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Efficacy of Alternate Renewable Energy Sources in Saudi Arabia

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Abstract: ***A small residential community in Jubail industrial city in Saudi Arabia was selected to assess the economic feasibility and optimal renewable energy combination systems that cover the energy demands of the community and help in reducing carbon emissions. Jubail is a 40 years old industrial city that has a significant role in the economic impact of the Kingdom of Saudi Arabia. The maximum part of the area of the city consists of industrial companies ranging from petrochemical, mineral, and manufacturing. The population of this industrial city is estimated to be around 100,000. In our study, we considered a small community in Jubail that represents a residential complex of two hundred residential buildings for the Royal Commission in Jubail. We examined the efficacy of using alternative renewable energy sources for the residential community in Jubail, Saudi Arabia considering the present economic scenario. The analysis indicates that the wind farm has a good potential in increasing the renewable fraction while maintaining a relatively low cost of energy. At the same time, the photovoltaic (PV) energy system is a slightly expensive choice unless the government subsidy is raised to a high level. However, considering the location of the country, it has a huge potential in contributing to the energy resources requirement.***

1. Introduction

1.1 Energy Demand In Saudi Arabia

The drop in Oil revenue has urged the Saudi government to draw down more than $100bn in financial reserves and borrow $17.5bn on global bond markets to help finance its budget (1). In this circumstance, alternate energies play a key role in the economic transformation of the country. In particular, renewable and nuclear energy are vital to cut domestic demand for oil, freeing up production for export. From recent reports, it is to be noted that the Power demand in the Kingdom is growing 8% annually (2). Further, around 53% of the total consumed power in Saudi Arabia is by households. Of these, most of the energy is used for cooling. Reports indicate that in the last year alone, the amount of power used at peak times showed growth by 10% (3). This substantial growth of local power consumption will jeopardize the ability to export to the international markets.

Very recently as part of its Vision 2030 plan of new economic and social objectives, the government's National Renewable Energy Programme (NREP) revealed plans to develop 3.5 GW of renewables by 2020 and a further rise to 10 GW by 2023. This requires around $50 billion of investment. It is estimated that this strategy could replace the equivalent of 80,000 barrels of oil a day now burned for power. Furthermore, by 2032, the Kingdom aims to acquire a substantial amount of capacity through alternative and renewable based power generation in which solar energy (41 GW) being considered as the most prominent source followed by nuclear (17.6 GW) and other renewables (13 GW) (3). To implement this plan, Saudi Arabia's energy ministry has created the Renewable Energy Project Development Office (REPDO) to oversee the development of renewable energy projects. At the moment the Kingdom produces very little renewable energy, representing less than 1% of the total produced. However, the present reforms aim renewable energy contribution equating to around 4% of energy use in the kingdom (2). Prevailing reports indicate that the Kingdom is currently seeking bids to build 700 MW of wind and solar power and is expected to launch for another 1 GW of projects later this year, with the cost of power forecast to be the lowest in the world (4). It is known that Saudi Aramco now runs the country's biggest solar plant, 10 MW facility mounted on a parking lot roof. In January this year, the company also started the kingdom's first commercial wind turbine in the northwest region. The wind power projects are located in Tabuk province, in the northwest part of the country. Another tender for two 50MW solar power plants that are to be built at Al-Jouf and Rafha was launched recently.

It is worth to note that constructing additional solar and wind power stations and developing a nuclear power industry project is part of a broader government plan to diversify away from crude sales as the main source of country's income. The current plans indicate that these projects will be financed and operated by private investors as well, and international financial institutions are expected to participate. In this aspect, Saudi Arabia is also finding ways to collaborate its power projects with countries like Yemen, Jordan, and Egypt.

1.2 Electricity Prices and Subsidies

The current cost of electricity production is $0.10/kWh. The present average electricity price is about SR0.26/kWh (3,4).Now the question here is if the low prices charged are subsidized or simply low prices?

It is well known that as per the International Energy Agency (IEA), fuel subsidies are cost spend by the government resources to reduce the fuel price for the citizens than the real cost of production. Note that several countries are subsidizing fuel and electricity prices to their citizens. Reports indicate that Saudi Arabia is the second largest country after Iran as far as the subsidizing prices are concerned. Also, it is worthwhile to note that around 70% of the fuel consumption is subsidies to oil whereas 30% to electricity. It is estimated that these subsidies are costing Saudi Arabia around $188 billion. Figure 1 shows the Fuel subsidies in different countries (5).

