Status and Trends of Renewable Energy Development in Gaza

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The Asian Conference on Sustainability, Energy & the Environment 2013

Official Conference Proceedings 2013

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1. Introduction

According to the Political situation on Gaza Strip and the mandatory siege since 2006 by the Israeli occupation after Palestinian election, Power Generation Sector faced several obstacles starting with destroying main generators of Gaza Power Plant in June 2006 through blocking fuel entry into Palestinian Territories in 2008 ending to unknown and horrible situation.

Total energy consumption in the Palestinian Territories is the lowest in the region and costs more than anywhere else in the Middle East [1]. The people in Gaza get only 0.17 kWh energy-shares per capita, in comparison to Israel 6356 kWh per capita [2].

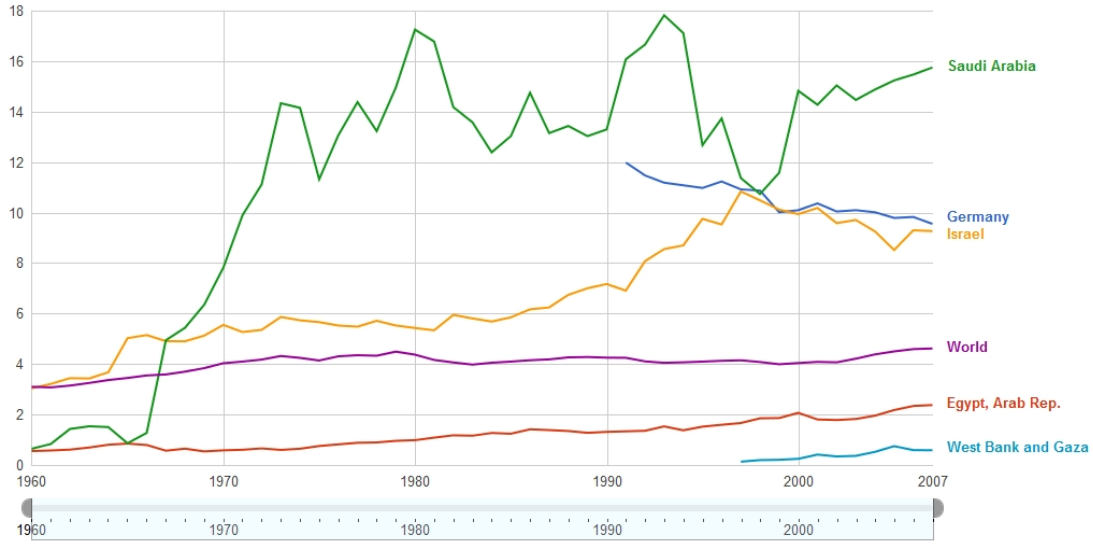


Fig.1 *CO2 Emissions in West Bank and Gaza Strip (metric tons per capita)[3].*

Therefore, the CO2 emission in Gaza Strip in comparison to other countries is minimal. Carbon dioxide emissions are those stemming from the burning of fossil fuels. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

2. Energy Situation in Gaza

The total amounts (100%) of fossil fuels consumed in the Gaza Strip are imported. Gaza is completely dependent on Israel for all its supplies of fuel. Fuel enters Gaza via underground pipelines which cross the Israel-Gaza border at Nahal Oz. The fuel comes in four types:

- Industrial gasoline - exclusively for Gaza's power plant for the production of electricity.
- Gasoline - for vehicles.
- Diesel - for vehicles and back-up generators which are vital during Gaza's frequent electricity cuts.
- Cooking gas

