ISSN (e) 2520--7393
ISSN (p) 5021-5027
Received on 12th Mar, 2018
Revised on 28th Mar, 2018
www.estirj.com

Analysis of Photovoltaic System at Various Sites of Pakistan Using Retscreen Software

Yasir Ali Bhutto[1], Mukhtiar Ahmed Mahar[2], Abdul Sattar Larik[3], Shafqat Hussain Bhellar[4], Assadullah Khuwahar[5]

[1,2,3,4]*Department of Electrical Engineering Mehran university of Engineering and Technology Jamshoro*
[5]*Department of Electrical Engineering Quaid-e-Awam University college of Engineering Sciences and Technology Larkano*

Abstract: Energy generation by safe, secure, environment friendly and economical source is prime matter for the world. Since the world is moving towards achievement of the Paris summit agreement goals and Kyoto protocol targets, many of the countries are in transposition phase from fossil fuel based generation to renewable energy generation. Pakistan is developing country having the severe issues regarding electricity shortfall, load shedding, load management and green house gases emissions. Pakistan is solar rich country having potential of 2.9 million MW almost entire land of country is feasible for the generation of electricity through photovoltaic system and can be the solution to cater electricity problems. This study analyze the 5kw photovoltaic system at various sites of Pakistan such as Karachi, Sukkur, Bahawalpur and Quetta, the analysis examine electricity generation, green house gases emissions reduction and financial terms, using RETScreen simulation software. Photovoltaic system performance analysis is weather data dependent which is imported by RETScreen software using NASA database system. According to RETScreen simulation results, the electricity generated annually at Quetta, Sukkur, Bahawalpur and Karachi are 9327kwh, 8743kwh, 8516kwh, 8638 kWh, respectively. The green house gases emission reduction results are 3.816 tco_2 for Quetta, 3.577 tco_2 for Sukkur, 3.4841 tco_2 for Bahawalpur, 3.5338 tco_2 for Karachi. The financial analysis reveals the results for simple payback time in the range of 7 to 7.7 years and equity payback time is in the range of 3.5 to 4.3 years. As per comparative analysis of the sites, Quetta site is proposed site over Sukkur, Bahawalpur, and Karachi whereas Bahawalpur site less suited site over Quetta, Karachi, and Sukkur in all three sections of energy generation, tco_2 reduction and financial terms. The implementation of Photovoltaic system will be beneficial in curing the issue of energy shortfall and carbon dioxide emissions in Pakistan.

Keywords: Photovoltaic system; Green house gases emission; Payback time; Retscreen ; Renewable energies

1. Introduction

Energy demand of the world is the one of the current issues to deal with, as Energy demand of the world is increasing every day, it is forecasted that energy demand of the world will be doubled by 2020 [1]. Pakistan is the country which suffers from high population increment rate, rapidly increasing urban areas therefore energy demand is one of the main problem in power sector, about 38% of Pakistan's population has not grid access [2], the range of electricity shortfall lies in between 6000-7000 MW [3], this shortfall produces social and financial problems in the country, if these issues prevails and preventing measures are not taken the country's electricity demand might reach to 312 twh by 2030[4]. Another problem is Green house gases emissions, one of the chronic issues present in the globe, according to Paris summit on climate change on 28 December 2015 known as Paris agreement signed by 196 nations to hold and suppress global warming below 2 centigrade and take strong steps by countries to take warming on 1.5 centigrade or below[5]. According to bp statistical world energy review 2017 Pakistan's emissions are 192.7 million tons of carbon dioxide with growth rate of 8.5% and 0.6% of world emissions [7]. According to world health organization WHO 1.6 million people die every year due to climate change caused by fossil fuels and this number may be doubled by 2020 [8]. The photovoltaic system is clean energy which can reduce carbon emissions. The world is now turning toward PV system, Since last decade, small scale photovoltaic system is preferred over other conventional power plants due to decrease in their cost [9].

