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Technical & Economic Assessment of Electricity using Off-Grid Solar Photovoltaic Technology in Peshawar - KPK

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Abstract: *In comparison to electricity generated by national grid, Solar PV electricity remains a bit costlier. As a result, common man does not consider this option as their first preference. So, in result to this, just like many Developed World countries, Khyber Pakhtunkhwa government needs to subsidize electricity generated by PV, in order to promote this option amongst common people a little more. And with the aim of understanding and carrying out an evaluation and assessment of monetary traits of grid-connected rooftop photovoltaic energy system for a common man in locality of Peshawar, this paper is presented, so that to analyze as how much will it interest a common man and what strategy government can adopt in future for promoting Green Energy in Khyber Pakhtunkhwa. And also this analysis can prove out helpful in formation of tariff formula for promotion of solar photovoltaic energy for government of Khyber Pakhtunkhwa.*

Keywords: *Economic Aspect, Electricity, Solar photovoltaic, National grid, Grid-connected*

I. Introduction

Worldwide, power sector contributes in production of 18,000 terawatt-hours of electrical energy ever year; cumulating 40% of world's total energy consumption [1]. The rate of global commercial energy consumption is thousands of times smaller than the energy flows from the sun to the earth. Primary energy consumption is reliant on fossil fuels (oil, natural gas, and coal), which represent nearly 80 percent of the total fuel mix [2]. In doing so, approximately 10 Giga tonnes of carbon dioxide is produced that contributes to the largest sector contribution of humanity's fossil-fuel derived emissions

One way to cut down carbon emissions is to maximize the system's efficiency but certainly there exists a limit to up to which we can enhance system's efficiency considering a familiar paradox that greater energy efficiency means greater energy consumption. Thus, there is only one way via which we can de-carbonize our environment by using carbon free resources. This requires evaluating measures that implicate the usage of renewable energy resources to ensure a green and clean environment for all.

II. Solar Energy

Solar energy is not even vast but also highly untapped resource in a developing country like Pakistan. The World Energy Council estimates the earth's surface, on average, has the potential to capture around 5.4 GJ (1.5 MWh) of solar energy annually. While solar energy contributed to 0.1% of total energy consumption globally in 2007, it's use has been increased significantly after that [3]

By end of 2013 the cumulative installed capacity of solar PV system exceeded 141000 MW in IEA member countries alone [3]. At the end of 2000, this was approximately 1400MW. This has been clearly depicted in Fig. 1. As per the figure, installation of overall solar PV system has been increasing at a rate of 25% since 2000 globally.

The phenomenon of Solar PV technology is simple- converts sunlight directly into electricity using photovoltaic cells. PV systems can be on grid, off grid or hybrid, depending upon choice, flexibility and budget. Similarly, can be installed on rooftops, integrated into construction designs, or scaled up to megawatt scale power plants. PV systems can also be used in conjunction with concentrating glasses or lenses for large scale integrated power.

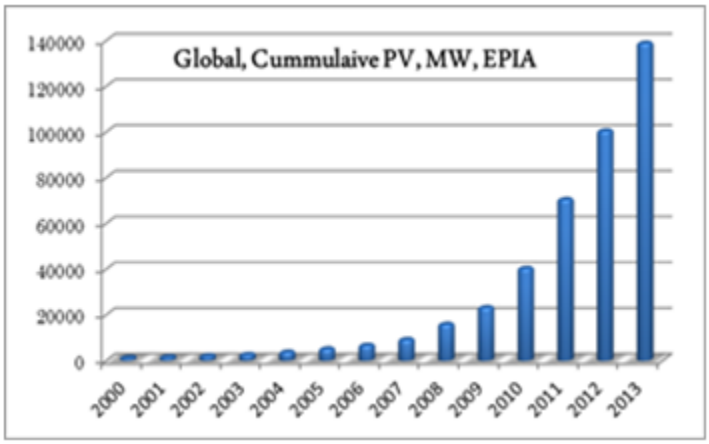


Fig.1 CumulativePVCapacityMW

The world's energy demand is quite huge as compared to the solar energy currently incident on Earth's Surface. Therefore, it is quite evident that solar energy has a huge potential when it comes to generating energy via non-renewable energy resources. The only limitation to such energy production is its huge capital cost.

The issues related to high installation cost have always been a point of key concern for both technologists and power generating industries. No doubt, the cost of Solar PV technology has remarkably reduced after the increasing manufacturing capacity, but still the cost of electricity production via PV is far exceeds the conventional methods of energy producing technologies.