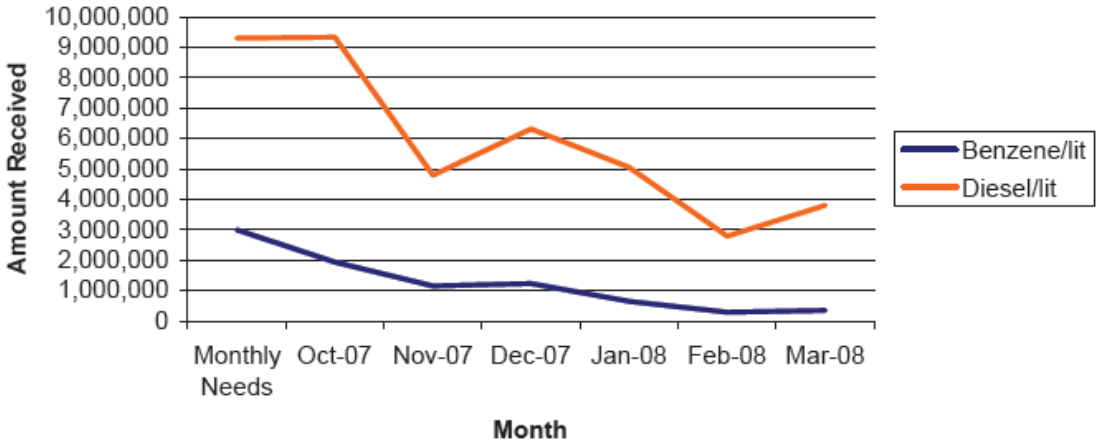


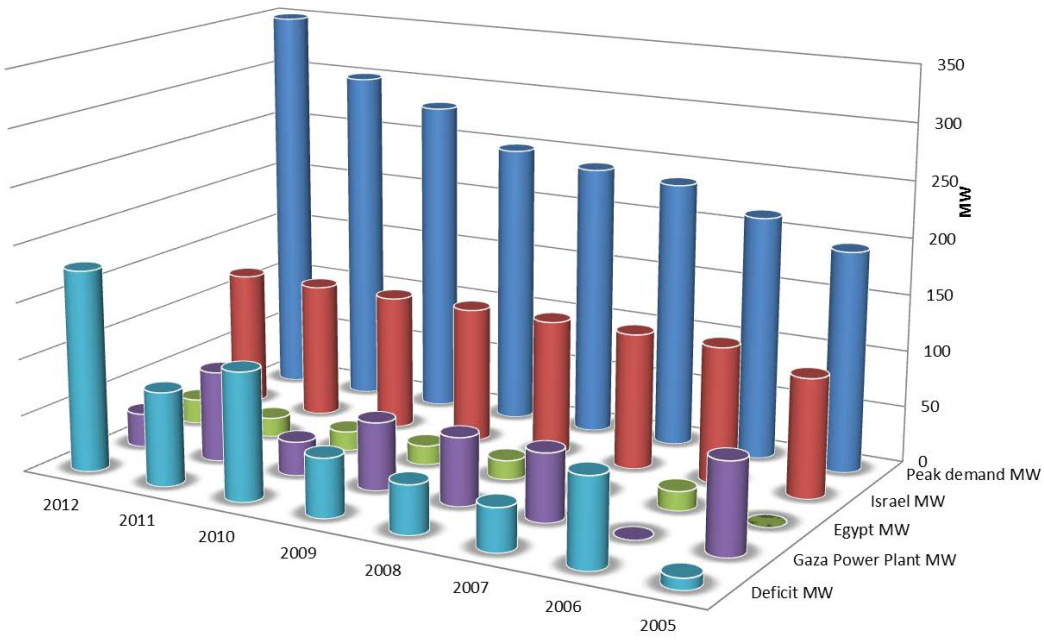
Fig. 2 *Petrol and Diesel Supplies into Gaza*

Before 28 October 2007, Gaza's fuel supplies were dictated by market forces and supply was related to demand. On 28 October, following a decision of Israel Government to declare the Hamas government a 'hostile entity', Israel began reducing the supply of fuel to Gaza. In March 2007, 8.8 million liters of diesel and 1.7 million liters of gasoline were supplied to Gaza. In March 2008, the figures were reduced to 3.8 million liters of diesel and 340,000 liters of gasoline, representing a reduction of 57% and 80% respectively [4].

3. Electricity distribution in Gaza

The Gaza Strip's needs range between 240 and 280 megawatts (MW), of which at least 42 percent is purchased from Israel. Gaza is connected from north to south by eleven connection points with Israeli power network, via transmission lines with 22 Kilovolt and total capacity of 115MW. In Gaza, the power supply comes from three sources, Israel, Egypt and generated by its own Gaza power plant (GPP). Currently, the Gaza Strip's needs range 350 megawatts (MW), of which at least 42 % is purchased from Israel, distributed in separate feeder lines along the Gaza Strip, and 6-7 % is purchased from Egypt, distributed mainly to the Rafah area.

The remaining electricity need is supposed to be met by the GPP. Following the latest decline in production, however, the GPP is able to meet less than 13 % of the electricity needs. This is resulting in a deficit of up to 51 %, compared to 21% in 2009. Figure 3 shows the various electricity suppliers with its related shares in Gaza between 2005 and 2012 [5]. Figure 4 shows a Map of the Power Supply Deficit in the Gaza Strip, the following facts come from the United Nations Mai 2010 [6]. The Gaza Electricity Distribution Company copes with the electricity shortage by applying a load sharing system, through which it schedules electricity cuts in one area in order to feed another.



