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Energy and Emission Benefit Analysis of Solar Powered Electrical Power Generation in Pakistan

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Abstract: An analysis of solar power generation and CO_2 emission reductions for a site at Sukkur, Pakistan is carried out to demonstrate the capability of solar powered power generation as an alternative valuable energy source to conventional fossil fuelled power generation systems. In this paper, energy and emission analyses are used as means for an estimation of the amount of electrical power that can be produced and along with CO_2 emissions reduction per specific area per time, if solar energy is used as an alternative fuel for power generation. The results show solar potential is more than adequate for electrical power production to meet the local electricity needs in environmentally sustainable manner on account of considerable amount of emissions that could be avoided accordingly.

Keywords: Non-fossil electrical power, environmental sustainability, emissions reduction,

1. INTRODUCTION

The fossil fuels energy scenario reflects a gap that exists between energy demand and supply. Such energy shortages have resulted in numerous challenges to the modern way of living (Lloyd and Subbarao 2009, Harijan *et al,* 2007). The energy scenario in Pakistan is also characterised by the problems of energy scarcity and the release of anthropogenic emissions (Sheikh, 2010). For instance the process of electrical power supply in majority of non –urban remote areas is affected considerably (Ghaffar, 1999). The environmental emission levels are quite high. The severity of the situation can be realised from the fact that Pakistan occupies 33rd position out of 186, in the global list of emission producing countries (WRI, 2005).

These challenges indicate a bleak fossil fuels energy scenario and underlining the dire need to supplement energy needs with renewable energy sources (MacKay 2008, Asif 2009). In the current paper, the effects of fossil fuelled electrical powered generation systems and their effects on environmental sustainability are analysed. Based on the study, an alternative solution of indigenous solar energy resource is evaluated in an effort to accomplish an environmentally feasible energy generation scenario.

The climate in Pakistan is favourable for solar energy utilisation. Most southern areas of Pakistan remain hot for most of the year. The hot season is usually dry and the temperature soars to 40°C and beyond. The temperature along the sea coast ranges between 25°C to 35°C (Shah and Zhang, 2010). It is thus possible to launch a small and medium scale solar powered generation process in the areas of Pakistan (Mirza *et al,* 2009).

It is believed that the energy scarcity problem could be resolved to a considerable extent by the utilisation of solar energy in an environmentally sustainable manner (Rasool 2010). Therefore, solar potential assessment and environmental emissions reduction analysis for a site at Sukkur, Sindh, Pakistan are worked out. This is to demonstrate the capability of solar energy potential towards energy adequacy and environmental sustainability i.e. carbon dioxide emission reductions in the long run.

2. METHODOLOGY

RET Screen International Clean Energy Analysis tool is used for the energy and emission analysis for Sukkur, Sindh, Pakistan It is an integrated renewable energy analysis tool for the evaluation of energy production and greenhouse gas emission reductions for various types of renewable energy technologies (RETs), including photovoltaic (Thevenard *et al*, 2001).

The energy analysis is used to calculate the amount of electrical power that can be generated in kWh/m^2/day by an isolated grid system. The monthly mean values of the global solar radiation on a horizontal surface, the monthly mean temperature, site latitude, PV

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module specifications and inverter specification are used as inputs for the energy analysis. Inverters are used in the energy analysis for the conversion of DC to AC power, which could then be feed directly into the national grid. Array losses are also accounted for in the inverter calculations. Export electricity losses, i.e. transmission and distribution losses are also included in the analysis. These are considered to be in the range of 1-20%.

The emission analysis is used to calculate the amount of emissions (kg CO_2) that can be avoided per kWh solar powered electrical power generation per square meter per day. In emission analysis, the amount of emissions that could be avoided is calculated on the basis of emission factor (Thevenard, 2001). This emission factor is country and time specific and varies with fuel category and location. The emission factor of, Sukkur, Sindh, Pakistan is used for the calculation of amount of emissions that would be escaped for this site in kg/CO_2/kWh electrical power generation. The emission factor used for Pakistan is 0.413 CO_2 kg/kWh for electric power generation.

3. RESULTS

According to energy analysis, the electricity that could be exported to the grid including 20% transmission and distribution losses per square meter per day is 0.66 kWh. The power generation capacity of solar photovoltaic process related to this amount of power is predicted to be 0.12 kW. The breakdown of solar powered electrical power that can be generated per meter square per day are shown in **(Table 1).**

In the emissions reduction analysis, the amount of emission related to the estimated solar powered electrical power generation system capacity is calculated as 0.10 kg CO_2 on basis of above mentioned CO_2 emission factor for Pakistan The breakdown of solar power based emission analysis is shown in **(Table 2).**

Table 1. Breakdown of the electrical power that could be generated per square meter per day at a site in Sukkur, Sindh, Pakistan

