Utilization of Natural Resources in Jordan for Energy Storage

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Abstract— Jordan is a developing and non- producing oil country. The majority of its energy needs is imported from the neighboring Arab countries; where only 4% of its needs is produced locally and 96% is imported. However, Jordan is very rich in renewable energy resources. The main objective of this work is to discuss the challenges facing the Jordanian energy sector, and evaluate the renewable energy resources of the country. The main renewable energy resources in Jordan are: solar, wind, geothermal and biomass. Using these energy resources may significantly decrease the energy reliance on oil which is imported from the Arab oil neighboring countries and improve the Jordanian population's access to energy and hence enhance the economic situation and hence improve the standard of living of the people in the country. It is expected that wind and solar energy resources have the potential to account for certain percentage of electricity demand; the utilization of the geothermal energy for heating and cooling can reduce the cost of conventional energy used for these applications especially Jordan is very rich in this item and the geothermal wells are distributed all over the country. Regarding the biomass resource, the conversion of agricultural waste into biodiesel can also reduce diesel imports. Similarly, the conversion of animal waste into biogas has the potential to replace certain % of the imported LPG. Finally, a reliable economical insulated storage tank which utilizes sand as a storage medium which can be easily maintained is suggested and discussed.

Index Terms— Utilization, Natural resources, Jordan, Energy storage, Wind energy, Solar energy, Geothermal energy.

1 Introduction

Historically, in the last five decades international politics played a great role in making nations, developed and undeveloped, all over the world live in energy crises period where the energy prices were getting higher and higher every year, for example in Jordan the price of fuel had risen more than 300% times in the previous last five years, and only this year,2015, it has gone down; again due to politics and wars in the region. Most countries currently rely heavily on fossil fuels e.g. coal, oil, and natural gas for their energy needs. Fossil fuels are non-renewable, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. In contrast most types of renewable energy resources-such as wind and solar energy are constantly replenished and will never run out. Climate changes is one of the most important challenges of the 21stcentury. Its most severe impacts may still be avoided if efforts are made to transform currently used energy systems to renewable energy ones. The latter has a large potential to displace emissions of the green- house gases from the combustion of fossil fuels and hence to mitigate climate change. If implemented properly renewable energy sources can contribute to social and economic development to energy access, and to a secure sustainable energy supply resulting in reduction of negative impact of energy on the environment and human health. Renewables are not only seen as sources of energy, but also as tools to address the following items: Improving energy security, reducing the health and environmental impacts associated with fossil and nuclear energy, mitigating greenhouse gas emissions, improving educational opportunities, creating jobs, reducing poverty and increasing gender equality. Fossil fuels account for 87% of all energy used globally as reported by the IEA in 2013 as indicated in Fig.1, from which it can be seen tha fossil fuels accounts for 87% of the glopal consumption.

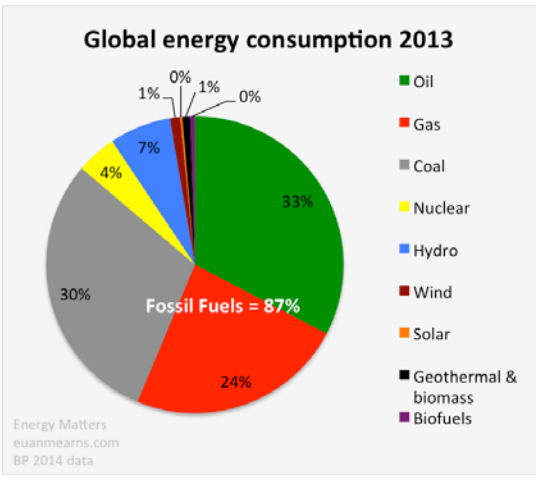

Fig. 1. The glopal energy cosumption, [1], After IEA 2013

1.1 Energy Situation in Jordan

Jordan is a Mediterranean country which falls part of the fire ring. Its area is 89213 sq.km, its population is 6.15 million in 2010. However, this figure has been increased since then at least by two millions of Iraqi and Syrian refugees. The GDP is 14,190 million JD, and the GDP per Capitan is 2,2425 JD with a GDP growth of 7% annually, [2]. Its primary energy consump-

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tion is as follows: 58% crude oil and oil products, 39% natural gas, 2% renewable energy, and 1% imported electricity. Regarding its electrical energy consumption by usage is as follows: 41% household, 25% the industrial sector, 16% commercial sector, 15% water pumping, and 3% street lighting, [3]. However, Jordan is a very rich country in different types of renewable energies which include: solar, wind, geothermal and biomass energies. Detailed discussion of each type of these renewable energies will be given and discussed later in this paper. Figure1shows Jordan map.

