Renewable Energy Potentials in Saudi Arabia

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ABSTRACT:

This paper addresses the current status and the future potentials of renewable energy applications in the Kingdom of Saudi Arabia. The power in the earth's wind and in the solar radiation, which reaches the earth, is sufficient to make significant as well as strategic contributions to the Kingdom energy supply. Applications of solar energy in Saudi Arabia have been growing since 1960. However, effective utilization of solar energy in Saudi Arabia has not yet made reasonable progress mainly due to several obstacles. But, valuable lessons have been learned and a wealth of experience has been gained from the Kingdom experience. The technical and economic feasibility of wind energy utilization in the Kingdom has not yet fully explored. Several studies were conducted to assess the potential of wind energy in the Kingdom of Saudi Arabia. The wind map of Saudi Arabia indicates that the Kingdom is characterized by the existence of two vast windy regions along the Arabian Gulf and the Red Sea coastal areas. The mean annual wind speed in these two windy regions exceeds 9 knots (16.7 kmph) and ranges from about 14 to 22 kmph and 16 to 19 kmph over the Arabian Gulf and Red Sea coastal areas, respectively

INTRODUCTION:

Saudi Arabia is a large country with an area of 2.3 million km2. It is a relatively rich and rapidly developing country and so demand for electricity is growing on average at around 5% annually. Over the next 25 years, it is estimated that US$117 billion will be invested in the country's power sector. The state power grid system has supplied electricity to approximately 80% of the population living in the state capitals and industrial centers. It is highly uneconomical to extend the electrical power grid system into the sparsely populated regions of the Kingdom. Hence there are many small remote communities that need an independent source of electrical energy. These locations represent a significant potential for renewable energy applications. The importance of using renewable energy in Saudi Arabia will not only be confined to meeting the demands of remote sites, but can also contribute to the national grid, helping to meet the peak-load demand during the summer months.

Even though Saudi Arabia is a leading oil producer, it is keenly interested in taking an active part in the development of new technologies for exploiting and utilizing renewable sources of energy. The most natural renewable energy sources which are freely available are wind and solar. The power in the earth's wind and in the solar radiation, which reaches the earth, is sufficient to make significant as well as strategic contributions to the Kingdom energy supply.

WIND ENERGY:

Wind energy conversion is recognized as one of the most promising option of the renewable energy. The major challenge to using wind as a source of power is that it is intermittent, cannot be stored (unless batteries are used); and not all winds can be harnessed to meet the timing of energy demands. Further, good wind sites are often located in remote locations far from areas of electric power demand such as cities.
The interest and motivation for harnessing wind power have grown tremendously during the nineteen-eighties in many developed countries as a result of frequent energy crises and persistent issues of environmental pollution [1]. Recently wind energy has attracted a great deal of attention as one of the possible alternative renewable energy sources. By the end of 1998 the global installed capacity of modern grid-connected wind turbines was some 10000 MW and the growth rates of installation worldwide were 30% - 40% annually. The cost of wind energy was reduced by 30% between 1991 and 1997. Andersen and Jensen [2] reviewed the reasons behind the success of wind turbines and outlined the future potentials for wind energy technology. Also, according to the American Wind Energy Association (AWEA) and European Wind Energy Association (EWEA) [3], the total worldwide wind electric generating capacity has surged past 10,000 megawatts (MW). Worldwide, wind energy capacity has expanded at an annual rate of 25.7% during the 1990s, with the total doubling every three years and the cost of production declining steadily. The cost of electricity from wind generation is about one-sixth what it was in the early 1980s and further reductions is expected over the next decade. Industry analysts see the cost dropping by an additional 20 percent to 40 percent by 2005. The French Ministry of Industry, Electricity de France and ADEME (Agency for Environment and Energy Management) have launched French wind generation program EOLE 2005 in July 1996 to develop 250-500 MW of wind power by the year 2007 [4]. Wind energy activities in Japan have been summarized by Ushiyama [5]. The activities include development of a 500 KW wind machine, which has been in operation since 1996. The total installed capacity for power supply reached 8800 KW in 1997. Wind energy activities in China have been summarized by Junfeng and Zhuli [6]. There are 19 wind farms in China, the largest of which is located in Xinjiang with 10 MW total capacities. The total installed capacity of wind power reached 16 MW by the end of 1997. Presently, wind energy continues to be the fastest growing renewable energy source with worldwide wind power installed capacity reaching 14000 MW. Five nations – Germany, USA, Denmark, Spain and India – account for 80% of the world's installed wind energy capacity.