Photovoltaic system converts solar energy to electrical energy. It can work in fixed mode, one axis and two axis modes, two axis modes has highest efficiency but sometimes avoided due to increased cost [10], the energy generation by PV system depends upon various factors such as geographical location, installation configuration and PV system characteristics [9]. The present study will investigate the performance analysis of grid connected, fixed 5kw photovoltaic system at various sites of Pakistan such as Karachi, Quetta, Sukkur and Bahawalpur using RETSCREEN simulation software, the weather information

Corresponding author Email address: engryasirbhutto@gmail.com

is imported from NASA database using RETSCREEN software [11]. The information comprises of wind speed, air temperature, solar radiations and earth temperature etc. this work also comparatively analyze the results of four sites and proposed the best site from these.

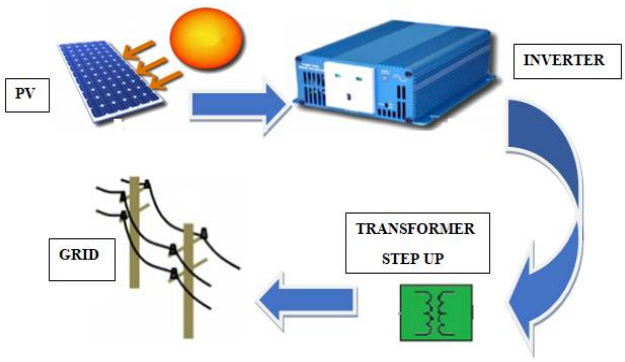

Fig: 1 layout of on grid PV system

Previously shown the layout of on grid photovoltaic system, energy generated by PV system is DC, it is then converted to AC by using inverter then the voltage is stepped up by transformer and directed towards the grid.

2. Pakistan's present electricity generation scenario

Pakistan is full with natural resources having abundance of coal, natural gas etc but with the passage of time resources like natural gas, oil are lessening time by time resulting increase in the fuel cost that effects tariffs. In 2010-2011 Pakistan's oil import bill was US$ 12.085 billion, in 2011-2012 it becomes US$15.27 billion and it is expected to reach US$ 41 billion in 2022. Further increment in the oil prices will put more pressure in the electricity tariffs. Pakistan's electricity generation in the year 2015-2016 is 74011 Gwh having the share of Hydal 24544 Gwh, Thermal 45252 Gwh, Nuclear 3078 Gwh, Imported 335 Gwh and Renewable 802 Gwh [12]. Thermal energy having the highest share of 61%, Hydal 33%, Nuclear 4.1%, Imported 0.45% and of Renewable is 1%.

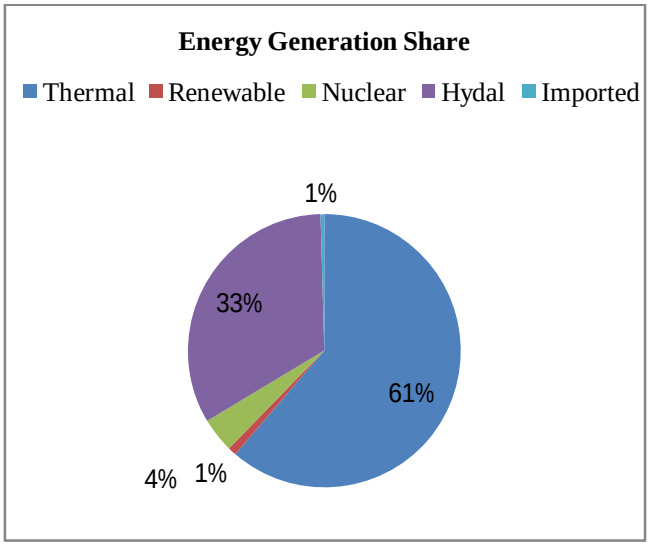

Fig: 2 energy generation share

From renewable resources energy generation in the year 2016 is 802 Gwh having the share of wind energy 457 Gwh, Bagas cogeneration 319 Gwh and Solar 25 Gwh, inspite of having the potential of 2.9 million MW in solar energy Pakistan generate only 25 Gwh through solar.