	2005	2006	2007	2008	2009	2010	2011	2012
Peak demand MW	195	215	235	240	249	280	300	350
Israel MW	105	120	120	120	120	120	120	120
Egypt MW	0	17	17	17	17	17	17	22
Gaza Power Plant MW	80	0	60	60	60	30	80	30
Deficit MW	10	78	38	43	52	113	83	178

Fig.3 *Electricity supply in Gaza Strip between 2005 and 2012*

In June 2006, Gaza only power plant was destroyed. The plant was capable of producing up to 140 MW. Since the bombing, eight new transformers have been installed, with a maximum output of 80 MW. The power plant was fully dependent on fuel supplies from Israel. The plant needs 3,300,000 liters of fuel per week to produce 78MW but the Israeli occupation allow for just 2,200,000 liters as a minimum amount per week which sufficient to generate 55 MW only [7]. Palestinian engineers have made it possible to operate the power plant with cheap fuels coming currently official from Egypt through Israelis. That can always change according to political circumstances, and the Israelis can any time block the delivery of the necessary fuels.

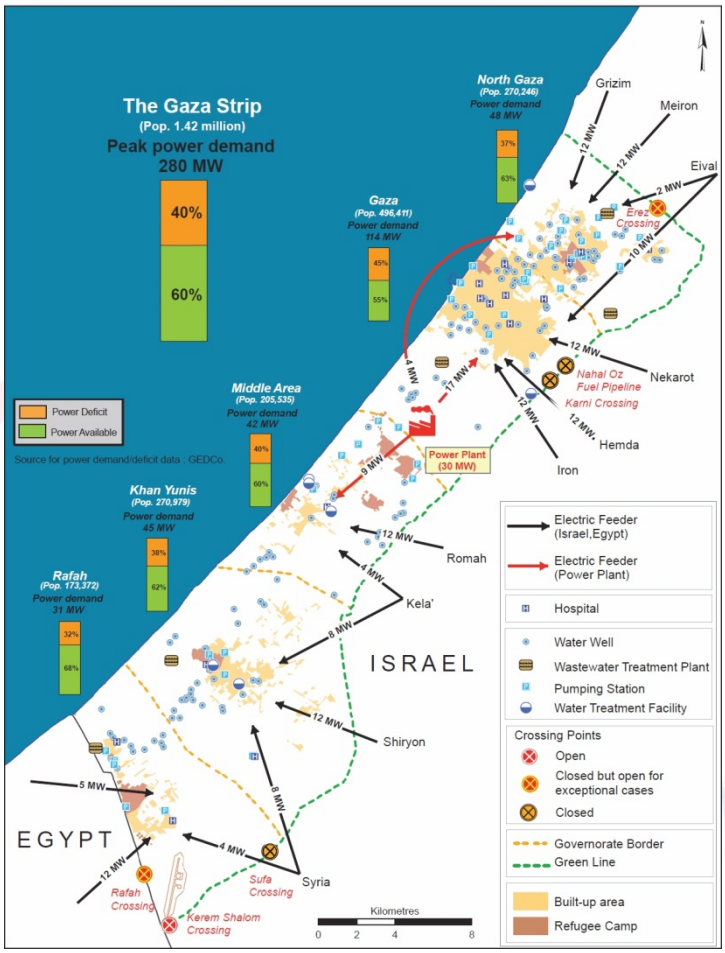


Fig.4 *Power Supply Deficit in the Gaza Strip in Mai 2010*

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4. Renewable Energy Trends

The potential threat of global climate change increasing energy demand of the developing world, and inevitably, although not rapidly, diminishing fossil fuel resources have made sustainable energy supply a planetary issue that has to be addressed by literally every sector of human life. At the same time buildings continue to play a significant role in the global energy balance. Typically they account for some 20-30% of the total primary energy requirements of industrialized countries. With increasing awareness of the ecological consequences of energy consumption, the

need for energy and environment conscious building design has become more and more pressing [8].

