Utilization of Solar Energy as a Thermal Energy Storage System in Palestine

Adnan I. O. Zaid, Ahmad O. Mostafa, Ali M. Othman

Abstract— Energy and water are vital items for the development of any nation. People of Palestine are living in critical situation regarding their needs of energy and water due to the lack of fusel fuels and shortage of water and other conventional resources. In addition to the continuous Israeli occupation, which has been about seven decades. It controls the water and energy needs and hinders the development policies and plans of both the private and governmental sectors. This has reflected on the socio economic development of the whole population of the country. Despite all the occupation obstacles, the Palestinians are taking every possible chance to overcome these obstacles and utilize their natural resources. In this paper, the scope of utilizing a thermal energy storage system which uses sand as a storage medium which is readily available in most regions in Palestine is very promising in fulfilling part of the energy needs of the country. The use of this type of renewable energy will reduce the green gases emission and results in a cleaner environment. Furthermore, a system for heating and cooling buildings using sand as a storage medium is also presented and discussed.

Index Terms— Palestine, Solar energy, Thermal energy storage system, Utilization.

1 Introduction

Palestine is a middle eastern country of 14 million population (according to the Palestinian Centre Bureau of Statistics), of which 4.5 million in the occupied territories, (Gaza Strip and West Bank), 4 million in Jordan, 1.5 millions in the 1948 occupied Palestine, about 2 millions in the rest of Arab countries and one million outside the Arab countries of which 0.5 million are in Chile. Its area is 6220 km^2.Palestine depends on fulfilling its needs of power on fusel fuel. Furthermore, over 90%of it is imported from the Israeli occupier. A thorough outlook on the renewable resources in Palestine it might be considered as a rich country in renewable energy resources which include: I). Solar energy, II). Wind energy, III). Geothermal energy, and IV). Biomass energy. The headline figure from the authoritative REN21 stated that renewable energy accounted more than 59 percent of all new electricity generating capacity installed worldwide during 2014, [1].

The International growth has been driven by both renewable energy support policies and the increasing cost-competiveness of renewable energy. Nonetheless, the report also finds that growth continues to be tempered by subsidies to fossil fuels and nuclear power, particularly in developing countries. The Executive Secretary of REN21, summarises the perennial challenge for renewables by saying that removing fossil-fuel and nuclear subsidies globally would make it evident that renewables are the cheapest energy option.

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Because Palestine is sunny the great majority of the days of the year as the temperature goes few degrees below zero only few days during January and February in small parts of the country at locations of 850 m above sea level, and as research and development, as well as most of the published work are concerned with the utilization of solar energy and the most efficient method and material for storing it, in addition to the limited number of pages allocated for the paper, only the solar energy thermal storage system will be dealt with in this paper. However, it is noteworthy that in the extensive field of the science and the technology concerning the application of the solar thermal energy storage is but only one of the many alternative renewables which may be investigated.

1.2 Energy Situation and Consumption in Palestine

Energy situation in Palestine is unique; with the exception of renewable energy, the Palestinian energy sector is distinctive of scarce sources and inability to fully exploit currently available ones, causing it to largely depend on importation from Israel. The ongoing Israeli occupation and control over borders and crossing point as well as over a vast area of the Palestinian territory have impeded implementation of many plans and programs developed by national sector bodies.

Production and trade is considered as one aspect of the "energy tragedy" in the Palestinian Territories, energy consumption is the other. Total energy consumption (primary energy supply) did not exceed 944 million tons of oil equivalent (Mtoe) in 2000, while this figure was 22,999 Mtoe for Israel (nearly 22 times as much). On the other hand, energy consumption for Jordan (with nearly 5 million habitants) was 4,455 Mtoe (four times greater), while for Lebanon (with 4.3 million habitants) this figure was 5,469 (five times that of west Bank and Gaza Strip) [2].

A more comparable indicator is the energy consumption per capita, which clearly shows the gravity of the energy problem for the Palestinians. 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, 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. The West bank and Gaza strip energy sector review is clearly shown in the map of Figure 1.