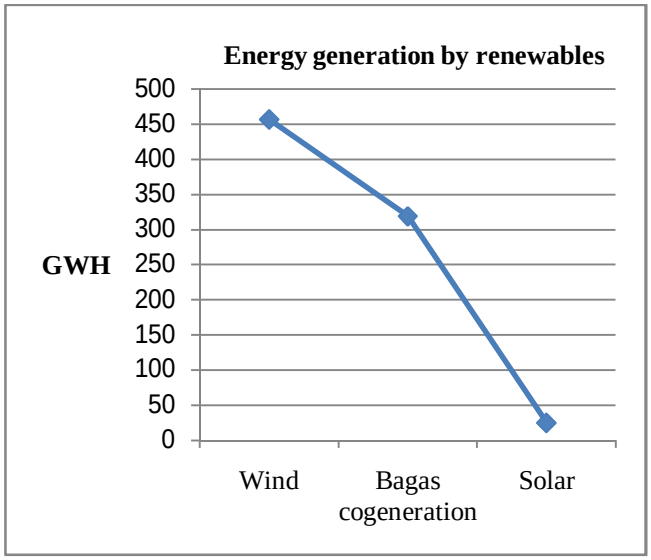

Fig: 3 energy generation by renewable

3. Pakistan's Solar Scenario

Pakistan is gifted with solar energy by the God having more than 300 sunny days, 3000-3300 sunny hours in the year [8] [13]. Almost 95% of area is suited for solar generation. Pakistan is situated between 23–271 north latitude and 61–76 east longitude on the global map[10] and having the capacity to generate 2.9 million MW of electricity through solar here shown the solar map of Pakistan.

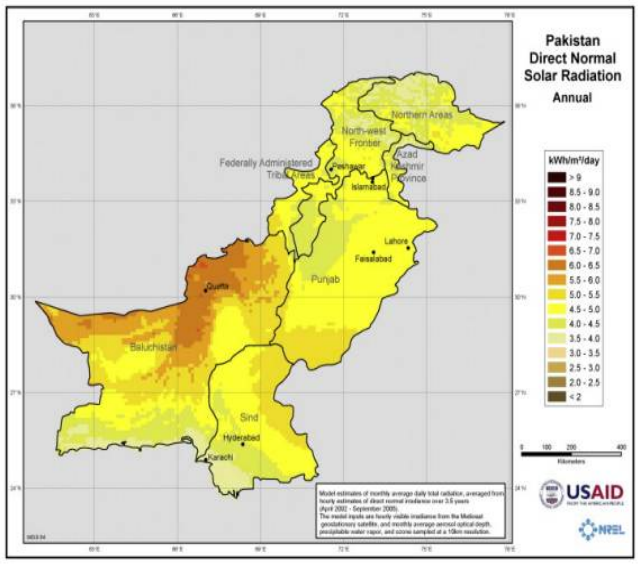

Fig: 4 solar map of Pakistan [14]

Photovoltaic system is preferred over other resources because of environment friendly, less noise, easy to install and short term construction [15]. Instead of having enormous potential Pakistan has only generated 25 Gwh in

the year 2016, the reason behind it is the high capital cost, the household consumers also suffering from this problem [16].

4. Research data information

The data for analysis for this paper has been taken from different sources such as natural resource Canada, Canment energy [11], water and power development authority (WAPDA), bp statistical reviews of world energy, Pakistan metrological department, national renewable energy laboratory, online data and research journals and papers.

5. Research study sites:

Pakistan has 1900 – 2200 kwh/m2 of solar irradiance in the country, whereas Sindh and Baluchistan having quite high solar irradiance ratio [17], current research sites are taken from Pakistan near the load centers cities like Karachi, Quetta, Bahawalpur and Sukkur

6. Research methodology:

Retscreen renewable energy technology simulation software is used in this work, RET Screen software is generated by government of Canada, this software is user friendly and best suited for solar projects, key advantage of Retscreen is that it automatically generates the weather conditions by importing from the NASA database. Canment energy research centre, natural resource Canada has designed it and easily available free of cost in viewer mode on internet [11]. This software contains models such as energy model, financial model, emission model, risk and sensitivity model. Different sites can be evaluated using this software.

Fig. 5 Retscreen simulation software

Here shown the specific specification of RET Screen software it requires product data, climate data and project data to get technical, financial and environmental analysis as results.