Using renewable energy has become a global trend. In 1997, the Kyoto Protocol was agreed upon; it is the world's only international agreement with binding targets to reduce greenhouse gas emissions. As such, it is the primary tool with which governments of the world can address climate change; so far, 129 countries have ratified or acceded to the protocol [9]. The effect of the Kyoto Protocol has no role in Gaza. Furthermore the energy authorities do not consider at the details of this Protocol, because the Gaza Strip counts of the few countries with minimal CO2 emissions. In particular in Gaza gets the use of alternative energies more and more significant interests of the nation, increasing trend. Main reason for these increasing trends is the will of Gaza People to be independent on the Israeli fuel imports. The first step toward Palestinian energy independence and security would be the development of its renewable energy sources, both for large-scale energy production and smaller-scale, standalone systems [1]. "Also renewable energy promotes independence".

a. Solar energy

On the super-regional level, the continent Africa has a great photovoltaic solar electricity potential. Gaza Strip is in the average of overall potential of Africa [10]. According to the U.S. National Aeronautics and Space Administration NASA, Gaza Strip receives high radiation levels ca. 5.5 kWh/m2 per day annually [11].

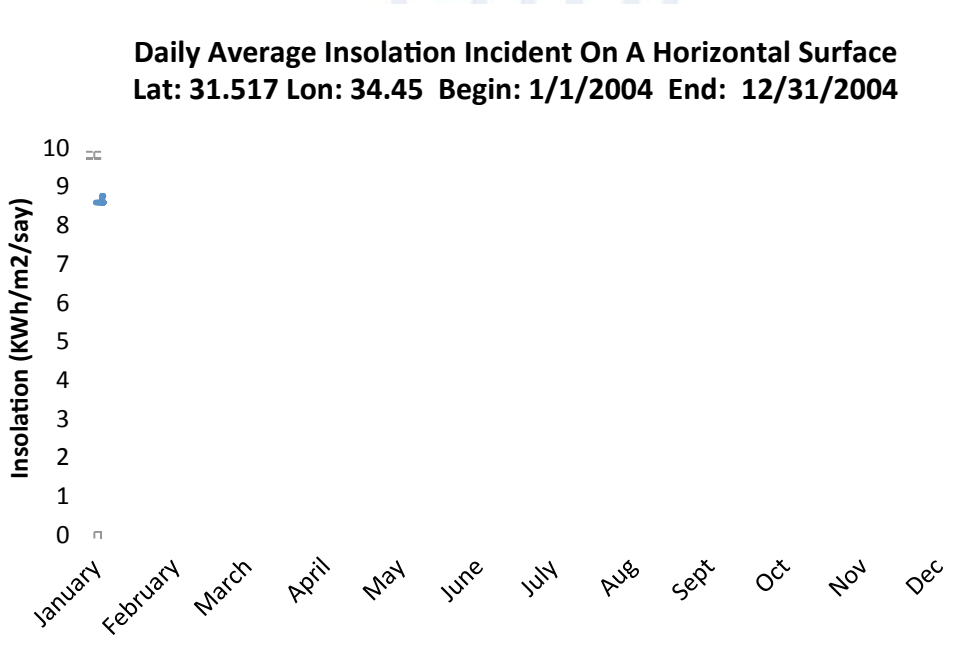

Fig.5 *Solar Irradiance in Gaza, 2004*

The total annual sunshine is approximately 3400 h. These are excellent conditions for harnessing solar energy for both large-scale and stand-alone applications.

Indigenous energy resources are quite limited to solar energy for photovoltaic and thermal applications, mainly for water heating. Utilization of solar energy for water

desalination is still the subject of research and investigation in Palestine, and also of course in Gaza Strip [12].

There are three major application of solar energy in Gaza; Solar dryers, Solar thermal panels (solar water heaters) and Photovoltaic Systems PVS. The Solar Dryers are used little in Gaza. Drying fruits and vegetables with this system is a cost-effective long-term food storage solution that requires no external electricity to operate, and eliminates the need for chemical preservatives. The aid organizations fund usually these devices to the farmers in villages.

Solar water heaters are extensively used in the residential sector in Palestine more than 70% of households use solar family systems. The existing installed capacity (up to year 2007, Source: Palestinian Central Bureau of Statistics PCBS) in all sectors is totaled 1,500,000 m^2. This can produce 940 GWh per year and saves 85 M€ yearly to the national economy. The corresponding avoided emissions of CO2 are evaluated at 650,000 tons per year or avoided damage 2.3 M€ [12-13].