Realizing the growing importance of wind energy, manufacturers have steadily been developing new techniques to assess wind resources for techno-economical viability.

WIND ENERGY DATA

Wind speed data is available from different sources in the Kingdom. Among these are the Meteorology and Environment Protection administration (MEPA) [8], Saudi Aramco [9] and King Fahd University of Petroleum and Minerals(KFUPM) [10]. In 1995 the Energy Research Institute (ERI) at King Abdel-Aziz City for Science and Technology (KACST) initiated a project in order to record reliable data and to assess the wind potential in Saudi Arabia. Five locations, namely, Abha, Arar, Dhahran, Solar Village and Yanbu, were selected for this purpose (namely Abha, Arar, Dhahran, Solar Village and Yanbu) as a first developmental stage of the project. The installation of monitoring and assessment equipment at those sites has been completed and data collection is still in progress.

Several studies were conducted to assess the potential of wind energy in the Kingdom of Saudi Arabia. Wind data for seven stations in the Eastern Province of Saudi Arabia have been analyzed. The derived monthly and annual average wind speeds range from 2.4 to 6.1 m s^{-1} and from 3.2 to 5.3 m s^{-1}, respectively. Maximum extractable monthly and annual average wind powers were found to vary between 14.2 and 162.5 W m^{-2}, 31.7 and 94.6 W m^{-2}, respectively [11]. Wind data for 20 locations in Saudi Arabia have been analyzed [12]. Monthly and annual mean wind speeds and wind powers have been determined. The latter range from 2·5 to 4·4 m s-1, and from 21·8 to 77·7 W m-2, respectively. Results suggest that wind power would be more profitably used for local and small-scale applications. The characteristics of wind regimes and the availability of wind energy resources in Makkah, its outskirts and selected sites on the eastern and western coasts of the Red Sea have been studied [13]. Statistical analysis of the wind speeds involving fitting of observed cumulative distribution to Weibull distribution function by least square technique, determination of the Weibull parameters and evaluation of wind power density by two methods, was carried out. The mean annual wind energy density at 10 m A.G.L. lies between 250 and 500 kWh/m2 on the Red Sea coast sites and drops to about 50 kWh/m2 in inland areas. Yanbu on the east coast has the highest resource while Makkah, affected by the Sarawat Mountains, has the lowest wind energy density. The solar energy in all these areas is abundant. In Makkah and Port Sudan the mean annual solar energy density exceeds 2.0 MWh/m2. Hourly wind -speed data recorded at automatic solar radiation and meteorological monitoring station, Dhahran (26° 32' N, 50° 13' E), Saudi Arabia has been analyzed to determine monthly wind power [14]. The wind power is then compared with the monthly mean solar radiation energies for the period 1987–1990. The monthly average wind speeds for Dhahran range from 4.46 to 6.89 m/s while the solar radiation varies from 3.46 to 7.43 kWh/m2/day. The annual maximum attainable wind power potential per unit area of the wind stream is 543 kWh/m2/year and the annual solar potential per unit area of the earth surface is 2.03 MWhr/m2/year. Hourly mean wind -speed data for the period 1986–1993 [except the years 1989 (some data is missing) and 1991 (Gulf War)] was recorded at the solar radiation and meteorological monitoring station, Dhahran (26° 32' N, 50° 13' E), Saudi Arabia [15]. The monthly average wind speeds for Dhahran ranged from 4.21 to 6.97 m/s. The wind power on the east coast of Saudi Arabia has been assessed [16]. A comparison between the wind and solar power showed that the mean attainable wind power is 70.6 W/m2, while the mean attainable solar power is 500 W/m2. However, the mean producible wind power is about 50 W/m2—using Cp = 0.42, while the mean producible solar power through photovoltaic cells is 90 W/m2 (using 18% efficiency). The availability of wind power in this area is 55% while the availability of solar power is 39%. The use of shrouded walls to improve the performance of WEC is feasible due to the narrow band wind direction, (280° to 30°).