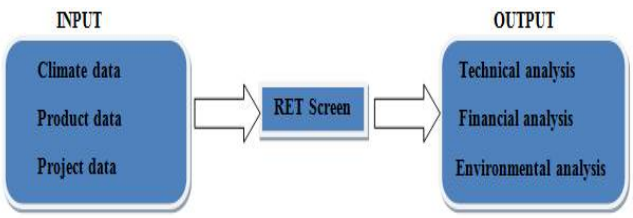

Fig: 6 Retscreen simulation software specifications

6.1 Electricity Exported to Grid

Electricity generation will be evaluated through energy model; primarily site location will be selected first then by importing data to energy model net annual electricity exported to the grid can be evaluated. This paper analyze the 4 different sites of Sindh of Pakistan, the selected sites are Karachi located at 24.90 N latitude 67.13 E longitude, Quetta located at 30.3 N latitude 66.9 E longitude, Bahawalpur located at 29.4 N latitude 71.7 E longtitude and Sukkur located at 27.70 N latitude 68.85 E longitude. Other important weather information is shown the table.

Property **Climate information of PV model locations of Pakistan**

Location	Karachi	Quetta	Sukkur	Bahawalpur
Latitude	24.90° N	30.3° N	27.70° N	29.4° N
Longtitude	67.13° E	66.9° E	68.85° E	71.7° E
Earth Temperature °c	29.2 °C	21.5 °C	27.2 °C	29.8 °C
Daily solar radiations horizontal (annual) kwh/m^2/d	5.34	5.46	5.35	5.13
Air temperature	26.1°c	18°c	24.6°c	26.3°c
Wind speed	3.5 m/s	4.5 m/s	3.9m/s	3.4m/s

Table: 1

According to table Quetta has the highest Daily solar radiations horizontal (annual) kwh/m2/d while Bahawalpur having the lowest Daily solar radiations horizontal (annual) kwh/m2/d.

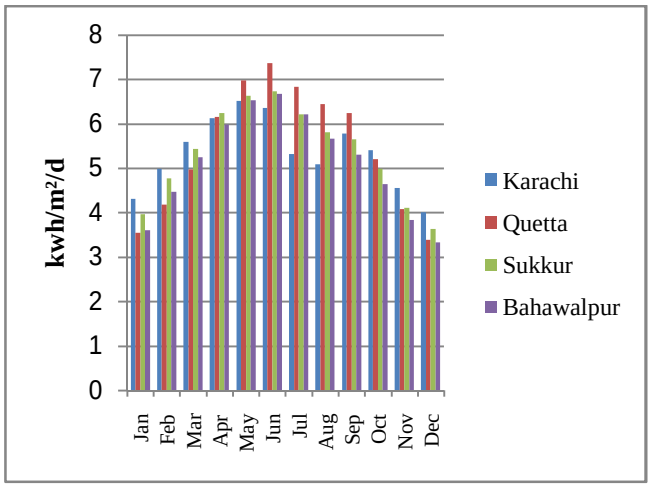

Fig: 7 monthly solar radiations

The solar technology is selected as photovoltaic and preferred over concentrated solar power because of residential conditions and initial cost [18], Solar tracking

system is selected as fixed at 45 degrees. Photovoltaic model is selected as Poly crystalline of Jinko power company poly-Si - jkm270p - having efficiency of 13.92%. For 5kw on grid system 20 plates of 270w per unit are taken having total collector area of 38.8 m^2

Table. 2 for PV model input parameters are shown below:

Technical Data of Photovoltaic Array	
Type	Poly-Crystalline
Manufacturer	Jinko Power
Model	Poly-Si-Jkm-270p
Efficiency %	13.92
Capacity Per Unit (Watt)	270
Frame Area Per Unit(m^2)	1.94
Number of Units	20
Capacity Of Array (KW)	5
Nominal operating Cell Temp: °C	45
Solar Collector Area (m^2)	38.8
Temperature Coefficient % / °C	0.4
Capacity Factor %	18.3
Solar Tracking Mode	Fixed
Slope	45°

The inverter chosen for this system is infini having efficiency of 96 % and losses of 4%. Some assumptions are also taken such as the performance of the PV model will remain same for 25 years, 5% system losses are taken into account and it is also assumed that PV model will always remain neat and clean.