The max kilowatt PV system installed in Palestine is about 50kwp (The Palestinian Energy and Environment Research Center PEC), there are numbers of PV system projects are implemented in Palestine's villages in West Bank. The installation of PVS in Gaza is still comparable to the West Bank is very low. The Reasons for that are different, especially the height cost, the lack of experienced personnel and the difficulties of the imports PV-Modules. Unfortunately, the PV modules, Voltage Regulators and inverters which available in Gaza strip are limited [14]. Nevertheless, some projects have been implemented in Gaza; Gaza municipality lights some main streets using PVS, Fig. 6 shows an example of Street lighting by Wadi Gaza (Valley of Gaza). The system is currently does not work due to shortage of maintenance. In the Shifa hospital in Gaza City, a 5 KW PV-solar system was powered the intensive care unit ICU. On the roof of the kindergarten Umm al-Nasser in Khan Yunis, a city in the southern Gaza Strip, was installed a 10kW PV-solar system.

Fig.6 *PV Street Lighting System at the Valley of Gaza*

b. Wind energy

Wind, available in nature as a result of the different levels of earth surface heating, produces kinetic energy which can be converted into mechanical or electrical energy by means of two types of wind energy conversion technologies (WECT): horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). The amount of power extracted by this WECT is represented by the following Eqs. (1) and (2):

$$P_{\mathrm{WT}} = C_p(\lambda, \omega)\frac{1}{2}\pi R^2 \rho v^3 \quad (1)$$

$$\lambda = \frac{\omega R}{v} \quad (2)$$

Where Cp is the wind power coefficient (function of pitch angle, ω and tip speed ratio, λ), R is the rotor blade radius (m), ρ is the air density (kg/m^3) and ν is the wind speed (m/s). The first equation indicates that the generated wind power has a large dependency on wind speed (generated power is proportional to the cube of wind speed), hence a slight wind speed change can significantly affect the overall output of the wind turbine. As the wind speed is an important parameter, this study shows the wind speed measurement at 100 m hub height above ground level (AGL) [15].

Usually, Wind speed and direction are basic data required to identify wind resource in a site, however, these data need to be analyzed in a proper way to provide us better understanding of wind characteristics. Wind resource assessment studies have been conducted in the Israeli side and the Palestinian side before; however, the previous studies were restricted with the political border either Palestinian or Israeli except one of them that was based on measurements dated to 1940-1983 [16]. Moreover, the studies were performed years ago, with simple techniques and based on old data [1, 16].

The wind resource assessment ends up with identifying sites with higher potential that are situated in four selected sites, North of Palestine/Israel, North of West-bank, Jerusalem, and Eilat, the higher potential was in Eilat area bearing mean wind speed of 9.88m/s at 100 m hub height.