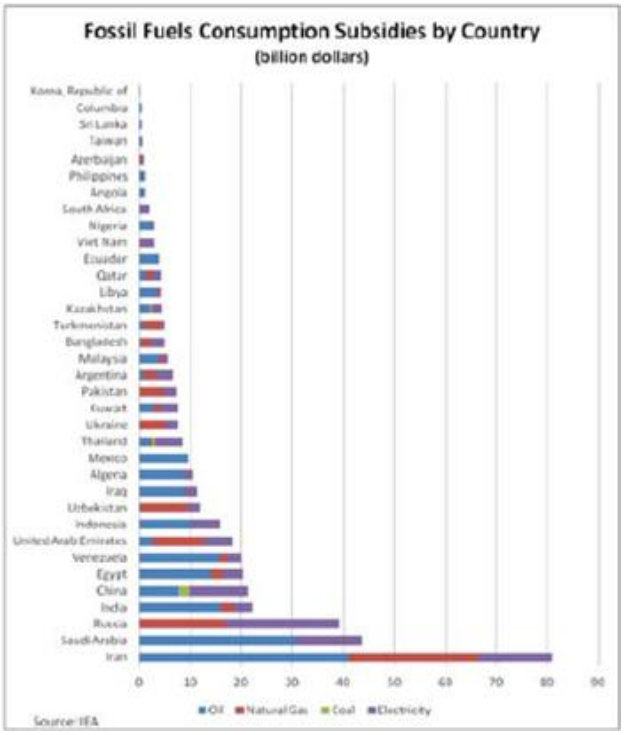

Figure 1: Fuel subsidies in different countries

Without this fuel subsidy by the government (estimated, in 2013, to be around SR 150 billion), the average electricity cost in 2013 would have been about SR 0.80/kWh compared to the value of 0.26 (3). It is reasonable to assume that this high-priced subsidizing system is meant for redistributing the country's oil wealth to the citizens. On the other hand, the disadvantage of the subsidy system is that it would significantly reduce investments in the alternative renewable energy systems. Therefore the Government has pushed forward with cutting utility and petrol subsidies. These current reforms are expected to save about $55bn a year by 2020. It is interesting that according to available reports these reforms had already resulted in a significant drop in demand growth of power energy from an average 5-6 percent to 0.5 percent last year.

1.3 Electricity in Jubail

Figure 2 shows the map of Jubail Industrial City, which is the location of our study (6). In the Jubail industrial city, Marafiq operates the world's largest integrated water and power facility in a joint venture with SEC, Public Investment Fund of the Ministry of Finance (PIF), Suez Energy International, ACWA Power projects of Saudi Arabia, and Gulf Investment Corporation of Kuwait.

Figure 2: Location of the case study

The primary fuel used is natural gas and high-speed diesel used as a backup fuel. The plant operates using a combination of both gas and steam based turbines, with a total nameplate installed capacity of 2745 MW. The entire power produced at the plant is supplied to SEC.

2. Objectives

It is well known that conventional power plants emit greenhouse gases such as CO_2, SO_2, and NO_x, which are responsible for global warming. Reports suggest that Saudi Arabia leads the Gulf Cooperation Council countries in its CO_2 emissions, contributing 56% (7), and is ranked 14 in the world for CO_2 emissions (8). It is of concern that the relationship between electricity consumption and CO_2 emissions (8) is approximately linear. Accordingly, future use of conventional generation will increase the levels of CO_2 emissions in Saudi Arabia proportional to the expansion of its generation capacities. The objective of this study is to investigate the efficacy of utilizing alternative renewable energy systems to provide the community with its needs of electricity. It is envisaged that such a system would help the city to have better energy efficiency along with environmental benefits by reducing harmful gas emissions. A likelihood of utilizing an alternative renewable energy system along with the traditional conventional power plants would be a relevant option.

3. Sources and Data Collection

Some of the data required for this study were obtained from a survey conducted with residential communities in Jubail that are based on the data from the original sources such as Marafiq (utility company in Jubail) and the Royal Commission in Jubail which is responsible for residential development. Some other data were collected from different previous related researches, especially renewable energy researches done specifically for Jubail.