6.2 Green House Gases (GHG) Emissions Reduction

Solar photovoltaic system consumes small amount of energy and emits small amount of green house gases, but these gases are emitted during the manufacturing process of photovoltaic system [19]. Therefore energy generation process by photovoltaic system is environment friendly.
This paper investigates the GHG emission reduction in tones of carbon dioxide by all sites and compared with liters of crude oil not consumed, liters of gasoline not consumed and hectare of forest absorbing carbon.

6.3 Financial Viability

One of the major drawbacks of photovoltaic system is the high capital cost but policies like carbon-tax revenue can subsidize the cost of the PV system [20]. Financial analysis investigates whether or not the system in viable to install at that site financially, finance model requires some input parameters such as escalation rate, interest rate debt ratio, total PV system cost etc.

According state bank of Pakistan interest rate for the year 2016 is taken as 6% [21], debt ratio is taken as 77.6% and inflation rate is taken 3.3% as per state bank of Pakistan monitory policy [22].

Initial cost 5 kw photovoltaic system with suntech poly-Si - jkm270p is taken from Pantera energy Pvt Ltd internationally working company [23], as per Pantera energy Pvt Ltd Pakistan complete cost for 5kw system is 5714$ and 619 $ bidirectional meter and net metering fee so cost per watt is 1.14$. Electricity export rate is taken as 0.097 $ as per kwh as net metering policy of nepra for domestically electricity producers from Photovoltaic System [24].

7. Results

Results of this paper are divided in three sections; Technical, Emission and Financial analysis. Technical analysis suggests that how much power is delivered to the Grid in Kwhs, Emission analysis suggests the net annual Green House Gases emissions like tones of carbon dioxide by each site and financial analysis suggests the payback time and equity payback time for the system. Results of Retscreen are as under;

7.1 Technical analysis

According to technical analysis net electricity exported to grid annually in Kwhs highest is at the site of Quetta 9327Kwhs, while at Karachi are 8638bKwhs, Sukkur 8743 Kwhs. Bahawalpur site has the lowest generated Kwhs which are 8516 Kwhs. As per revenue generation Karachi generates 838$ annually, Quetta 905 $ Rs, Sukkur 848 $ and Bahawalpur 826 $ annually.

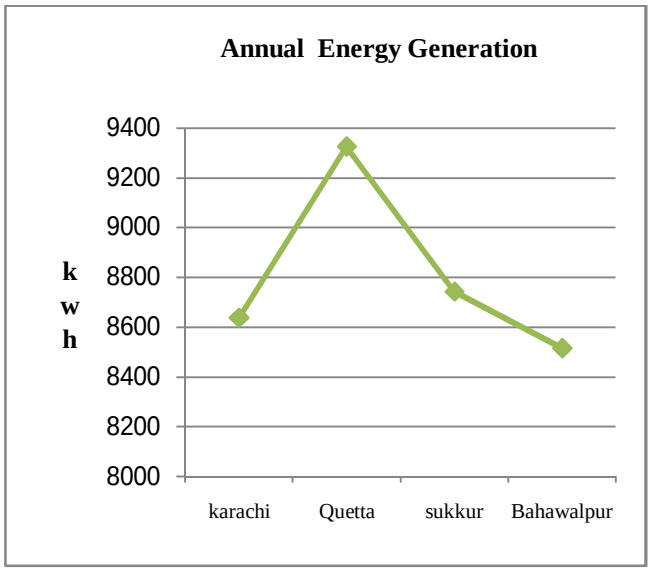

Fig . 8 Annually kwh generation

Here shown the monthly kWh generation for all sites as per monthly results the highest monthly kWh generation is highest for Quetta for the month of October having 900

kwh and lowest for karachi for the month of July having 5500 kwhs.