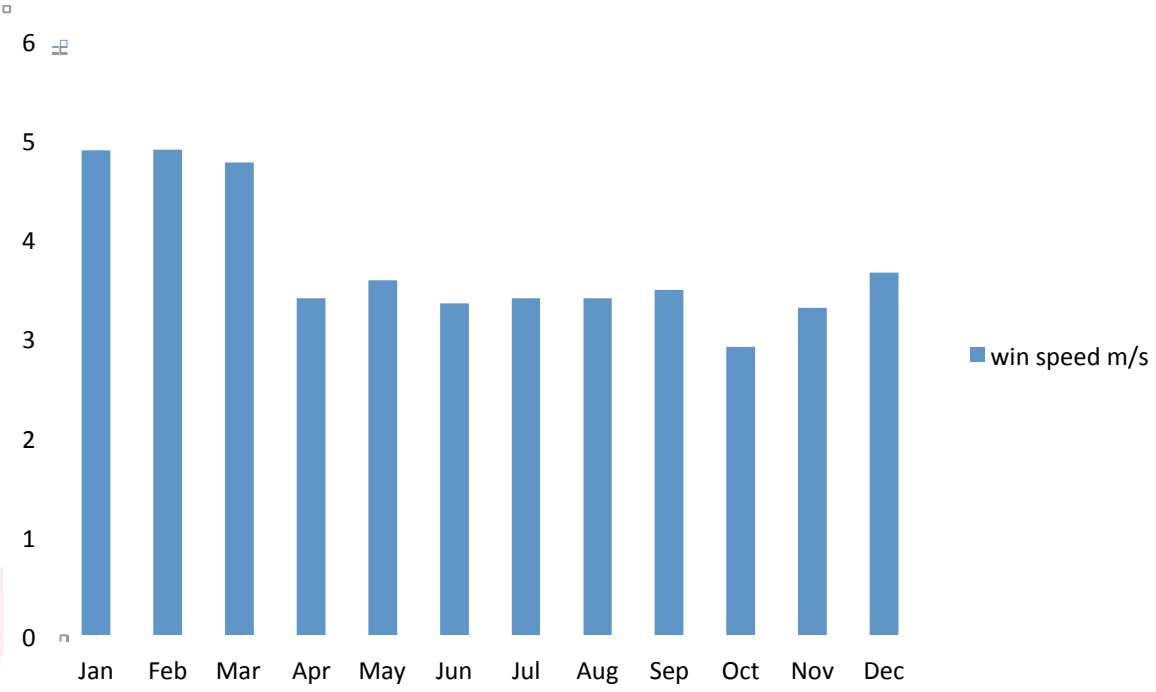

Fig.7 *Average Wind Speed in Gaza Strip, 2012*

Figures 7 show histograms of the observed wind speed in Gaza. Data has been collected in year 2012. The direct coastal location on the Gaza beach ensures passage-free wind and so the wind turbine harnesses most of the wind energy because of the absence of any obstacles. The average annual wind speed recorded in Gaza is 3.75 m/s , and the highest wind speed recorded is 18 m/s in winter . With such wind speeds it is feasible to construct a wind-energy system in this geographical location. The number of days-of-autonomy, where the wind speed will be less than the speed limit required for the turbine blades to rotate and turn with them the electric generator, is approximated to 6-days in July according to the wind speed records of Gaza.

Table 1 and Figure 8 provide an overview of wind directions that were measured during the year 2012 in Gaza. Wind Direction in Gaza Strip is between south-west and north-west, but the average could be determined to 247.5°, also WSW.

Tab. 1 *Average Wind Direction of the Year in Gaza, 2012*

M/D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	SW	WSW	WSW	SE	WSW	WSW	NW	SW	NW	WNW	SW	ESE
2	WSW	W	W	W	WSW	WSW	NW	NW	NW	NW	ESE	N
3	NE	ENE	W	SW	W	WSW	WSW	NW	NW	NW	NNE	SSW
4	NE	E	WSW	S	NW	NW	NW	WNW	W	NW	SW	WSW
5	W	E	NNW	NW	SW	NW	NW	W	NNW	WNW	NNE	WNW
6	SW	ESE	NNW	NNW	WSW	NW	NNW	WNW	NNW	NW	S	SSW
7	SE	SSW	ESE	ESE	NW	NW	WNW	WNW	NNW	WNW	SSW	SW
8	SW	WSW	ENE	SSE	WSW	WSW	WNW	SW	WNW	WNW	NW	SW
9	SSW	WSW	NNE	W	NW	WSW	WNW	SW	W	NW	WSW	ENE

10	SW	W	NNE	WNW	WNW	NW	WSW	SW	NW	NNW	WSW	SW
11	SW	NE	E	WNW	NW	NW	NW	WNW	WNW	SW	W	WSW
12	SW	ESE	WSW	NW	SSE	NW	NNW	NW	WNW	E	WSW	SE
13	WSW	WSW	WSW	SW	W	NNW	NNW	NW	NW	NNW	NNW	W
14	SW	W	W	E	WNW	NW	WSW	NW	W	E	NW	NNW
15	SSW	W	W	S	WSW	WNW	WNW	WNW	WSW	ENE	NE	S
16	SW	W	W	WSW	S	NW	NW	WNW	NNW	S	ESE	NW
17	WSW	WSW	SW	SE	NW	NW	NW	NW	WSW	SSE	ESE	SSE
18	E	W	ENE	SSW	SSW	NW	NW	S	SSW	SW	WNW	S
19	NW	WNW	ENE	W	W	NW	NW	WSW	S	NW	NW	SSW
20	NW	NE	E	WSW	NW	W	WNW	NW	SSW	NW	S	SW
21	S	ENE	S	NW	NW	W	WNW	NW	NNW	NE	N	WSW
22	WSW	ENE	WSW	NNW	WSW	WNW	WNW	NW	NNW	NW	WNW	SSW
23	W	0	SE	NW	WSW	SW	SW	NW	NW	NNW	WSW	SE
24	S	NNW	ENE	WSW	NW	SW	NW	NW	NW	NNW	NW	
25	S	NW	WNW	NNW	SW	W	WNW	NW	NW	WNW	NW	SE
26	SW	WSW	WNW	NW	NNW	WNW	WNW	NW	WSW	W	NW	NNW
27	WSW	WSW	W	NW	SSW	WNW	WNW	WNW	SW	NNW	NE	NNE
28	WNW	SSW	WSW	NW	E	W	NW	WNW	NNW	ESE	ENE	NNW
29	0	WSW	WSW	SSW	WNW	WNW	WNW	WNW	WSW	NNW	ESE	NW
30	SE		W	SSE	WSW	WSW	WNW	NW	S	NNW	ESE	S
31	SW		SSW		NNW		WSW	WNW		NNW		N
Average	**SSW**	**S**	**WSW**	**WSW**	**W**	**WNW**	**WNW**	**WNW**	**WNW**	**W**	**SSW**	**SSW**

