ISSN 2229-5518

Scope of Utilization of a Hybrid System of Solar and Wind Energies as a Storage System in Palestine

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Abstract— Energy is a vital item for the development of any nation. People of Palestine are living in critical situation regarding their needs of energy due to the lack of fusel fuels and other conventional resources; in addition to the continuous Israeli occupation, which has been about seven decades. It depends totally on the occupier for the supply of petroleum and petroleum products and more than 90 % of its electricity needs. By this, the occupier controls the energy needs and hinders the utilization of the natural resources in the country and worse than that he divided the country into four regions separated by reinforced concrete walls which made connecting it to single energy and electricity network rather impossible. Despite all these hindering's, the Palestinians are taking every possible chance to overcome these obstacles and utilize their natural resources. In this paper, the scope of utilizing a hybrid system of solar and wind energies, which are readily available in most regions in Palestine, and store them to be used when they are needed both in the populated regions and in the remote areas of the country. The use of these types of renewable energy will reduce the green gases emissions and results in a cleaner environment. Furthermore, a system for heating and cooling building, using these storage materials, is also presented and discussed.

Index Terms— Green gases emission, Hybrid, Palestine, Renewable energy, Solar, Solar radiation, Utilization, Wind.

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1 Introduction

Palestine is a middle eastern country of 14 million population and of 6220 km² area. It is located on the Eastern coast of Mediterranean Sea with elevation ranging from _276 m below sea level in Jericho in the Jordan Valley to about 1000 m above sea level in Hebron. Geographically, its coordinates fall between between 34°20′ degrees to 35°30′ degrees east longitude and 31°10′ to 32°30′ degrees north latitude.

It is a non-producing oil country and depends on importing almost all its energy needs from the Israeli occupier. It is the poorest country in the region according to the energy consumption per capita, which clearly indicates the gravity of the energy problem for the Palestinians.

Palestine depends on fulfilling its needs of power on fusel fuel. Furthermore, over 90%of it is imported from the Israeli occupier. Energy consumption per capita for the Palestinian Territories in 2006 did not exceed 0.3 tons of oil equivalent (toe), which is the lowest in the region. Israel's per capita energy consumption (3.5 toe) was ten times greater than consumption level in Palestine, while that of Jordan and Syria was three times superior (respectively 0.9 and 1.1 toe). The American consumption per capita, with 9.7 toe, is 32 times higher than the Palestinian level. Table 1 illustrates the electricity per capita in Palestine with respect to other Arab Countries.

It can be seen from this Table that Palestine has the lowest electricity consumption per Capita among Arab Countries. Despite using relatively small amounts of energy and electricity per Capita, the energy efficiency was low in the Occupied Palestinian Territories and had worsened throughout the 1990s, resulting in unnecessary releases of GHG to the atmosphere. The UNDP and Palestinian Energy Authority launched an energy efficiency improvement project in 1998. It is, therefore, a great necessity to look for other available natural resources to overcome these obstacles. A thorough outlook at the available renewables in occupied Palestine it can be recognized that it is very rich in these resources. This will be dealt with in the following section.

TABLE 1
ELECTRICITY CONSUMPTION PER CAPITA (MWH) IN DIFFERENT ARAB COUNTRIES

Country	Electr./Capita (MWh)
Jordan	1.300
Syria	1.500
Lebanon	1.800
Palestine	0.350
Egypt	1.100
Algeria	0.723
Morocco	0.570
Tunisia	1.046
World	25.001

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ISSN 2229-5518

2 RENEWABLE ENERGY IN PALESTINE

The following types of renewables are available in Palestine:

