies,
b) Low consumer awareness leading to low market demand,
c) Lack of market intermediaries, private sector associations or other institutions for promotion of RE technologies,
d) Low awareness of local banking sector, and consequently lack of proper financing schemes, and
e) RE has very high expensive cost investment.

Positive externalities of RE generation in Palestine are not being considered. There is a general lack of consideration of the external costs in society derived from human health, environmental avoided costs and other issues regarding to the climate change that may be highly reduced with the implementation of this generation sources. So, Palestinian Energy and Natural Resources Authority will have to solve the following barriers to RE development in Palestine: absence of clear financing mechanisms, legal and

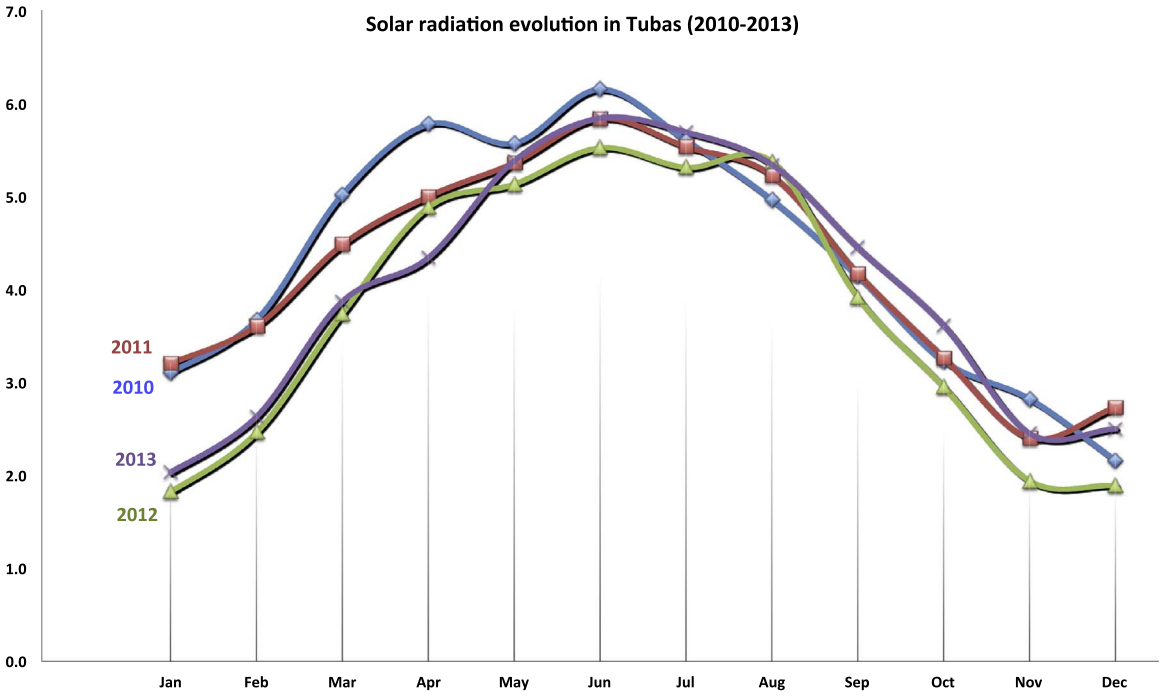

Fig. 18. Solar Radiation (kW h/m^2/day) for Tubas, years (2010–2013).