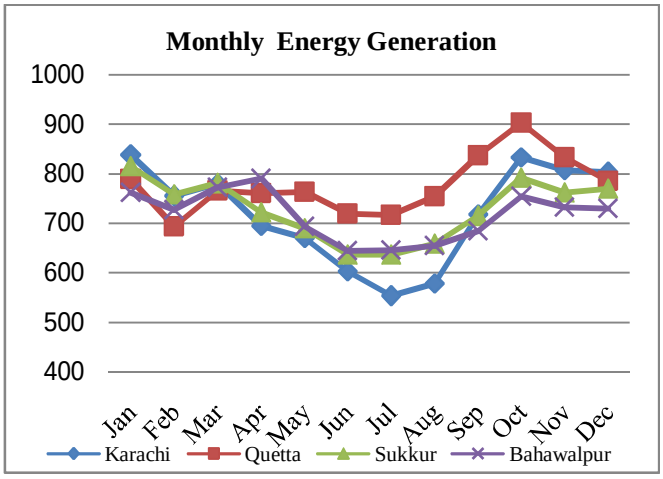

Fig. 9 monthly kWh generations

7.2 Emission Analysis

Emission analysis refers to tones of carbon dioxide reduction by using Photovoltaic system, according to Paris summit agreement countries will have to take actions to reduce carbon dioxide emission; Photovoltaic system can be the good choice in sorting this issue as well. According to Retscreen results Karachi's annual gross GHG reduction is 3.533 tones of CO2, Quetta annual gross GHG reduction is 3.816 tones of CO2, Bahawalpur's annual gross GHG reduction is 3.484 tones of CO2 and Sukkur has annual gross GHG reduction of 3.577 tones of CO2. Here shown in the table TCO2 emission equivalence.

Table: 3 TCO2 equivalents

Property	Karachi	Quetta	Sukkur	Bahawalpur
GHG Reduction T/CO2	3.533	3.816	3.577	3.484
Liters of gas not consumed	1518.3	1639.6	1536.9	1497
Hectares of fores absorbing carbon	0.325	0.351	0.329	0.320
Barrels of oil not consumed	8.21	8.87	8.31	8.10

Annually CO2 reduction by sites

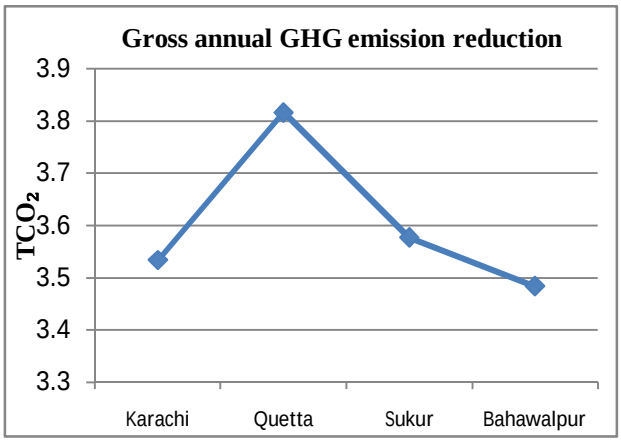

Fig. 10 Gross annual GHG emission reduction

7.3 Financial Analysis:

The financial analysis refers that either a site is financially viable or not, as per Retscreen results Karachi's simple payback time is 7.6 years, equity payback time is 3.6 years, for Quetta simple payback time is 7 years, equity payback time is 3.1 years, for Bahawalpur simple payback time is 7.7 years, equity payback time is 3.7 years, and for Sukkur simple payback time is 7.5 years, equity payback time is 3.5 years. Here shown the graph for simple payback time for the sites:

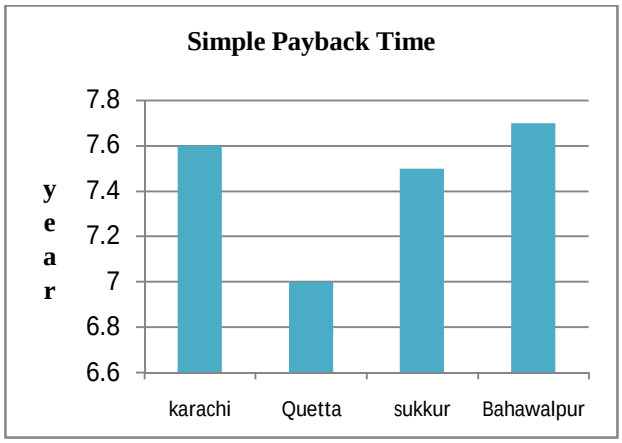

Fig. 11 simple payback times

8. Conclusion

This paper presents the performance analysis of 5kw photovoltaic system at various sites of Pakistan including Karachi, Quetta, Sukkur and Bahawalpur. The performance includes their energy generation, economic and financial analysis. The goal of this study is to compare results of these sites in all three aspects and suggest the most viable site for the photovoltaic system.