The cost is relatively high in those countries where the price for conventional methods of electricity production is very low. Also, it is expected that the main factors influencing the implementation of solar energy would be government policies, the huge capital investment, the associated risks and future projected demand of electricity by consumers.

Solar energy, although expensive but it has the potential to play a crucial role in the world's energy supply, now and in the future. The last five years has been a period when PV energy changed from being a small-scale contributor to energy supply to being a more substantial one, and the next five years look like being a period when the technology could have an even more substantial impact.

Cost calculations clearly revealed that even in the sunniest place, it is very difficult for PV to compete against conventional methods without the intervention and application of government subsidies and low cost tariffs.

Solar radiation is not a very consistent and reliable source because of daily and seasonal variations. However, It does carry the ability to provide maximum efficiency during peak day time hours. Therefore, Photovoltaic systems are assumed to work well under off-grid technology applications, and in those areas where cost of electricity generation is higher [4]. Again, huge investment costs during installations and associated risks remain the primary limitation to this exogenous source of electricity production. At the same time, both Government regulation and policies and structured R&D will remain critical for the commercialization of Solar Power Technology.

III. Solar Exposure in Peshawar

The factors necessary to take into account while considering any site for solar power is the amount of solar radiation, the proximity to load centers, and the availability of suitable sites.

The amount of solar power available per unit area, also called irradiance or radiant flux density, varies with latitude, longitude, elevation and season of the year in addition to time in a particular day.

Sun Radiation data for Latitude and Longitude are valid for Peshawar only. Latitude & Longitude for Peshawar is 34.01^{o}N 71.58^{o} E respectively. This has been shown in Fig. 2.

Fig.2 Map of Peshawar

The extent of sun radiation varies between 699.09 WJ/m2 in April to 401.91 WJ/m2 in November with the annual average of 194567 WJ/m2. This has been shown in the Table 1.

Table 1 Tilted surface (kWh/m^2/month) of Peshawar

Tilt:13^0	Jan	Feb	Mar	Apr	May	Nov
kWh/m^2	3.31	5.72	6.89	6.99	3.92	4.01

IV. Solar PV Production Estimation

The radiation data were noted practically and gave results almost uniformly. On the basis of production estimation, following results were generated as in the graph below.

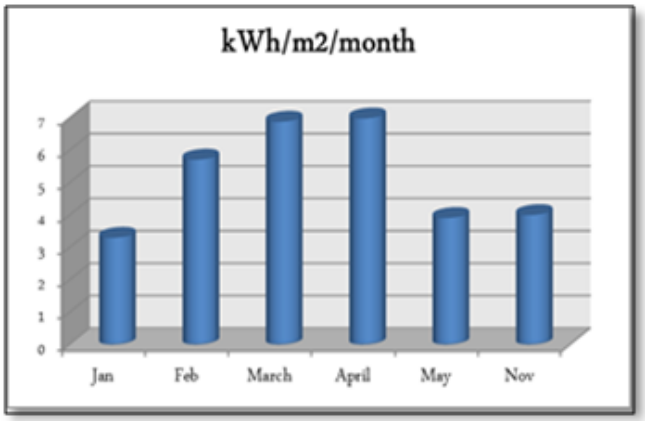


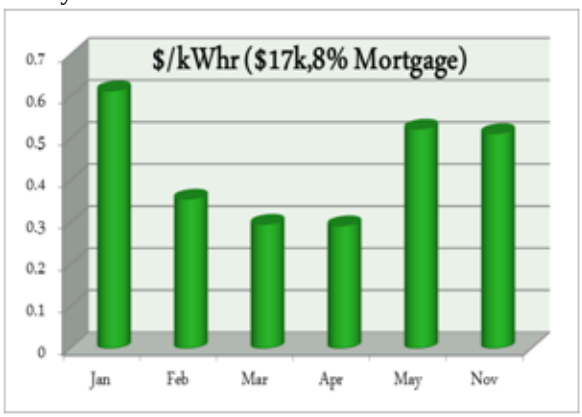
Fig. 3 Variations in Daily Solar Energy Availability

Table 2 Data used to estimate the electricity production cost of solar

Inflationrate	7.75%
Discountrate	9.5%
SizeinkW	10
Lifetime(Year)	20
Battery Voltage	12V
Solar Tracking Mode	Fixed
Mortgage	8%
O&M($/kWh)	0.04
O&M($/System/year)	339.6
O&M forlifetime	6184
Performanceratio	0.85

Using data from Table II, cost calculation for 10kW grid connected solar PV Technology is then undertaken assuming that capital cost is taken as a loan from bank with a Mortgage % of 8% at an average and $cost of Power/kW is calculated by taking three different capital costs assuming inflation as well. Since per Watt PV Panel Cost is $1.20 [5] which makes $12k as a capital cost for the designed solar panel, costs have been calculated at $17k, $14k and $11k due to fluctuating inflation & Discount rates.