3.1 Electrical Load

The total electrical load for the residential community is estimated with the data obtained from the survey. On average electricity is used for heating domestic water and mostly there are no heating loads in the winter due to the moderate temperature of the place. In the analysis, a typical residential building with two persons was used to estimate the overall power consumption. The results indicate that the minimum power consumption varied from 1000kWh (during winter) to 4000 kWh per month (during summer)in a year with an average consumption of 2000 kWh in a month. It means that the average electrical load for one residential building is 2.78 kWh. The community consists of 200 buildings, so if we multiply the number of buildings by the 2.78 kWh, we will have a total electrical load of 556 kWh for the whole community. There might be a possibility of a small difference between the actual load from the utility company and the estimated load. This can be ascribed to the behavior of different occupants when dealing with lighting and comfort situations, and the construction materials.

3.2 Wind Energy

Recently, Baseer reported the wind resource assessment for Jubail Industrial City (6). Their assessment includes annual, seasonal and diurnal wind speed statistics, wind roses, Weibull distribution parameters, local values of wind shear exponent and energy output from a 2 MW rated wind turbine. It is well known that the energy output is highly dependent on wind speed. By analyzing five-year data (2008-2012), they reported that at 10, 50 and 90 m above ground level the mean wind speeds were 3.34, 4.79 and 5.35 m/s respectively. Fig. 3 shows a typical wind rose plot at 90 m height (6).

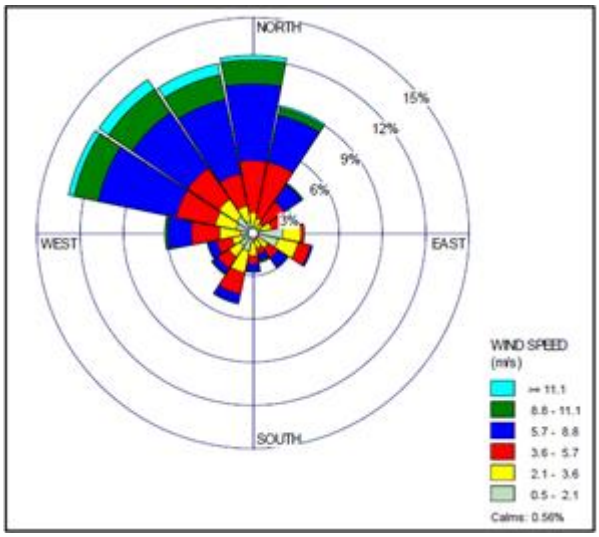

Figure 3: Wind rose plot at 90 m

It was observed that the wind speed is highest in the month of June and lowest in October. The most prevalent wind direction in Jubail is from the north-west. This data is vital in choosing the orientation of the wind turbines to have the best performance in power generation. It is also reported that the annual energy production from a commercially available wind turbine of 3 MW rated power is about 6285 Mwh with a plant capacity factor of 25%.

Fig. 4 shows the average monthly wind speed data estimated using the five years of data between 2008 and 2012 (6).

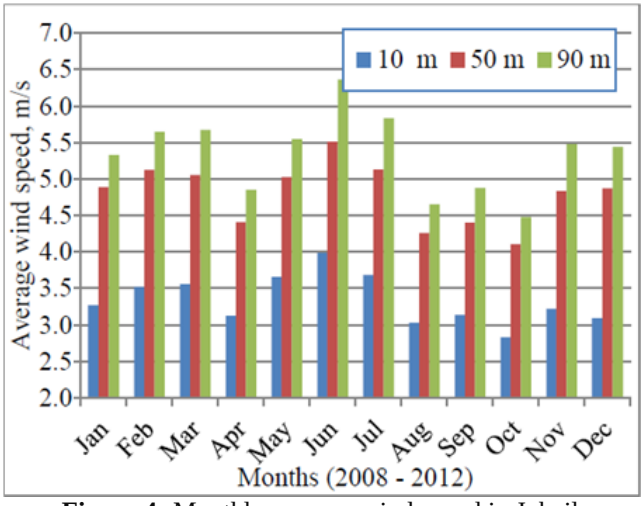

Figure 4: Monthly average wind speed in Jubail

As known, Saudi Arabia is a country located in the Middle East. Hence, it has a strong demand for electricity in the summer. That also matches with the consumption data where the electrical load peak is between June and October. Observations indicate that the wind speed during summer is higher than that in winter. This is in accordance with the earlier observations (6). They report that the wind speed was highest in June and lowest in October. Further, it is interesting to note from their report that the wind speed is higher between 3.00 PM and 4.00 PM.