2.1 Solar Energy

Palestine is very rich in solar energy. The average solar insulation in Palestine is 5.4 kWh/m²/day, indicating a high potential. According to the U.S. National Aeronautics and Space Administration, parts of the West Bank, in the Jordan Valley, receive high radiation levels of 5.40-5.98 kWh per day annually. Total annual sunshine is approximately 3,000h. These are excellent conditions for harnessing solar energy for both large-scale and stand-alone applications. The potential of solar sources is estimated to account for 13% of electricity demand. In addition, domestic solar water heating (SWH) is widely used in Palestine - it is estimated that at least 70% of houses have such systems. SWH has proved to be feasible compared with other alternatives. For example, the energy cost from solar heater is about $ 0.17/Kwh and is much cheaper than the electricity price from the grid, ($ 0.11/Kwh). A solar thermal plant for warm water supply and central heating came online in December 2009.

2.2 Wind Energy

The average wind speeds in Palestine vary from 3-4 m/s in coastal regions, to 6-10 m/s in more elevated areas of the country, indicating a moderate potential for wind power. Using a 100-m wind turbine with blade length of 52 m and power coefficient of 0.4, the annual power that can be generated is 3.3 and 3.8 GWh for the northern and southern West Bank, respectively. Using a wind farm of 50 turbines, each would generate 355 GWh/year, which could account for 6.6% of the electricity need in the Palestinian Territories. The high density of buildings and the scarcity of open and empty lands in the Gaza obviate the possibility of building wind farms there. However, offshore wind farms could be installed in the Mediterranean Sea where it does not form 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.

2.3 Geothermal Energy

Although little is mentioned in literature about geothermal energy potential in Palestine compared to other renewable sources, it has been proven that it has enormous potential as a source of energy for heating and cooling. A pilot project on a residential building in the West Bank city of Ramallah by a company named 'MENA Geothermal' provided evidence of the major reduction in energy costs paid for heating and cooling by more than 70% with a payback period of 4.5 years [15]. The geothermal system essentially uses the stable temperature of the ground converted to electricity and fed to the grid, can be used as fuel in vehicles, and can substitute natural gas after upgrading (gas cleaning). Biogas can be produced from various agricultural, industrial and municipal organic wastes [13]. The anaerobic biogas production processes have many advantages: low energy requirement for operation, low initial investment cost and low sludge production [14]. Middle East and North Africa Geothermal (MENA, announced in June 2010 the opening of the country's first geothermal power plant in Ramallah, with a 23kW cooling load and a 21kW heating load [1].

2.4 Biomass Energy

Palestine is an agricultural country, with many different types of plant products that can be used as energy sources. The main source is a rejected residue of olive oil pressers called, (Jefit in Arabic). Usually, Jefit is used in households for heating in the winter. Annual production of Jefit had not been totally assessed yet but there are plans to do so in cooperation between the Ministry of Agriculture and the Palestinian Central Bureau of Statistics. It is estimated that 22,800 tons of diesels can be generated from agricultural residues, which could account for nearly 5% of the national diesel consumption. Furthermore, there is also a vast number of animals, agricultural and food related wastes. The use of organic wastes in biogas production would not only provide energy but it would also eliminate the harmful effects of this type of waste on the environment and public health when disposed of without treatment. The total recoverable biopotential in Palestine from cattle, sheep and goats was estimated to be around 12,416 m³ of biogas per day or approximately 4.5 million m³ per year [2]. Biogas consists of approximately 55% methane (CH_4), 45% carbon dioxide (CO_2) and a very little amount of other contaminants. Methane has an energy value of 37.78 MJ/m³; thus, biogas at 55% CH_4 has an energy value of 21 MJ/m³. So the annual 4.5 million m3 biogas production in Palestine has the potential to replace 1.7% of the imported LPG. It is worth mentioning in this respect that the manure of goats and sheep in the villages of the Palestinian Territories is utilized for cooking. Assuming 50% collection, the availability of fresh manure and similarly amounts to approximately165,000 kg per day. If 20 kg of wet mass of manure produces 1 m³ of gas at 25 °C, then the total biogas production for the Palestinian Territories' amount of cattle would be 8250 m³ per day. Similarly assuming 50% collection, the availability of fresh manure of goats and sheep amounts to 50,000 kg per day. Based on the literature, 6 kg of wet mass produces 0.5 m³ gas per day at 25 °C, and produces a total of 4166 m3 of gas per day. Combined with the cattle's biogas production, the Palestinian Territories could produce 12,416 m³ of biogas per day or approximately 4.5 million m³ per year. The produced biogas could account for 10–20% of cooking energy needs for the rural population.