Fig. 2. Jordan map

1.2 Energy Storage Materials and Systems

Energy Storage Materials, ESM, is relatively a new topic in the field of renewable energy. play the essential role. To have a clear and recent knowledge helping in the development in the storage materials technology and implementation, a general review of the energy storage materials is a necessity. In this paper a review of the different used storage materials together with their recent applications for storing thermal energy are briefly presented and discussed. This will help in implementing the most suitable and available energy storage material to be used. This will reduce the cost of the storage material and make it feasible to use it in the concentrated solar power systems for small districts and will increase the value of these materials and enhance the use of renewable energy instead of fusel fuels; which in turn will reduce the green gases emissions and result in a cleaner environment. Energy Storage Materials play the essential role in the amount and efficiency of the storage system. To have a clear and recent knowledge helping in the development of the storage materials technology and implementation, a general recent review of the energy storage materials is a must. In this paper a review for the used storage materials is to be done. The developments in using these storage materials in the last years are to be discussed and the scope of implementing the new resources as storage materials is to be investigated. Implementing the suitable energy storage material will reduce the cost of the storage material and make it feasible to use it in the concentrated solar power systems for small districts. It will increase the value of these materials and enhance the use of renewable energy instead of fusel fuels. The use of renewable energy will reduce the green gases emissions and result in a cleaner environment. Renewable Energies in Jordan, [4-10] Awareness and realization of the importance of renewable energy by the industrial countries and the support of their governments started in early seventies after October 1973 war, when Saudi Arabia and the Arabian Gulf Countries stopped supplying them with petrol. Since then, large scale research programs, both governmental and private, were started to investigate and utilize the renewable energy resources. Similarly, Jordan as a non-producing oil country followed the same trend in investigating the possible utilization of the available renewable energy resources. In this section, these available resources will be discussed which include: solar, wind, geothermal and biomass energies.

i) Solar energy resources: Jordan is a sunny country it is sunny during the great majority of the days of the year; the temperature goes only few degrees below zero within few days during January and February in small parts of the country at locations of 850 m above sea level, and not in all years The annual daily average radiation on the horizontal is 5.6 kWhm^2 and the annual irradiance is 1660 – 2300 kWh/m^2. Today's choices about how energy is produced and used will determine the sustainability of the future energy system and, thereby the socioeconomic progress. The utilization of solar energy in Jordan on small scale dates back to middle seventies for heating water in houses and became more publicized in early eighties. A computer program simulation based on the F-chart was carried out to study five active solar heating systems and two passive heating systems in Jordan. Cost analysis for these systems were carried out over 20 years. The heating system tends to have the best life cycle saving. The passive heating systems analysis indicated that 60% of the heating load may be met by solar energy if passive solar houses were designed accordingly, [4]. Recently after realizing the importance of solar energy by both the governmental and the private sector it developed and is still developing. Now Solar cells made from silicon which absorbs the sun's radiation, also called photovoltaic cells. The photovoltaic process involves the movement and displacement of electrons to absorb the sun's radiation and create electricity, but there are also solar systems that use large-scale mirrors to heat water, or produce high temperatures and generate steam, which is used to turn a generator. PV panels are totally silent, producing no noise at all.

Figure 3 shows the utilization of solar energy in water heating systems in buildings in Jordan from 1986 to 2009. It can be seen from this figure that the utilization of solar energy in water heating during this period reached its peak in 1997 where 24% of buildings were using it, after this year the percentage started to drop to reach the same percentage of year 1986, about 12%.

2. Suggested Reliable Non-Expensive Solar Collector Storage System

Latent heat storage is one of the most efficient ways of storing 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 temper-

atures. 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. 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.