WIND ENERGY APPLICATIONS:

The wind map of Saudi Arabia indicates that the Kingdom is characterized by the existence of two vast windy regions along the Arabian Gulf and the Red Sea coastal areas [17]. The mean annual wind speed in these two windy regions exceeds 9 knots (16.7 kmph) and ranges from about 14 to 22 kmph and 16 to 19 kmph over the Arabian Gulf and Red Sea coastal areas, respectively. The application of wind energy in Saudi Arabia is nil except the recent installations by KACST as part of a feasibility study of wind energy utilization in Saudi Arabia [17]. Four sample sites are selected for possible installation of both small and large wind energy conversion systems. These sites are: Yenbo and Al-Wajh on the Red Sea coast, Dhahran on the Arabian Gulf coast and Quaisumah in the north east of the Kingdom. Using the manufacturers pre-mass production unit capital costs ($/kW) to estimate the cost of electricity produced, in cents/kWh, it is concluded that further reduction in the manufacturers unit capital cost is still required to enable wind energy to compete with other conventional energy sources.

SOLAR ENERGY:

Recognizing the sun as a major natural resource with which Saudi Arabia is blessed in abundant measure (2200 thermal kilowatt hours (kWh) per square meter) it is believed that solar energy is a valuable and renewable energy source that should be fully exploited for the benefit of the country.

SOLAR ENERGY DATA

Solar radiation data is available from different sources in the Kingdom. Among these are the Meteorology and Environment Protection administration (MEPA) [8], Saudi Aramco [9] and King Fahd University of Petroleum and Minerals (KFUPM) [10]. Reliable quantitative data on the daily and annual distribution pattern of solar energy at given locations are essential not only for assessing the economic feasibility of solar energy utilization, but also for the thermal design and environmental control of buildings and greenhouses. It has been found that the existing Saudi Solar Radiation Atlas does not cover all the parts of the country. Additionally, it does not contain the reliable information that is required for solar-energy applications, as it is based on the data collected by old and uncalibrated instruments; and the magnitude of global solar radiation has changed due to global weather variations and the environmental impacts of the Gulf War. In view of the importance of the need for exact measurements of solar radiation, the Saudi Atlas Project was initiated in 1994, as a joint R&D project between the ERI and the

NREL. Twelve locations in the following cities throughout the country were carefully selected: Riyadh, Gassim, Al-Ahsa, Al-Jouf, Tabuk, Madinah, Jeddah, Qaisumah, Wadi Al Dawasir, Sharurah, Abha, and Gizan. All of these stations are connected to a central unit for data collection and all the instruments are calibrated on a regular basis (at 6 month periods) in order to derive reliable and accurate data. To promote further dissemination, the analyzed data is made available on an Internet site.

SOLAR ENERGY APPLICATIONS:

Applications of solar energy in Saudi Arabia have been growing since 1960 [18]. Research activities commenced with small-scale university projects during 1969, and systematized major R&D work for the development of solar energy technologies was started by the King Abdulaziz City for Science and Technology (KACST) in 1977. For the last two decades the Energy Research Institute (ER!) at KACST has conducted major research, development and demonstration (RD&D) work in this field. The ERI has a number of international joint programs in the field of solar energy including SOLERAS with the United States of America, and HYSOLAR with the Federal Republic of Germany. These joint programs were directed towards projects that were of mutual interest to the committed countries involved and concentrated on large demonstration projects such as electricity generation, water desalination, agricultural applications, and cooling systems. Major solar energy RD&D projects executed by the ERI are listed in Table 2. A brief description of these projects and their associated technical accomplishments are reported by Huraib et al [18] and Alawaji [19]. The solar-energy RD&D activities throughout Saudi Arabia have confirmed that it has a multitude of practical uses. These include lighting, cooling, water heating, crop/fruit drying, water desalination, the operation of irrigation pumps, and the operation of meteorological stations, and in providing road and tunnel lighting, traffic lights, road instruction signals and for small applications at remote sites [19]. However, effective utilization of solar energy in Saudi Arabia has not yet made reasonable progress mainly due to several obstacles, some of which are listed as follows [19]:

i) The wide availability of oil, its superiority to solar energy as a source of energy and its relatively low cost

ii) The dust effect, which in some parts can reduce solar energy by 10—20%.

iii) The availability of governmental subsidies for oil and electricity generation and non-availability of similar subsidies for solar energy programs. If such subsidies must continue then solar energy will require incentive programs.