2.6 Hydropower

Hydro-electric potential in the country is limited, with no major resource survey has been conducted

3 THE SUGGESTED HYBRID SYSTEM FOR PALESTINE

Before suggesting any storage system, the main requirement of a good storage system should be considered. These include: i) High heat capability; ii) Good cost and thermal stability; iii) Easy handling; iv) Easily maintained; v) Low vapor pressure at operating temperature; vi) Compatible with containment material; vii) Should have a good insulated sink; viii) Availability at low cost.

solar power tower compared to other systems mean more energy and cheaper storage costs because less material is needed to transfer heat. Reoperation temperatures for the falling particle receiver could exceed 1,000 degrees Celsius. It is expected that "This technology will enable higher temperatures and higher efficiency power cycles that will bring down the cost of electricity produced from concentrating solar power," Ho said. "In addition, the ability to cheaply and efficiently store thermal energy directly in the heated particles will enable power production at night and on cloudy days. Sandia chief engineer Cliff Ho, the project's principal investigator, said the goal of the testing is to develop a prototype, cost-competitive falling particle receiver that demonstrates the potential for thermal efficiency greater than 90 percent, while achieving particle temperatures of at least 700 degrees Celsius. "This technology will enable higher temperatures and higher efficiency power cycles that will bring down the cost of electricity produced from concentrating solar power," Ho said. "In addition, the ability to cheaply and efficiently store thermal energy directly in the falling particle receiver technology is expected to further advance the state-of-the art in developing power solar systems which are capable of generating up to 100 megawatts of electricity.

To be sure that the above requirement of the chosen storage solar-wind hybrid system is appropriate, first the solar radiation data during a year in addition to temperature measurements should be available on hourly basis for the design and sizing of the PV power systems and to be used by the simulation program for the evaluation process and the second is the average wind speed and profile which are essential to decide upon the suitable wind turbine. These are given in the following sections.

4 Solar Radiation in Palestine

Solar radiation and temperature measurements are complete and available for Nablus site. For Ramallah site the temperature measurements on hourly basis are not available, so Nablus data are used by the simulation program to evaluate Nablus and to be representative to other sites and cities in Palestine. Table 1 presents the monthly average of daily solar radiation for different months for Nablus site, while Fig.1 shows a histogram representing graphically these averages.

Details of the calculations of the monthly average of daily solar radiation in Nablus and the parameters affecting it are given in detail in Ref.[8].

TABLE 2
Monthly average of daily solar radiation for Nablus site

Month	Average daily solar radiation (kWh/m^2-day)
1	2.89
2	3.25
3	5.2
4	6.52
5	7.56
6	8.25
7	8.17
8	8.1
9	6.3
10	4.7
11	3.56
12	2.84

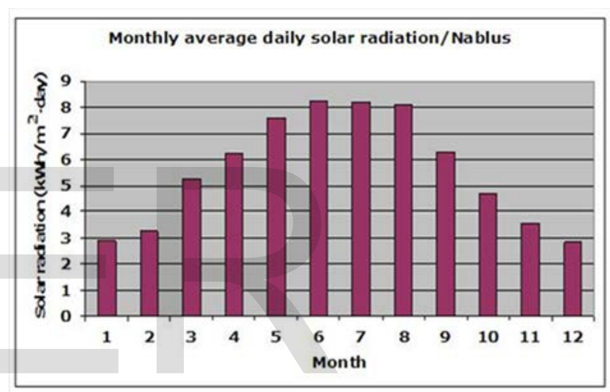

Fig. 1. Monthly average daily solar radiation for Nablus site [3].