1.3. Electric Power in Palestine

Electric power in Palestine is totally dependent on the Israeli occupier, except the electricity produced from renewables, about 95% of the electric power consumed in West Bank and Gaza Strip is imported from Israeli power plants via 22 and 33 kV feeders and through three substations of 161/33 kV in the West Bank, while the remaining electricity is generated by decentralized small diesel generators. However, some 79 localities in the West Bank are not connected to a public electricity network, including 38 in the Hebron district. Of the 531West Bank and Gaza Strip localities with connections, 165 receive their electricity from the Jerusalem District Electricity Co., 215 from the Israeli Electricity Co., 22 from private generators, 68 from community councils and 61 from other sources [3].

2 ENERGY STORAGE

Energy storage is all the more important where the energy source is intermittent such as solar energy. The use of intermittent energy sources is likely to grow. If more and more solar energy is to be used for domestic and industrial applications, then energy storage is very crucial. If no storage is used in solar energy systems, then the major part of the energy demand will be met by the back-up or auxiliary energy and therefore the so called annual solar load fraction will be very low. In case of solar energy, both short term and long term energy storage systems can be used which can adjust the phase difference between solar energy supply and energy demand and can match seasonal demands to the solar availability respectively. Thermal energy storage can lead to capital cost savings, fuel savings, and fuel substitution in many application areas. Developing an optimum thermal storage system is as important area of research as developing an alternative source of energy. The topic of use of thermal energy of all its methods has engaged researchers in the last decades. International Conferences have been held and many research papers have been published and devoted entirely to this topic. The information on the Solar Energy Thermal Storage, a topic which is more recent, is given in Ref.[1].

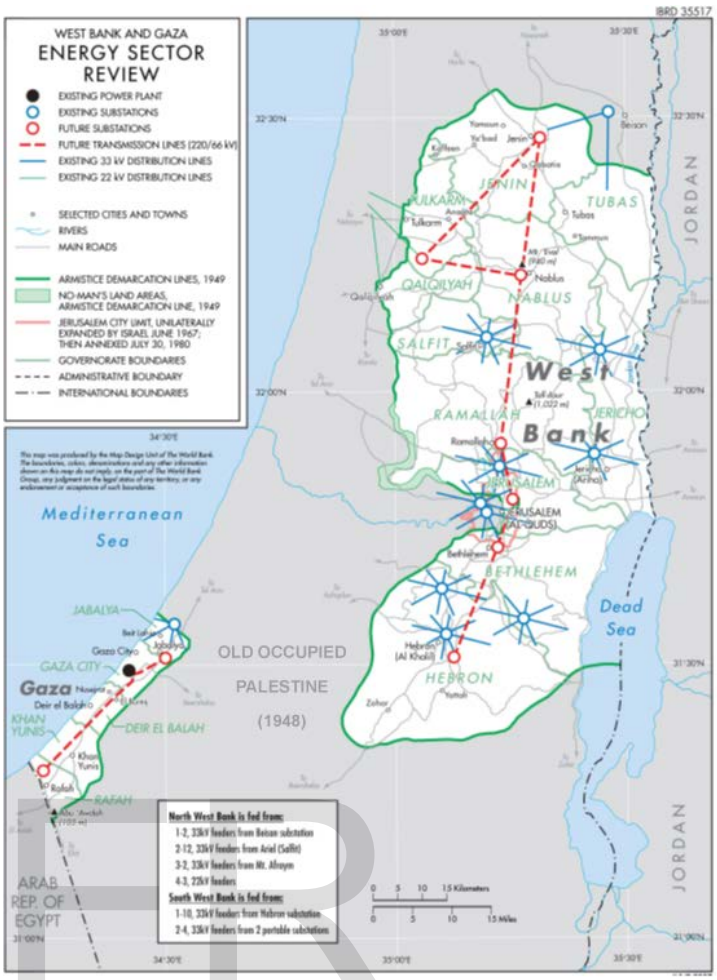

Fig. 1. A map illustrating the energy sector review of the West bank and Gaza strip.