Annual solar radiation – horizontal	1.9 (MWh/m²)
Annual solar radiation – tilted	2.58 (MWh/m²)
Photovoltaic	
Estimated power capacity	0.12 kW
Efficiency	11.7 %
Nominal operating cell temperature	45 °C
Temperature coefficient	0.40 %
Solar collector area	1 m²
Miscellaneous losses	1.00 %
Inverter	
Efficiency	95 %
Capacity	95 kW
Miscellaneous losses	5 %
Summary	
Electricity exported to the grid per square meter per day	0.66 kWh/day

Table 2. Breakdown of net amounts of CO_2 emissions (kg) that can be avoided per meter square per day because of the use of solar photovoltaic power generation processes

Base case system CO_2 reduction summary			Fossil fuel powered power (kWh)	CO_2 emission factor/kWh (Kg)	CO_2 emissions to be produced kWh power (Kg)
Fuel type (Kg)	Fuel output (kWh)				
Fossils	Electricity		0.660	0.413	0.1
Proposed case system CO_2 summary (Solar power project)			Solar powered electrical generation per m^2 per day (kWh)	CO_2 emission factor (Kg /kWh)	CO_2 emissions to be avoided per 0.660 kWh power (Kg)
Fuel type (kWh	Fuel output (kWh)				
Solar energy	Electricity		0.660	0.413	00
CO_2 emission reduction summary Solar photovoltaic power project	Base case CO_2 emission on fossil fuel power generation per m^2 per day (Kg)	Proposed case CO_2 emission per m^2 per day (Kg)	CO_2 emissions allowing for 20% T&D losses while exporting electricity to the grid per meter square day (kg)		Net emission avoided per square meter per day (Kg CO_2)
	0.1	0.00	0.1		0.10

4. DISCUSSIONS

The findings of the analysis of solar potential and CO_2 emissions reduction of a site at Sukkur (Sindh, Pakistan) reveal that considerable amounts of electrical power can be generated per square meter per day by the utilisation of available thereby reducing carbon dioxide emissions. Such a development process would provide in these areas a source of clean energy for electrical power generation, which is environmental safe and socioeconomic stable. The scope and volume of the operations can be diversified in the future on the basis of experience gained by the deployment of small scale solar power generation and desalination plants in various areas of Pakistan.

The results of environmental emissions assessment reveal that solar energy could provide an energy source free of CO_2 emissions in power generation sector in comparison to the use of conventional fossil fuels. The results would be very much promising for a developing country like Pakistan, which is a signatory of the Kyoto agreement looking towards reductions in the existing emission levels. There would also be financial benefits of CO_2 emission reductions in terms of the emission neutralisation cost savings, which are generally incurred in the use of carbon separation and sequestration.

4. CONCLUSIONS

The process of solar powered electrical power generation systems needs to be initiated on small and medium scale in various locations of Pakistan in a bid to resolve the problems of energy shortage and the alarming levels of environmental emissions. The utilisation of solar power as an energy fuel would overcome the problems of energy crisis in the country and facilitate the process of considerable reduction of carbon di oxide emissions. Since the potential advantages of such development are considerable; they are bound to leave a positive impact on social, cultural and economic sectors.

REFERENCES:

Asif, M. (2009) "Sustainable energy options for Pak.." Renewable and Sustainable Energy Reviews 13.

Ghaffar M. A. (1994) "The energy supply situation in the rural sector of Pakistan and the potential of renewable energy technologies." Renewable Energy, 6, **(8):** 941-976.

Harijan K., M. A. Uqaili and M. Memon (2007) "Renewable Energy for Managing Energy Crisis in Pakistan." Springer-Verlag Berlin Heidelberg: 7.,449-455 Kher, S. (2008).

Lloyd, B. and S. Subbarao, (2009) "Development challenges under the Clean Development Mechanism (CDM)- can renewable energy initiatives be put in place before peak oil?" Energy Policy 37, 237-245

Loster, M, (2010) "Total Primary Energy Supply From Sunlight.", http://www.ez2c.de/ml/solar_land_area/, 1-2

MacKay, D. J. C. (2008), "Sustainable Energy - without the hot air." E-Book, UIT Cambridge, England 3: 1-15.

Mirza U., K, Nasir K, Harijan and T. Majeed (2009) "Identifying and Addressing Barriers to Renewable Energy Development in Pakistan", Renewable and Sustainable Energy Reviews, May, 2009,5, 927-931

Rasool, A. (2010), "To Develop technical feasibility of Very Large Scale Photovoltaic Systems for Deserts of Pakistan.," Thesis: 1-1

Shah, S. A. and Y, Zhang (2010), "Prospects of coastal solarisation for fresh water and electricity production in coastal areas of Pakistan," ISESCO Journal of Science and Technology Vision, Vol. **(06):** Issue 10, 82-87,

Thevenard, D., L. Gregory, and S. Martel, (2001), The Retscreen Model for assessing potential PV projects, PV Horizon, Workshop on Photovoltaic hybrid systems, Montreal, September,11, 2001, 1-4.

Water Resource Institute, (2005), "List of countries by greenhouse gas emissions.",http://en.wikipedia.org/wiki/List_of_countries_by_greenhouse_gas_emissions,1-2, dated 15.06.2013