The potential of solar sources is estimated to account for 13% of electricity demand. In addition, domestic solar water heating (SWH) is widely used in Palestine - it is estimated that at least 70% of houses have such systems. SWH has proved to be feasible compared with other alternatives. For example, the energy cost from solar heater is about $ 0.17/Kwh and is much cheaper than the electricity price from the grid, ($ 0.11/Kwh). A solar thermal plant for warm water supply and central heating came online in December 2009. The Palestinian Authority, however, has yet to take renewable energy into consideration in its energy planning.

5 Wind Energy in Palestine

The wind energy and profile in four locations in Palestine for four cities namely: Hebron, Jenin, Jericho and Nablus at the geographical latitudes, longitude and elevation of the stations used in the analysis are shown in Table 2 respectively; whereas the average wind speed in different Palestinian cities is shown in Table 3.

TABLE 2
LATITUDE, LONGITUDE AND ELEVATION OF THE STATIONS USED IN THE ANALYSIS

STATION	LATITUDE N	LONGITUDE E	ELEVATION M
NABLUS	32°13′	35°15′5″	70.0
JENIN	32°28′	35°18′	178.0
HEBRON	31°32′	35°06′	1005.0
JERICHO	31°51′	35°27′	260.0

TABLE 3
AVERAGE WIND SPEED IN DIFFERENT PALESTINIAN CITIES

	Year										
	2013	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**
Jenin	7.2	7.2	7.3	6.6	7	6.7	7.8	..	3.4	3.8	5.4
Tulkarem	..	..	6.1	..	6.8	5.2	3.4	..	3.5	3.5	..
Nablus	6.1	5.9	6.4	6.2	6.9	6.4	9.9	..	8.7	8.8	8
Ramallah	11.2	11.1	11.1	10.7	1	8.5	17.3	..	..	..	7.8
Jericho	4.6	5	5.1	4.5	5.6	7.1	12.3	..	7	7	8.1
Hebron	10.5	10.1	9.7	9.9	6	4.4	10.1	..	12.1	10.4	8.6
Gaza	..	..	..	..	..	..	..	..	8.4	10.4	10.3

TABLE 4
THE MAIN CHARACTERISTIC PARAMETERS OF HEBRON WIND SPEED [8]

Months	v_{obs} (ms^{-1})	v_w (ms^{-1})	σ^2	c (ms^{-1})	k	v^3_{avg} obs	$(v_{avg})^3$ obs	EPF	P (Wm^{-2})
January	3.78	3.80	2.04	4.26	2.89	48.52	44.41	1.09	32.98
February	3.70	3.71	2.92	4.19	2.31	51.61	45.11	1.14	32.21
March	3.05	3.05	0.81	2.37	3.76	47.93	43.61	1.10	25.66
April	3.70	3.54	9.41	3.73	1.16	41	37.93	1.08	29.65
May	3.44	3.42	0.76	3.75	4.44	36.23	34.96	1.03	22.57
June	3.24	3.24	0.39	3.50	5.78	43.44	41.78	1.04	19.86
July	3.30	3.29	0.27	3.52	7.20	42.47	40.7	1.04	19.67
August	3.24	3.00	1.26	3.36	2.89	50.88	49.02	1.03	18.55
September	3.33	3.33	0.28	3.60	7.40	43	41.06	1.04	20.56
October	3.14	2.92	1.97	3.30	2.20	36.04	33.38	1.08	18.03
November	2.98	2.98	1.34	3.35	2.78	39.73	37.6	1.05	15.23
December	3.19	3.20	1.89	3.60	2.49	50.85	45.5	1.11	19.91

TABLE 5
THE MAIN CHARACTERISTIC PARAMETERS OF JENIN WIND SPEED [8]