Research and development, as well as most of the published work are concerned with the utilization of solar energy and the most efficient storing method and material for storing it. Therefore, it is not by chance that only the solar energy thermal storage system will be dealt with in this paper. An estimated 19.1 percent of global final energy consumption in 2013 — the latest figures available — and growth in capacity and generation expanded in 2014, enough to supply an estimated 22.8 percent of global electricity. This growth has been driven by both renewable energy support policies and the increasing cost-competiveness of renewable energy. Nonetheless, the report also finds that growth continues to be tempered by subsidies to fossil fuels and nuclear power, particularly in developing countries. For all its impressive contribution to world's energy mix, Christine Lins, Executive Secretary of REN21, summarises the perennial challenge for renewables: "Creating a level playing field would strengthen the development and use of energy efficiency and renewable energy technologies. Removing fossil-fuel and nuclear subsidies globally would make it evident that renewables are the cheapest energy option.

3 Solar Energy in Palestine

Solar radiation data during a year are very important and essential for design and sizing of PV power systems. Solar radiation measurements in addition to temperature measurements are necessary to calculate the output power of the PV system. Solar radiation and temperature measurements should be available on hourly basis to be used by the simulation program for the evaluation process. Solar radiation and temperature measurements are complete and available for Nablus site. For other sites the temperature measurements are not available, so Nablus data are used by the simulation program to evaluate Nablus and considered to be representative to other sites and cities in Palestine. Table 1presents the monthly average of daily solar radiation for different months for Nablus site, while Fig. 1 shows a histogram representing graphically these averages. Radiation in the west bank of Palestine, taking Nablus city as an example, is shown in Table 1.

Details of the calculations of the monthly average of daily solar radiation in Nablus and the parameters affecting it are given in detail in [3].

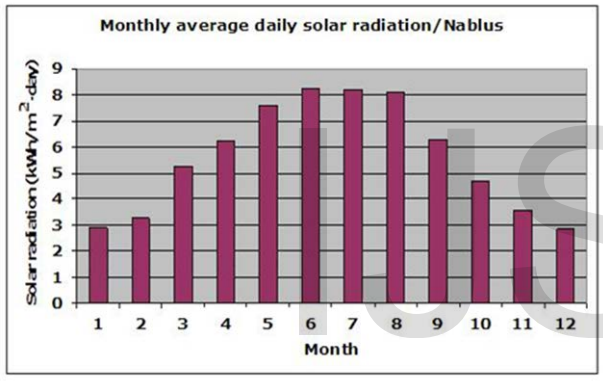

Fig. 2. Monthly average daily solar radiation for Nablus site [3].

4 Suggested storage system

TABLE 1
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

Before suggesting any storage system, the following main requirements of a good solar thermal storage system should be considered. These include

i) High heat capability
ii) Good thermal stability
iii) Easily handled and maintained.
Iv Low vapor pressure at operating temperature.
v) Compatible with containment material.
Vi Availability of a good insulated sink.
vii) Availability at low cost.

Investigation of the histogram of Fig. 1 indicates that the monthly average solar radiation over the year follows normal distribution with minimum radiation about 3 kWh/m2-day from January to April and from October to end December. The monthly average solar radiation ranges from 6.25 to 8.25 kW h / m^2-day from end of March until the end of October. These data are very suitable for adopting and implementing a solar concentrating tube with small sand particles as storage material, similar to the system used in Sandia National Laboratory, as the main part in the hybrid system and a wind farm as the auxiliary or supporting part. The suggested system for thermal energy utilizes a falling particle receiver, which works by dropping sand-like ceramic particles through a beam of concentrated sunlight, capturing and storing the heated particles in an insulated tank. The technology can capture and store heat at high temperatures without breaking down, unlike the conventional central receiver technology which uses the molten salt systems and is limited to temperatures close to 600 degrees Celsius; whereas higher re-operating temperatures in excess of 1,000 degrees Celsius can be achieved by the falling particle receiver method. Furthermore, mean more available energy and cheaper storage costs are achieved by it because less material is needed to transfer heat. It is expected that this system will enable higher temperatures and higher efficiency power cycles that will bring down the cost of electricity produced from concentrating solar power. In addition, the system is capable to store thermal energy directly in the heated particles which will enable power production at night and on cloudy days.