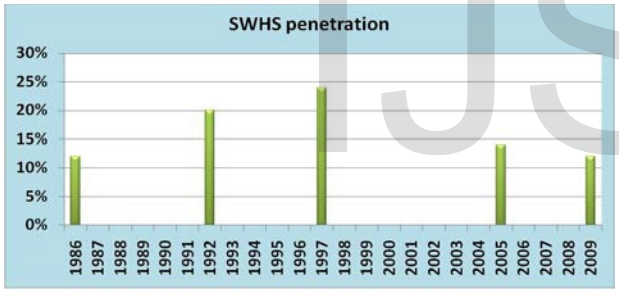

Fig. 3. Variation of the percentages of buildings which use solar water heating system over the period from 1986 to 2009

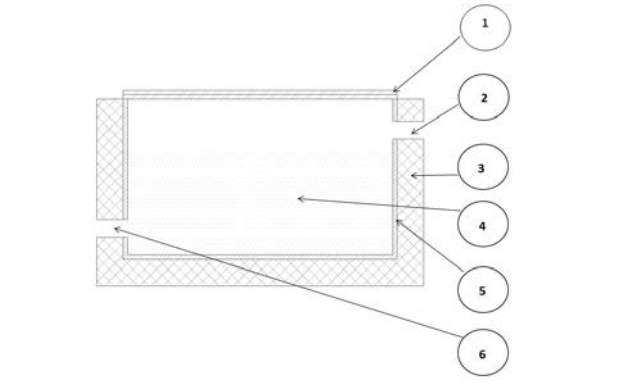

Fig. 4. Schematic drawing of the suggested solar collector storage system

TABLE 1
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

2.1 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 an 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

2.2 Wind Energy

Although wind energy exploitation dates back five thousand years ago, contemporary societies are based almost exclusively on fossil fuels for covering their electrical energy needs. On the other hand, during the last thirty years, security of energy supply and environmental issues have reheated the interest for wind energy applications. In this context, the present work traces the long and difficult steps of wind energy development from the California era to the construction of huge offshore wind parks worldwide, highlighting the prospects and the main challenges of wind energy applications towards the target of 1000 GW of wind power by 2030. Wind power is a very simple process. A wind turbine converts the kinetic energy (motion) of wind into mechanical energy that is used to generate electricity. The energy is fed through a generator, converted a second time into electrical energy, then fed into the grid to be transmitted to a power station. The top 10 countries accounted for 85% of year-end global capacity, but there are dynamic and emerging markets in al regions. However, Asia remained the largest market accounting for almost 52% of added capacity, followed by EU 32% and then North America by less than 8%. The leading countries for wind power capacity per inhabitant were Denmark by 863 W per person, Sweden by 487 6, Spain 420.5, Portugal 412, and Ireland 381W. The utilization of wind energy in Jordan is limited for pumping water and irregation purposes although it was first used for

water pumping in late eighties but it had not been developed since that time.

2.2.1 Advantages and Disadvantages of Wind Energy

2.2.1.1 Advantages of wind power

1. The wind is free and wih modern technology, it can be captured efficiently.
2. Once the wind turbine is built, the energy doesn't produce green house gases or any other harmful pollutants.
3. Although wind turbines can be very tall, each takes up only a small plot of land. This means that the land below can still be used. This is especially the case in agricultural areas as farming can still continue.
4. Many people find wind farms an interesting feature of the landscape.
5. Remote areas that are not connected to the electricity power grid can use wind turbines to produce their own supply.
6. Wind turbines have a role to play in both the developed and third world.
7. Wind turbines are available in a range of sizes which means a vast rage of people and businesses can use them. Single households to small towns and villages can make good use of range of wind turbines available today.

2.2.1.2 Disadvantages of wind power

1. The strength of the wind is not constant and it varies from almost zero to its maximum when the storm blows. This means that wind turbines do not produce steady state condition of electricity all the time, even here will be times when there will be no electricity produced, which is very disturbing for the people.
2. Many people feel that the country side should not be left as it is in its natural shape, without these large structures being built and the landscape should have left in its natural form and enjoyed by everyone.
3. Some people claim that wind turbines are noisy. However, the same level of noise or even more can be generated from a car travelling at 80 mph.
4. Many people see large wind turbines as unpleasant structures to look at and like to see the landscape on its nature.
5. When wind turbines are being manufactured, some pollution is produced. Therefore, wind power does produce some pollution.
6. Large wind farms are needed to provide entire communities with enough electricity. For example, the largest single turbine available today can only provide enough electricity for 475 homes, when running at full capacity, imagine how many would be needed for a town of 100, 000 people or more.