Months	v_{obs} (ms^{-1})	v_w (ms^{-1})	σ^2	c (ms^{-1})	k	$v_a vg^3$ obs	$(v_{avg})^3$ obs	EPF	P (Wm^2)
January	1.57	1.83	0.90	2.07	2.02	12.39	6.02	2.05	4.86
February	2.08	2.08	0.53	2.32	3.14	10.42	7.3	1.42	7.77
March	2.12	2.13	0.38	2.35	3.85	12.59	9.66	1.3	7.50
April	2.13	2.13	0.19	2.30	5.70	11.04	9.93	1.11	6.42
May	2.55	2.54	0.28	2.75	5.51	17.52	15.43	1.13	10.95
June	3.06	3.06	0.21	3.25	7.85	28.82	27	1.06	17.60
July	3.22	2.98	1.97	3.32	3.26	37.63	34.64	1.08	18.90
August	2.74	2.74	0.21	2.93	7.10	22.83	21.25	1.07	12.59
September	2.07	2.07	0.25	2.26	4.73	10.43	9.12	1.14	5.92
October	1.85	1.97	0.17	2.01	5.11	7.77	6.64	1.17	4.34
November	1.55	1.55	0.32	1.73	3.00	5.44	3.94	1.38	3.05
December	1.75	1.75	0.45	1.97	2.88	7.36	5	1.47	4.79

TABLE 6
THE MAIN CHARACTERISTIC PARAMETERS OF JERICHO WIND SPEED [8]

Months	v_{obs} (ms^{-1})	v_w (ms^{-1})	σ^2	c (ms^{-1})	k	$v_a vg^3$ obs	$(v_{avg})^3$ obs	EPF	P (Wm^{-2})
January	1.27	1.27	0.16	1.41	3.53	2.61	2	1.3	1.66
February	1.43	1.41	0.28	1.59	2.92	3.78	3.04	1.24	2.32
March	1.95	1.96	0.25	2.14	4.47	8	6.64	1.2	5.57
April	2.27	2.27	0.77	2.46	5.56	12.51	11.23	1.11	8.10
May	2.44	2.44	0.20	2.62	6.48	16.6	15.07	1.1	9.63
June	2.56	2.55	0.09	2.68	10.00	16.74	16	1.04	10.34
July	2.40	2.40	0.08	2.52	10.00	15.38	14.88	1.03	8.42
August	2.28	2.29	0.08	2.41	9.77	12.45	11.85	1.05	7.37
September	1.94	1.93	0.09	2.06	7.57	8.27	7.76	1.06	4.60
October	1.65	1.64	0.10	1.76	6.15	4.87	4.49	1.08	2.81
November	1.29	1.29	0.16	1.43	3.63	2.71	2.09	1.29	1.73
December	1.33	1.33	0.13	1.46	4.20	2.86	2.4	1.19	1.77

TABLE 7
THE MAIN CHARACTERISTIC PARAMETERS OF NABLUS WIND SPEED [8]

Months	v_{obs} (ms^{-1})	v_w (ms^{-1})	σ^2	c (ms^{-1})	k	$v_a vg^3$ obs	$(v_{avg})^3$ obs	EPF	P (Wm^{-2})
January	2.13	2.13	0.86	2.40	2.45	18.69	15.44	1.21	6.92
February	3.01	3.03	2.01	3.42	2.27	24.3	21.48	1.13	18.17
March	2.81	2.81	1.73	3.17	2.34	34.6	30.08	1.15	14.90
April	3.06	3.06	0.88	3.40	3.63	37.17	34.01	1.09	17.87
May	3.52	3.52	1.33	3.92	3.38	43.52	40.31	1.08	26.55
June	3.81	3.61	1.13	3.99	3.78	54.1	52.73	1.02	31.53
July	4.05	4.04	0.55	4.34	6.34	57.5	55.74	1.03	37.85
August	3.67	3.67	0.56	3.97	5.68	57.5	55.74	1.03	28.15
September	3.52	3.50	0.44	3.77	6.15	34.86	33.7	1.03	25.01
October	2.24	2.24	0.57	2.50	3.27	16.75	15.81	1.06	6.69
November	2.10	2.11	1.06	2.38	2.15	10.82	9.93	1.09	5.83
December	3.66	3.88	4.11	4.38	1.99	20.56	17.98	1.14	32.67