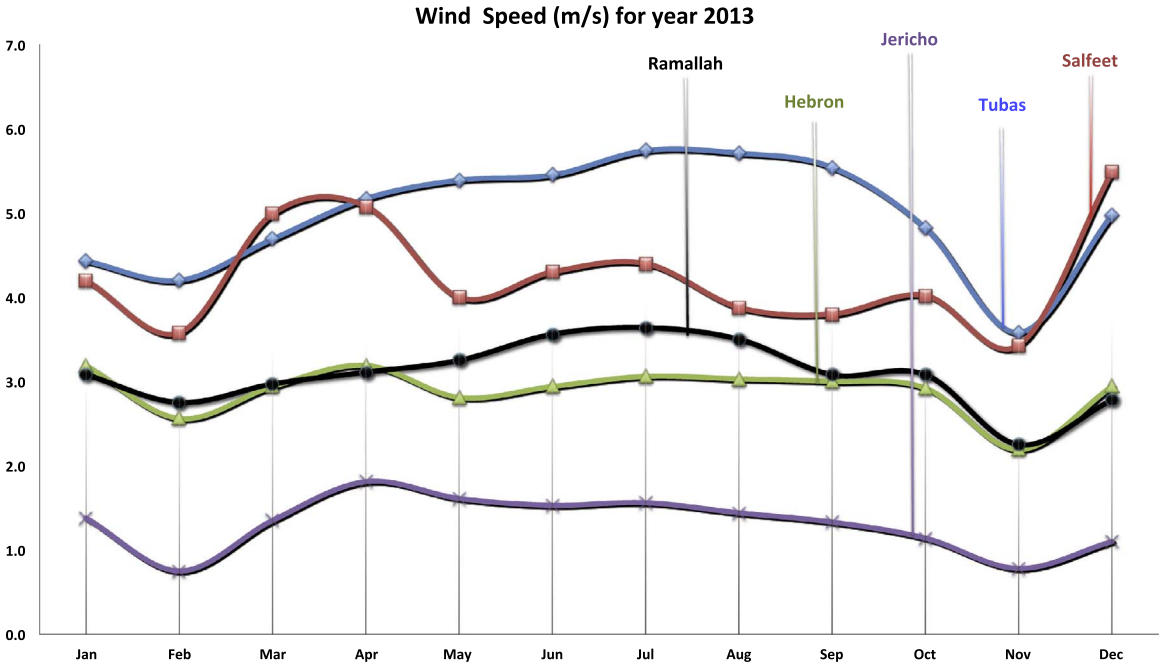

Fig. 19. Monthly wind speed in different cities in West Bank in year 2013.

Table 9
Wind speed averages in 2011 and 2013 for Tubas, Salfeet, Ramallah, Hebron and Jericho.

Governorate	Wind Speed (m/s)	
	Avg. (2011)	Avg. (2013)
Tubas	4.80	4.97
Salfeet	4.18	4.26
Ramallah	3.08	3.09
Hebron	2.68	2.90
Jericho	1.41	1.32

regulatory barriers. In addition, the development of RE needs research on data related to RE sources and make the National laboratories internationally accredited for RE technologies, and increase the professional skills related to the RE sector [16]. RE resources present a strategic goal for the Palestinian Energy Authority in order to achieve some degree of economic independence [62]. Recently, after the evolution of increasing oil prices, energy has become another major challenge to sustainable development for Palestinian [63]. Thus, the other main goal to achieve is to reduce the energy consumption in Palestine, these can be done by the development of a clear energy conservation and regulation policy [28]. Both goals can significantly reduce the energy reliance

Table 10
Scenarios and expected MW installed.

Scenario	RE Technology	2015	2016	2017	2018	2019	2020
Solar intensive	Solar	13	17	26	32	38	54
	Wind	3.5	6	8	10.5	13	17
Wind intensive	Solar	3.5	10	13	15.5	18	26
	Wind	9.5	15	20	26.5	33	41

on neighbouring countries and improve the Palestinian population's access to energy sources and to achieve a better quality of life.

4.6. Renewable energy scenarios in 2020

According to PEA (Palestinian Energy Authority) two possible scenarios are mentioned by the year 2020 for the government plans: solar intensive and wind intensive. Estimations indicate a contribution of 5% to the whole electricity consumption. This indicator gives a vision for the expectations of private market in the following years. With these scenarios, it tried to fulfill the RE target for the year 2020 and established 240 GW h the energy needs. Table 10 illustrates these scenarios and MW expected to be installed. The solar intensive scenario gives a higher development of solar technologies (CSP, PV-on the ground and small scale PV) and wants to reach 71 MW for 2020, instead the wind intensive considers a major development of the wind technologies (wind farms and small scale), the latter seeks to achieve only 67 MW.