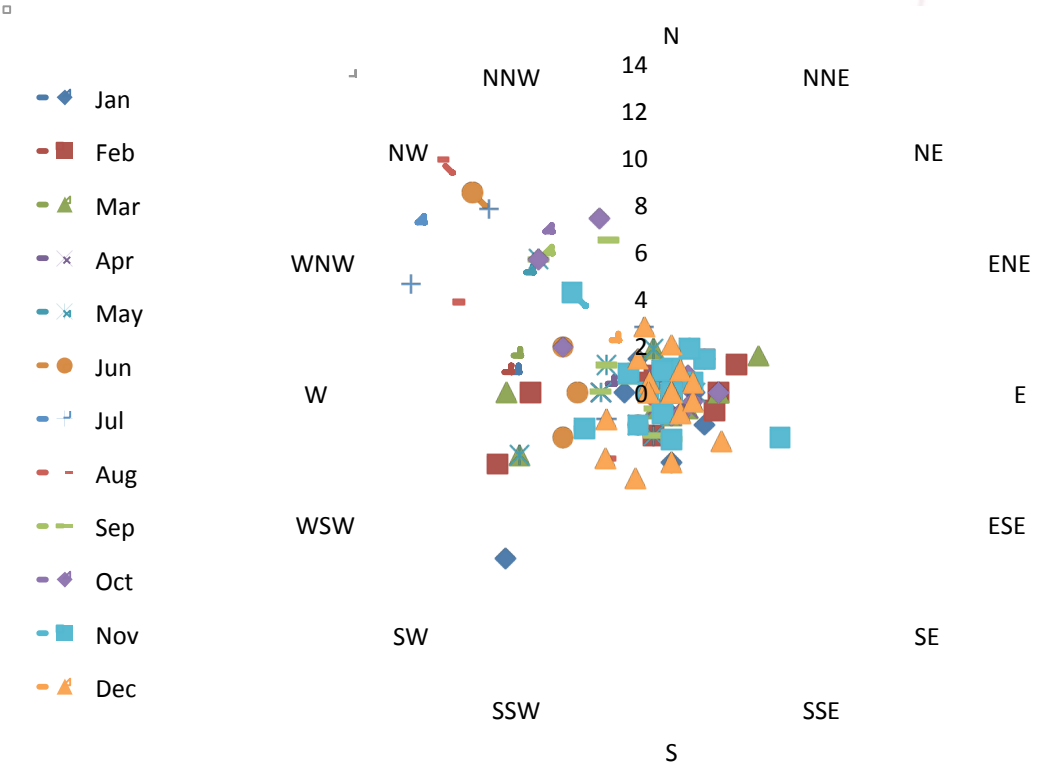

Fig.8 *Wind Direction distribution in the Gaza strip, 2012*

Running huge wind turbine (more as 1 MW) to generate electricity, which need wind speed not less than 10 m/s, is not recommended in Gaza Strip. However, this wind speed range can be used for small wind turbines' electricity generation. The high density of buildings and the scarcity of open and empty lands in the Gaza Strip obviate the possibility of building wind farms there. However, offshore wind farms could be installed in the Mediterranean Sea, were it not for present political obstacles. Today, the only large-scale wind turbine in the Palestinian Territories is at the Al-Ahli Hospital in Hebron. This turbine provides 40% of the hospital's energy needs [1]. The low speed winds in the Palestinian Territories may encourage using wind energy in stand-alone systems to provide small electricity loads, such as for water pumping, grain grinding and other purposes. Indeed, wind energy could make an important contribution to meeting the energy needs for development in rural areas, where 17% of the Palestinian population resides. Wind energy can be used to pump water that is stored in tanks and reservoirs or absorbed in the ground as well.

c. Waste-to-energy

Waste-to-energy (WtE) or energy-from-waste (EfW) is the process of creating energy in the form of electricity or heat from the incineration of waste. WtE is a form of energy recovery. Most WtE processes produce electricity directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels [17].