The 5kw PV system is taken as case study for all sites as per results net annual energy generation at Karachi, Quetta, Sukkur and Bahawalpur are 8638 kwh, 9327 kwh, 8743 kwh and 8516 kwh respectively. In terms of net GHG emission reduction annually at Karachi, Quetta, Sukkur and Bahawalpur are 3.5338 TCO2, 3.816 TCO2, 3.577 TCO2 and 3.4841 TCO2 respectively. As per financial analysis all sites have simple payback time less than 10 years. From results it is clear that Quetta site is most preferred and viable on other all sites in terms of energy generation, economics and financially whereas Bahawalpur site is least preferred site, sukkur is site is second best preferred site. Hence viability of PV system depends upon solar radiations, economic cost, government policies and tariff rate.

Future Recommendation:

On comparative analysis of all four sites, it is recommended to policy makers and stake holders that Quetta site most proposed site from above sites for the installation of Photovoltaic system technically, economically and environmentally.

References

[1] N. Caglayan, C. Ertekin, and F. Evrendilek, *"Spatial viability analysis of grid-connected photovoltaic power systems for Turkey,"* Int. J. Electr. Power Energy Syst., vol. 56, pp. 270–278, 2014.

[2] K. Harijan, M. A. Uqaili, and U. K. Mirza, *"Assessment of Solar PV Power Generation Potential in Pakistan,"* J. Clean Energy Technol., vol. 3, no. 1, pp. 54–56, 2015.

[3] M. Asif, *"Sustainable energy options for Pakistan," Renew.* Sustain. Energy Rev., vol. 13, no. 4, pp. 903–909, 2009.

[4] A. Mahmood, N. Javaid, A. Zafar, R. Ali Riaz, S. Ahmed, and S. Razzaq, *"Pakistan's overall energy potential assessment, comparison of LNG, TAPI and IPI gas projects,"* Renew. Sustain. Energy Rev., vol. 31, pp. 182–193, 2014.

[5] A. Mahmood, N. Javaid, A. Zafar, R. Ali Riaz, S. Ahmed, and S. Razzaq, *"Pakistan's overall energy potential assessment, comparison of LNG, TAPI and IPI gas projects,"* Renew. Sustain. Energy Rev., vol. 31, pp. 182–193, 2014.

[6] The Paris agreement summary from: http://www.climatefocus.com/sites/default/files/20151228%20COP%2021%20briefing%20FIN.pdf: accessed [2-07-2017].

[7] BP Statistical Review of World Energy. From <https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp statistical-review-of-world-energy-2017-full report.pdf> accessed [30-09-17]

[8] T. Muneer, S. Maubleu, and M. Asif, *"Prospects of solar water heating for textile industry in Pakistan," Renew. Sustain. Energy* Rev., vol. 10, no. 1, pp. 1–23, Feb. 2006.

[9] N. Cafo, *"ScienceDirect Economic feasibility analysis of small scale PV systems in different countries,"* vol. 131, pp. 81–95, 2016.

[10] B. Parida, S. Iniyan, and R. Goic, *"A review of solar photovoltaic technologies,"* Renew. Sustain. Energy Rev., vol. 15, no. 3, pp. 1625–1636, 2011.

[11] Natural Resources Canada–Canmet ENERGY, "The RETScreen Clean Energy Project Analysis Software ."

[12] S. H. I. Jaffery et al., *"The potential of solar powered transportation and the case for solar powered railway in Pakistan,"* Renew. Sustain. Energy Rev., vol. 39, no. November, pp. 270–276, 2014.

[13] W. Raza, H. Saula, S. U. Islam, M. Ayub, M. Saleem, and N. Raza, *"Renewable Energy Resources Current Status and Barriers in their Adaptation for Pakistan,"* vol. 3, no. 3, pp. 1–9, 2015.

[14] NREL, "Solar map of Pakistan," US National Renewable Energy Laboratory.

[15] K. Rouzbehi et al., *"Comparative efficiency Study of Single Phase Photovoltaic Grid Connected Inverters using PLECS ®,"* no. Ictck, pp. 11–12, 2015.