TABLE 8
POLYNOMIAL FIT PARAMETERS

	Intercept	
Station	b1	b2
Hebron	226.89_137.99	22.76
Nablus	9.64_11.46	4.47
Jenin	2.04_4.51	2.94
Jericho	3.45_5.85	3.27

The monthly mean wind speed data of four stations in Palestine namely: Hebron, Jenin, Jericho and Nablus are shown in Tables 4, 5, 6, and 7 respectively. Those measured values of wind speed were at about 6 m above the ground in Jenin, Jericho, and Nablus but at 10 m in Hebron. These data were fitted to the Weibull distribution function by [7-10]. They found that both Hebron and Nablus have higher mean wind speed values of more than 3.5 m/s, giving the average annual and maximum wind power density of 37.85 Wm² which was in July They also used the second order polynomial function to find the relation between the mean wind power and the mean wind speed. They also found that the second-order polynomial provided better fitting for all stations except for Hebron, due to its location in a complex topography area. The polynomial fit parameters for the investigated sites: Hebron, Nablus, Jenin and Jericho are shown in Table 8.

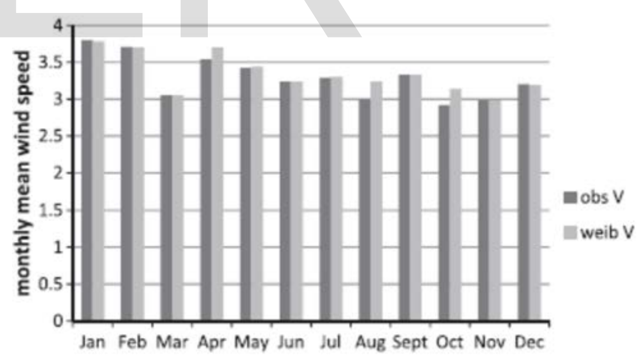

Fig. 2. Observed and theoretical monthly mean wind speed for Hebron [8]

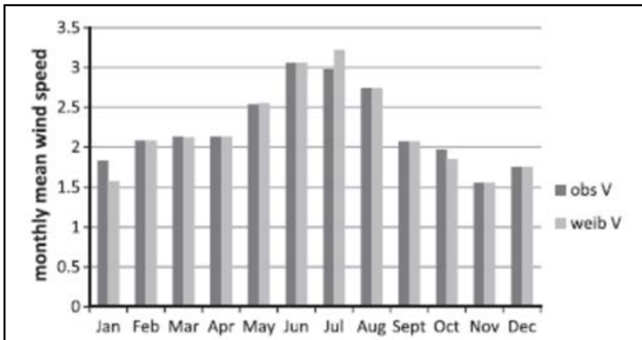

Fig. 3. Observed and theoretical monthly mean wind speed for Jenin [8]

ISSN 2229-5518

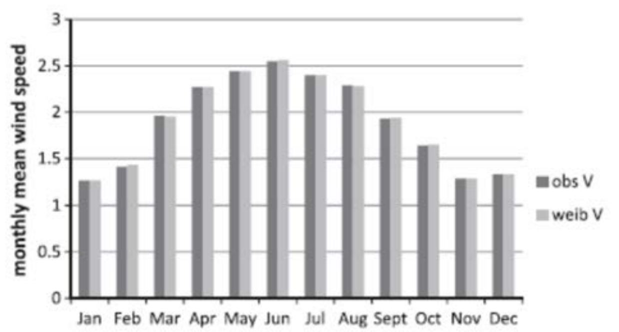

Fig. 4. Observed and theoretical monthly mean wind speed for Jericho [8]