There are a large number of technologies on the market at the moment and the use of many terms and definitions, with often different meaning. This reduces the possibility of comparing the different options.

1. Energy from Waste (E
2. fW); is the process of creating energy in the form of electricity or heat from the thermal breakdown of waste through any thermal conversion technology or combination of conversion technologies. Any technology discussed in this paper is an EfW technology. With conventional EfW we mean grate fired or fluidized bed combustion of waste.
3. Combustion/incineration; is the thermal breakdown of waste supplying an excess of air, producing a flue gas (CO2, O2, N2, water vapor) and heat.
4. Gasification; is the thermal breakdown of waste under oxygen starved conditions (oxygen content in the conversion gas stream is lower than needed for combustion), thus creating a syngas (e.g. the conversion of coal into city gas).
5. Plasma gasification; is the treatment of waste through a very high intensity electron arc, leading to temperatures of > 2,000°C. Within such a plasma, gasifying conditions break the waste down into a vitrified slag and syngas.
6. Pyrolysis; is the thermal breakdown of waste in the absence of air, to produce char, pyrolysis oil and syngas (e.g. the conversion of wood into charcoal) [18].

The daily solid waste generation across Gaza is more than 1450 tons (ca. 1.0 kg per capita). Nearly 65% of this waste is estimated to be organic, implying real opportunities for waste disposal schemes that emphasize recycling [19]. Scarcity of

waste disposal sites coupled with huge increase in waste generation is leading to serious environmental and human health impacts on the population.

The severity of the crisis is a direct consequence of continuing blockade by Israeli Occupation Forces and lack of financial assistance from international supporting helps organization. Most of the collected solid waste in the GS is disposed of in three main disposal sites; Johr al Deek Landfill east of Gaza City, Sofa Landfill east of Rafah City, and Deir El Balah Landfill in the Middle Area of GS. The three sites are reaching their maximum capacity, in addition to the fact that the expected amount of solid waste is expected to reach around 3700 tons/day in 2040. Accordingly there is a growing need for establishing an integrated Solid Waste Management (SWM) that to adequately handle the growing waste generation rates in GS with minimum impacts on public health and the environment. A sustainable solution with respect to social, environmental and economic impacts is therefore needed for the solid waste management in the GS [20].

Because a high proportion of the waste is organic, it may be environmentally preferable to incinerate solid waste. The Biogas potential in Palestine is over than 33 million m^3. Biomass (wood and agricultural waste) is traditionally used for cooking and heating in rural areas. Being Palestine one of the many olive oil producing countries in the region, the interest now is directed to utilize the olive mill solid waste (OMSW) to be used as clean source of energy. The olive harvest season is all year round and so the OMSW as a raw material is also constantly available. The annual average amount of OMSW is around 76,000 tons. The municipal solid waste in Palestine could be used as a source of energy, a new developing proposal projects were released by PEC to generate electricity from burning the wastes (WTE). The proposal project is for constructing an 18 MW waste to energy (WTE) power plant in order to get rid of municipal solid waste (MSW) of the northern provinces of the west bank; this is done by a controlled combustion of the wastes which is exploited generate electricity. All technologies of WtE are in Gaza not available. The usage of waste to produce electricity was executed by a research project at the Islamic University of Gaza by students, but unfortunately remains in the theoretical phases, at least for short term. In addition, there is due to financial and political situations in Gaza Strip can probably wait a long time for released projects regarding WtE.

5. Conclusion

Gaza is a fossil energy-poor country. Alternative energy resources can play knight role in Gaza, if the financial support available is. By stretch of the imagination and enough research, a trend in Renewable Energy could be realized, so that the deficiency in electricity could be prevented.

Moreover, the use of solar energy plays an important role. The wind, geothermal and WtE Energies have no great potential in Gaza Strip. The best in this period of time and due to lack of financial resources, the research in solar energy should be concentrated.

In addition, Establishing of a center interested in renewable energy sources is very important which the primary purpose of this center is to promote, coordinate, facilitate and implement research and development projects in renewable energy sources,

conservation and sustainability practices, and to bridge the gap between the state-of-the-art and the state-of-practice in alternative energy utilization in Palestine.

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