[16] T. M. Qureshi, K. Ullah, and M. J. Arentsen, "Factors *responsible* for solar PV adoption at household level: A case of Lahore, Pakistan," Renew. Sustain. Energy Rev., vol. 78, no. October, pp. 754–763, 2017.

[17] U. K. Mirza, M. Mercedes Maroto-Valer, and N. Ahmad, *"Status and outlook of solar energy use in Pakistan,"* Renew. Sustain. Energy Rev., vol. 7, no. 6, pp. 501–514, 2003.

[18] J. Khan and M. H. Arsalan, *"Solar power technologies for sustainable electricity generation - A review,"* Renew. Sustain. Energy Rev., vol. 55, pp. 414–425, 2016.

[19] A. B. Awan and Z. Ali, *"Recent progress in renewable energy – Remedy of energy crisis in Pakistan,"* Renew. Sustain. Energy Rev., vol. 33, pp. 236–253, 2014

[20] P. K. Wesseh and B. Lin, *"Modeling environmental policy with and without abatement substitution: A tradeoff between economics and environment?,"* Appl. Energy, vol. 167, no. November, pp. 34–43, 2016.

[21] Interest rate of Pakistan 2016. https://tribune.com.pk/story/1036946/sbp-keeps-interest-rate-unchanged-at-6/

[22] S. B. of Pakistan, "Monitory Policy Statement." 2016. www.sbp.org.pk/publications/inflation_monitor

[23] www.panteraenergy.pk

[24] Net metering empowering people to generate electricity,http://www.nepra.org.pk/netmetering%20awareness.htm

[9] Faraz Ahmed, Jamshed A. Ansari, Jahangir Soomro, Fayazuddin, Muhammad Waqas and Sohail Ahmed Soomro "A comparative analysis bases on energy efficiency of dual solar tracker system and fixed mount solar system Engineering Science and Technology International Research Journal-ESTIRJ Vol.1,No.4, Dec,2018 pp (38-43).

About Authors

Yasir Ali Bhutto received his B.E in electrical engineering in 2012 from QUEST Nawabshah, Pakistan. He is currently pursuing his masters in power system from MUET Jamshoro Pakistan. He is serving as Lab: Engineer at QUCEST Larkano Pakistan since 2014. His research interest includes power quality, energy system, energy management and planning.

Prof. Dr. Mukhtiar Ahmed Mahar received his B.E and M.E degree in Electrical Engineering department from Mehran University of Engineering and Technology Jamshoro and then Ph.D. degree in Electrical Engineering department from Mehran University of Engineering and Technology Jamshoro, he is presently working as Professor at MUET Jamshoro, his research area is Modeling and Simulation of Power Electronic Converters , Neural Network Control Power Electronic Converters , Flexible AC Transmission System (FACTS), Power Quality and Control of Electrical Machines.

Prof. Dr. Abdul Sattar Larik received his B.E and M.E degree in Electrical Engineering department from Mehran University of Engineering and Technology Jamshoro and then Ph.D. degree in Electrical Engineering department from Mehran University of Engineering and Technology Jamshoro, he is presently working as Professor at MUET Jamshoro, his research area is Power Semiconductor Devices, Sliding Mode Control, DC-DC Converter Topologies Control, Modeling and Simulation, Soft-switching Techniques, FACTS, Switch Mode Power Supplies (SMPS), Power Quality, converter control, modeling, and simulation.

Shafquat Hussain Bhellar received the B.E degree in Electrical Engineering department from Mehran University of Engineering and Technology Jamshoro and also M.E degree in Electrical Engineering department from Mehran University of Engineering and Technology Jamshoro and his research area is Power converter topologies, FPGA, FACTS devices.

Assadullah Khuwahar received his B.E in electrical engineering in 2008 from QUEST Nawabshah, Pakistan. He received his masters in power system from MUET Jamshoro, Pakistan in 2016. He was working as Lecturer at QUCEST Larkano, Pakistan since 2013 to 2016. Now he is serving as a Assistant professor at QUCEST Larkano, Pakistan since 2017. His research interest includes power quality, power control, and electrical machines.