3.3 Solar Energy

Saudi Arabia is one of the best locations in the world to take advantage of photovoltaic power plants. The geographical location of the country (between latitudes 31°N and 17.5°N) in the center of the so-called Sun Belt, with its widespread unused desert and rain-less land, and its year-round clear skies, all make it an excellent candidate for harvesting the most power from the sun to generate electricity (9). Earlier reports indicate that based on 12 months data between October 2013 and September 2014, although most regions in Saudi Arabia have sufficient solar resources, the western inland sites with an average daily totals of over 6474 Wh/m^2 (average yearly totals of 2400 kW h/m^2/year) are superior to the eastern sites (where Jubail Industrial City is located) with an average daily totals closer to 5510 Wh/m^2 (average yearly totals of 2000 kW h/m^2/year) (10).Fig. 5 below depicts the average solar radiation map in Saudi Arabia (9).

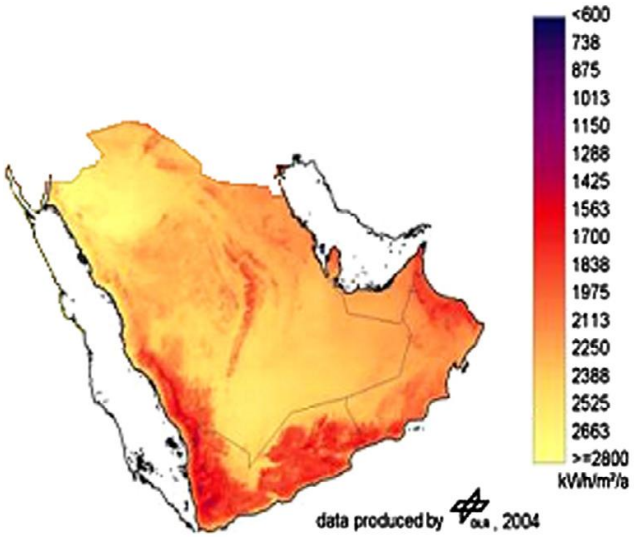

Figure 5: Average solar radiation map in Saudi Arabia.

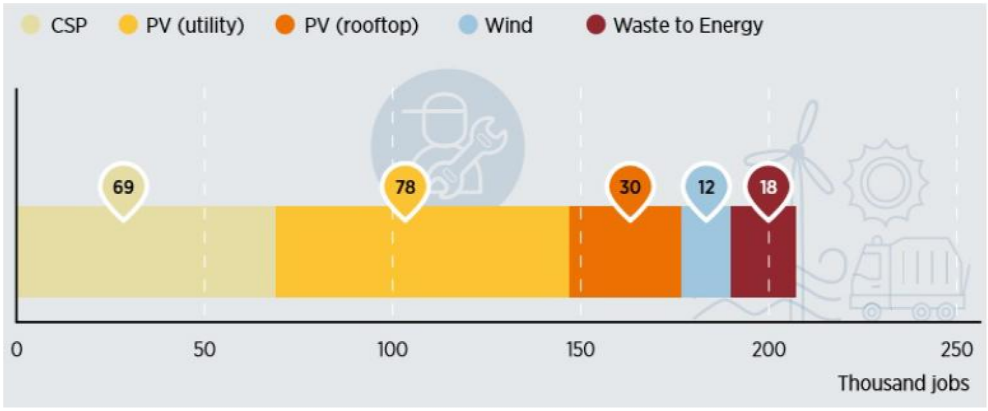

Figure 6: Predicted renewable energy jobs in GCC in 2030.

Further, as mentioned in the introduction section total PV installation capacity is increasing each year in Saudi Arabia. It means that there is a huge potential for using solar energy along with other efficient energy resources such as wind and nuclear energy. Furthermore, it is predicted that the jobs in the renewable energy sector in GCC countries will increase significantly in the coming years as shown by the layout in Fig 6. (11).

4. Conclusion

A renewable energy feasibility study was carried out for a residential community in Jubail, Saudi Arabia considering the present economic scenario. A comprehensive analysis indicates that the power production by alternative energy sources like solar and wind is truly worthwhile considering the corresponding power consumption by a typical residential community as an example in the Jubail province. Also, alternative energy resources would reduce the emission of harmful gases such as nitrogen oxides, sulfur oxides and carbon oxides that cause environmental pollution and consequently affect human health. Further, it is envisaged that renewable energy jobs will be dramatically increased in the near future.

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