5 Theoretical Considerations in the Design of Sand Bed Storage System

The system utilizes the latent heat as a concept for storing the solar energy. The earliest bed storage system using rock as a storage material was reported by Schuman, and outlined in [6]. Later similar system was designed, manufactueed and tested theoretically and experimentally experimentally by Hamdan. His experimental results were in reasonable agreement with the theoretical predictions. [7]. The mathematical part in designing the storage tank is similar to that reported in references [6] and [7], but using the appropriate characteristics and dimensions of the materials used in the construction of the suggested storage system. These details together with the obtained results will be the subject of an other published paper.

Latent heat storage is one of the most efficient ways of stor-

ing thermal energy. It has the advantage over sensible heat storage method because it provides much higher storage density, with smaller difference between storing and releasing temperatures. The main objective of this section is to shed the light on the different storage materials and systems and adopt the most appropriate method which suits the available natural resources in the country. Due to almost identical climate conditions and availability of simiar natural resources in the remote areas in Jordan and Palestine; the suggested cheap water heater by the first author of reference, [16] is recommended to be used in Palestine. Normally in solar collectors, water is used as a storage medium. In this system air is used as working fluid and sand or clay is suggested as the bed storage material which has the advantage over water that leakage is terminated beside their storage capacity which is much higher than water. Furtermore they are available in different places from north to south. Fig. 4 shows a schematic drawing of the suggested insulated storage tank and its componants. It consists of an insulated galvanized steel tank, box shape, of rectangular base made of two sheets each 1.5 mm thickness, separted by 30 mm spacing filled by pollysteyrene as insulating material. The other dimensions: length, width and height vary depending on the quantity of the required stored heat energy. The tank has two openings one near the bottom of the tank and the other near its top to accomodate the inlet and outlet air pipes of the blown airespectively. It has adouble glazing glass cover on its top. An electrical centrifugal blower of 0.5 HP was used for blowing the air inside the storage tank. At dfferent flow rates. The temperatures at the inlet, outlet, and inside the sand bed were measured using calibrated copper constantan thermocouples. The advantages of this suggested storage system is reliable, economical, little or no maintenance is required and can work as solar storage system and an integrated bed solar heater.

5.1 Suggested Reliable Non-Expensive Solar Collector Storage System

Figure 2 shows a Schematic drawing of the suggested solar collector storage system and its main parts are listed in Table 2.

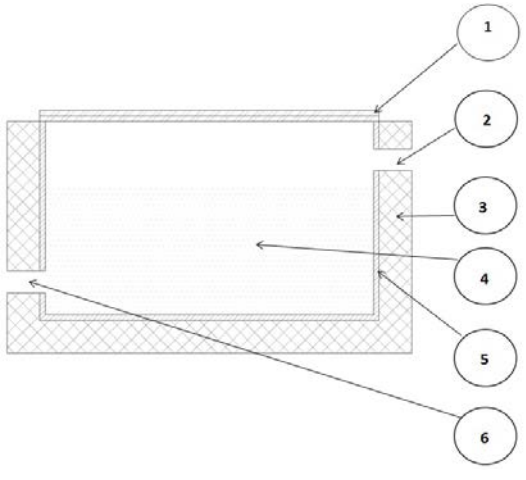

Fig. 3 Schematic drawing of the suggested solar collector storage system.

6 Conclusions

The following conclusions may be derived:

i) People of Palestine are living in critical situation regarding their needs of energy due to the scarcity of fusel fuels and the Israeli occupation. Despite these obstacles, Palestinians are taking every possible chance to overcome these obstacles and utilize their natural resources.

ii) The monthly average solar radiation over the year in Palestine ranges from 6.25 to 8.25 kW h / m^2-day from end of March until the end of October with minimum radiation about 3 kWh/m2-day form January to April and from October to end of December. These data are very suitable for adopting and implementing a solar concentrating tube with small sand particles as a storage medium

iii) With its high potential to generate energy from solar thermal storage, Palestine could reduce its vulnerability to political, economic and security shocks.

iv) Utilization of the solar thermal energy storage system will reduce the green gases emission and results in a cleaner environment.

TABLE 2
THE MAIN PARTS OF THE SUGGESTED SOLAR COLLECTOR STORAGE SYSTEM

Part Number	Part Name
1	Two layers of aglass cover
2	Opening for air outlet
3	Polesteyrene insulation
4	Sand
5	Galvanised steel storage tank
6	Opening for air inlet

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