2.3 Geothermal Energy

Jordan, which is considered as part of the ring of fire, is tectonically active and could be considered as potential region for future generation of energy from the available geothermal energy resources. Jordan encounters geothermal energy resources in two main forms, medium and low energy with variation of temperature ranges from 110–114 oC and 30–65 oC, respectively. The various hot springs and wells have been subjected. The possibility of utilizing geothermal energy in generating electrical power in Jordan was investigated previously, in terms of temperature and flow rate in order to determine the most suitable method for electric power generation. This comparison concluded that electrical power could be generated using geothermal binary power plants and geothermal Sterling engines. The geothermal energy is stored between the earth's surface and a specified depth in the crust. It is measured from local average annual temperature beneath a specified area. The most common criterion for classifying geothermal resources is based on the enthalpy of the geothermal fluids that act as the carrier transporting heat from the deep hot rocks to the surface. Enthalpy, which can be considered more or less proportional to the temperature, is used to express the heat content of the fluids, and gives a rough idea of their value. According to criteria that are generally based on the energy content of the fluids and their potential forms of utilization [5], the resources are divided into low, medium and high temperature resources. Thousands megawatts of power are currently being produced could be developed from already-identified hydrothermal resources. With improvements in technology, much more power will be available.

2.3.1 Advantages and Disadvantages of Geothermal Energy

TABLE 2
GENERAL CHARACTERISTICS OF THE MAJOR GEOTHERMAL WELLS IN JORDAN

Geothermal field	Temp. (oC)	Flow Rate (m3/hr)
Himmeh springs	38-44	300-3000
Mukheibeh wells	30-41	200-6000
North Shuneh well	57	700
Queen Alia airport	30-45	30-100
Zara springs	34-55	1-255
Zarqa Ma'in springs	30-63	1-350
Wadi Ibn Hammad springs	35-41	1-25
TS-1D thermal well	50	400
Burbeitta spring	39	315
Afra springs	45-47	376
Smeika thermal well	57	50

2.3.1.1 Advantages of geothermal energy

1. It is a renewable source of energy.
2. By far, it is non-polluting and environment friendly.
3. There is no wastage or generation of by-products.
4. Geothermal energy can be used directly. In ancient times, people used this source of energy for heating homes, cooking, etc.
5. Maintenance cost of geothermal power plants is very small.
6. Geothermal power plants don't occupy too much space and thus help in protecting natural environment.
7. Unlike solar energy, it is not dependent on the weather conditions.

2.3.1.2 Disadvantages of Geothermal Energy

1. Only few sites have the potential of geothermal energy
2. Most of the sites where geothermal energy is produced, are far from markets or cities, where it needs to be consumed.
3. Total generation potential of this source is too small.

4. There is always a danger of eruption of volcano.
5. Installation cost of the steam power plant is high.

4 Biomass Energy

Biomass is a very versatile form of renewable energy. Biomass power plants burn biomass fuel in boilers to heat water and turn a steam turbine to create electricity. Biomass fuel is everything from wood to landfill trash, which is currently being used to convert into methane for the production of dry natural gas. Agricultural research is seeing unique results, including dairy farms in converting cow manure into energy. Although biomass is developing fast in developed countries and in some of the developing countries, the utilization of biomass energy is still modest in Jordan and its use is limited to cooking in small villages and remote areas. The United States is the top country in producing electricity from biomass followed by.

5 Conclusions

As a non-producing oil country which 96% of its energy needs is imported; it is of vital importance for Jordan to utilize its available natural resources of the renewable energies and utilize the appropriate storage systems, like the one suggested in this paper, for storing the energy from these resources and utilize it for thermal energy and electric power generation when needed. This will reduce the dependence on imported oil and other fossil fuels which will guard the country from the effects of external shocks and energy price volatility. The current reliance on imported energy, as, leads only to minimal economic growth and development. as it may significantly decrease the energy reliance on imported oil, and improve the Jordanian 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.

Acknowledgment

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