5. Analysis of the strengths and drawbacks of the current situation of RE in Palestine

The analysis of the strengths and drawbacks provides a framework for reviewing strategy, position and direction. This analysis compares internal and external factors and yields a range of strategic alternatives or choices. Based on these alternatives, the strategies, which match the resources and capabilities to the Palestinian environment, are identified. The external factors can be divided into six main areas that influence on the development of the investment in RE in Palestine. These areas are political, economic, social, technological, legal and environmental areas. The internal analysis, on the contrary, is focused upon identifying the organization's resources, capabilities and competencies.

5.1. Strengths

Strengths are the positive tangible and intangible attributes available in the Palestinian's region and in the RE sector. The foreseeable strengths for the deployment of RES in Palestine are listed below:

a) High solar radiation.
b) Palestine is geographically situated in an area with very good solar conditions. It has an average of solar irradiation of 5.4 kW h/m^2/day.
c) Awareness of the Palestinian government about renewable energies.
d) Palestine government is in the way to develop the RE law and also creating a wind map.
e) Local experience using RE.
f) Solar thermal is widely used by around the country. About 70% of hot water is produced by solar thermal technology, which means people already know and rely on RE technology.
g) Entrepreneurship character of the private sector.
h) Significant potential contribution to cover the future energy demand increase - Electricity energy demand increases yearly for about 6%. RE can help to cover this annual increment.

5.2. Drawbacks

Drawbacks are factors that are within the Region's control which detract from our ability to investment in RE in Palestine, or areas needing improvement. The foreseeable weaknesses for the deployment of RES in Palestine are listed below:

a) No specific RE regulations defined. Since there are no regulation in the RE market, it is very difficult to create new companies and make investors establish their projects in the country.
b) Energy dependency. Palestine depends on the energy imports mostly from Israel.
c) Poor infrastructure. Currently the grid in Palestine it is divided into several isolated groups. It's being working for connect the different groups, and so have less points of connection with Israel and more managing capability of the energy in Palestine.
d) Small of land surface availability. This is an issue for large scale RE installations. Palestine lacks of terrain, in most of its area it is not possible to build installations or it is needed for agriculture.
e) Poor conditions to develop local industry. Due to the lack of energy it is difficult to develop industry.
f) Government policy. Government does not have plans to solve the increasing demand of electricity problems neither to solve the shortcuts problems.

6. Conclusions

This work offers a compressive review of energy sector in Palestine. It is highlighted that renewable energy plays an important key for sustainable development and achieving environmental benefits resulting from reduction of CO_2 emissions in Palestine. The Palestinian government had the goal to generate 10% of electricity through renewable resources by the year 2020. The possible RE technologies to be used are mainly solar and wind energy, but also others like geothermal or biomass. Solar energy is already extensively utilized in domestic water heating but it is not widespread use in the commercial feasibility for producing electricity especially considering that Palestine has 3000 sunshine hours per year and an annual average of solar radiation of 5.4 kW h/m^2/day. Wind energy resource is moderate therefore; microturbines can be used where as backup sources instead of diesel generators for PV hybrid systems, which renders the utilization of such hybrid systems more attractive for remote areas. Wind speed in Gaza Strip is considered very low; therefore, potential wind applications are restricted partially to mechanical water pumping, also it is not possible to install wind facilities due to the high population density. High oil prices and the desire for national energy sovereignty have recently led to a reconsideration of the potential for RE in at least meeting part of growing Palestinian energy needs and requirements. The importance and the needs for the commercial RE applications in Palestine, addressing the potential and possibility of adopting RE resources, in particular for many sectors with high energy consumption and also for electrify remote communities are far from the grid. Using renewable energy sources may significantly reduce the energy reliance on neighbouring countries in a long-term and will improve the Palestinian population's access to energy sources.

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