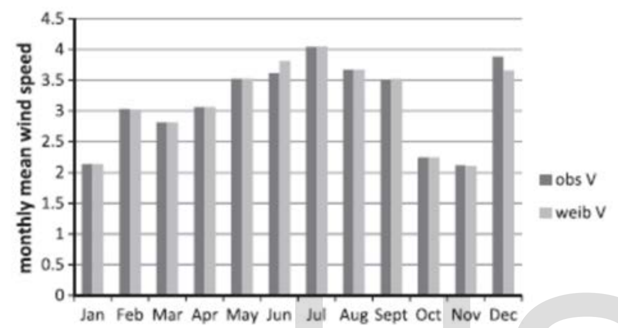

Fig. 5. Observed and theoretical monthly mean wind speed for Nablus [8]

Using a 100-m wind turbine with blade length of 52 m and power coefficient of 0.4, the annual power that can be generated is 3.3 and 3.8 GWh for the northern and southern West Bank, respectively. Using a wind farm of 50 turbines, each would generate 355 GWh/year, which could account for 6.6% of the electricity need in the Palestinian Territories. The high density of buildings and the scarcity of open and empty lands in Gaza obviate the possibility of building wind farms there. However, offshore wind farms could be installed in the Mediterranean Sea where it does not form political obstacles. Table 2 shows the average wind speed for different cities in Palestine over the period from 2003 to 2013. It can be seen from this able that the wind speed in Palestine cities is moderate which cannot be used for generating high power and can only be used as auxiliary system.

6 Auxiliary Equipment

A three-phase inverter which has high-in-class efficiency and capable of controlling more PV panels than the smaller previous one can be added to the system. It will offer more flexibility and control to installers that have large installations with varying aspects or orientations beside its high efficiency ratings up to 98.2% with very wide input voltage range which makes the inverter suitable to installations with reduced string size. It also includes a special built-in heat sink compartment and front panel display system and is free of electrolytic capacitors which leads to a longer product lifetime.

7 Conclusions

Today's energy planners and policy makers must strive to balance many conflicting factors at the most basic level. The most successful planners and policy makers are the ones who plan their strategy to take into consideration following important points:

i) Seek to balance energy needs (demand) and energy resources (supply).
ii) Ensure access to adequate, affordable and secure energy services to satisfy human needs and achieve socioeconomic development.
iii) Encourage know-how transfer and upgrading of technical capacities for the new technologies.
iv) Promote production and use of energy services in ways that give benefits for those who pay the tax to achieve continuity and sustainability.
v) Provide scientific and technological research facilities.
vi) Provide technical consultancy to decision makers, end users and interested bodies both in the public and private sectors.
vii) Raise energy efficiency for lower energy bills and environment protection.
viii) Although the Palestinian government has recognized the importance of exhausting the opportunities in renewable energy for the adequate supply of clean energy for residential, commercial and industrial needs. Recently, a national strategy for expanding the use of renewable energy has been launched, which calls for the production of 120 MW of electricity using different alternative energy sources. However, the Palestinian Authority, has always to consider and give priority to renewable energy in its energy planning.
ix) Utilize all the available energy sources effectively and efficiently.

As a non-producing oil country; making benefit of the above mentioned points is of vital importance as it may significantly decrease the energy reliance on imported oil, and improve the Palestinian population's access to energy which in turn will result in enhancement of the socioeconomic situation which will eventually improve the standard of living of the people in Palestine and place a good base for political stability which has the highest priority for the country and the middle east region.

Acknowledgment

The first author is grateful to the Applied Science Private University, Amman, Jordan for the financial support granted to this research (Grant No. DRGS-2015).

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