HYBRID SYSTEM:

The variations in resource availability and end-use suitability tend to limit any particular single renewable technology to specific locations and uses. The solution that is increasingly being favored as the best means of providing decentralized power with high reliability is the hybrid system. Hybrid systems do not rely on a single energy source, but two, three or even four potential sources. For economical reasons there is typically only two, but all hybrid systems will normally include a diesel generator set. The required electrical energy for rural electrification can be met using one or a combination of options that include wind, solar or hybrid (solar & wind) conversion systems beside the diesel and grid extension. The selection of one or more of these options depends mainly on the available energy, the performance of conversion system and the characteristics of the electrical load. It also depends on the capital and operational costs of each option. The maintenance requirement and the availability of the required support are also important parameters to be considered in the selection of the suitable options. Very few studies [15] are conducted on the feasibility of utilizing hybrid systems in meeting power demand in the Kingdom of Saudi Arabia. This is a potential area that needs to be explored more.

CONCLUSION:

The experience gained in the field of renewable energy R&D in the Kingdom of Saudi Arabia during the last two decades has been in the field of solar energy and has been very valuable. The international joint programs have assisted in the establishment of a series of independent RD&D projects on solar energy by the ERI, and several other users throughout the country. The following can be concluded in this regard:

1. Valuable lessons have been learned from the Kingdom experience in the field of solar energy, which are believed to be very useful to other countries with similar climatic conditions, as well as to the scientific community in general.
2. A wealth of experience has been gained in the assessment, instrumentation, calibration, data collection, monitoring and analysis of solar energy projects.
3. Low and medium solar thermal energy applications in the Kingdom of Saudi Arabia are technically and economically feasible and should be encouraged and supported by the government.
4. The feasibility of wind energy utilization in the Kingdom has not yet fully explored. Experience in this regard will be gained from the installations by KACST.
5. More feasibility studies have to be conducted in the field of hybrid systems.
6. In developing countries efforts should be directed to finding applications of those renewable systems that have already been developed in industrialized nations.
7. Effective utilization of renewable energy systems requires government subsides.
8. Interaction between regional renewable research centers and local research centers and industries must be promoted.
9. Awareness among the public about the use and importance of utilization of renewable energy has to be increased.
10. Renewable energy education and training programs must be incorporated as part of educational programs.

ACKNOWLEGEMENT

The authors gratefully acknowledge the support of King Fahd University of Petroleum and Minerals in supporting this study.

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Table 2 List of solar energy project conduction by ERI, KACST [19]

Projects	Location	Duration	Applications
350 kW PV System (2155 MWh)	Solar Village	1981-87	AC/DC electricity for remote areas
350 kW PV hydrogen production plant (1.6 MWh)	Solar Village	1987-93	Demonstration plant for solar hydrogen production
Solar cooling	Saudi	1981-87	Development of solar cooling laboratory
1 kW solar hydrogen generator	Solar Village	1989-93	Hydrogen production testing and measurement (laboratory scale)
2 kW solar hydrogen (50 kWh)	KAU, Jeddah	1986-91	Testing of different electrode materials for solar hydrogen plant
3 kW PV test system	Solar Village	1987-90	Demonstration of climate effects
4 KW PV system	Southern regions of Saudi Arabia	1996	AC/De electricity for remote areas
6 kW PV system Solar seawater desalination	Solar Village	1996-98	PV grid connection
PV water desalination ($0.6m^3$ per hour)	Sadous Village	1994-99	PV/RO interface
Solar-thermal desalination	Solar Village	1996-97	Solar distillation of brackish water
PV in agriculture (4 kWph)	Muzahmia	1996	AC/Dc grid connected
Long-term performance of PV (3 kW)	Solar Village	Since 1990	Performance evaluation
Fuel cell development (100-1000 W)	Solar Village	1993-2000	Hydrogen utilization
Internal combustion engine (ICE)	Solar Village	1993-95	Hydrogen utilization
Solar radiation measurement	12 stations	1994-2000	Saudi solar atlas
Wind energy measurement	5 stations	1994-2000	Saudi solar atlas
Solar dryers	Al-Hassa, Qatif	1988-93	Food dryers (dates, vegetables, etc.)
Two solar-thermal dishes (50 kW)	Solar Village	1986-94	Advanced solar stirling engine
Energy management in buildings	Dammam	1988-93	Energy conservation
Solar collectors development	Solar Village	1993-97	Domestic, industrial, agricultural
Solar refrigeration	Solar Village	1999-2000	Desert application