$/kWhr is calculated at the respective capital costs of $17k, $14k & $11k, further time Value of Money has also been considered to calculate costs needed to payback within one year period of time.



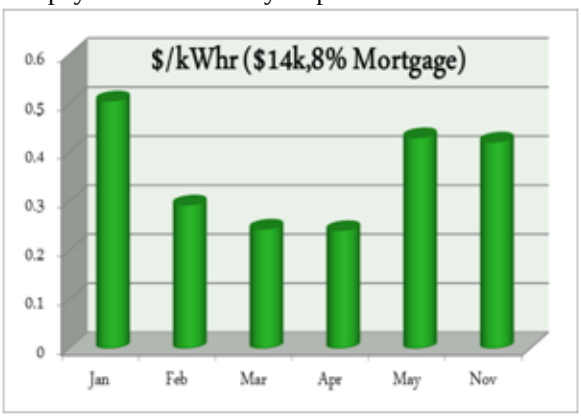


Fig. 4 PVElectricitycost,$17K,mortgage:8% Fig. 5 PV Electricity cost, $14K, mortgage: 8%

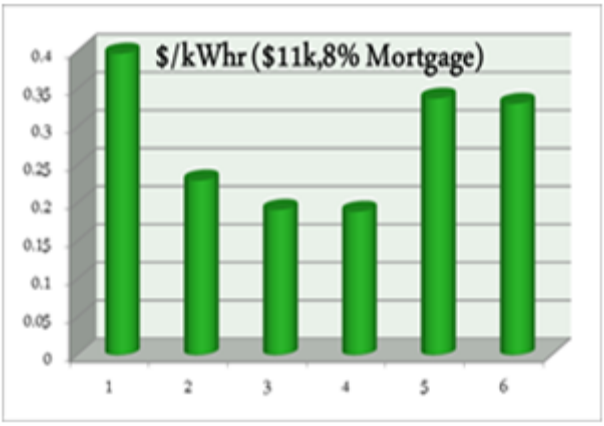


Fig. 6 PVElectricitycost,$11K,mortgage:8%

Economic performance of any project is also very important to evaluate to figure out whether the project is practically feasible and economically viable or not . For this very purpose, NPV (Net Present Value) and IRR (Internal Rate of Return) are calculated using the following formulas:

$$(1) \quad -CF_0 + \sum_{i=1}^{t}\left[\frac{CF_i}{(1+r)^i}\right] = NPV = 0$$

$$(2) \quad -CF_0 + \sum_{i=1}^{t}\left[\frac{CF_i}{(1+r)^i}\right] = NPV$$

Where i= 0, 1, 2…..t

NPV is a suitable criteria to calculate time value of coming cash flows at a particular discount rate while IRR is a form of rate of return that makes NPV of the project to Zero.

Fig. 7 $payment/Month @ 17k loan

Fig. 8 $payment/Month @ 14k loan

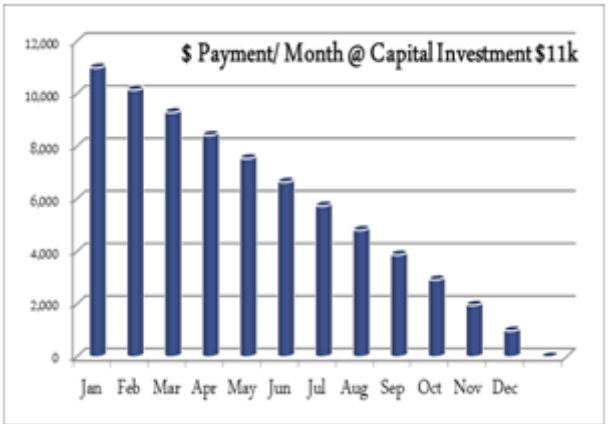


Fig. 9 $payment/Month @ 11k loan

Last but not the least, payback period of any investment project is also very important consideration while taking an investor's perspective [6]. Two Paybacks are taken into consideration;

A. Investment Payback Period: It can be simply calculated using:

(3) Payback period= Cost of Project/Annual Cash Flows

B. Energy Payback Time (EPBT): the period required for a renewable energy system to generate the same amount of energy (total primary energy equivalent) that was used to produce the system itself [7].

$$(4) \qquad EPBT = (E_{mat} + E_{manuf} + E_{trans} + E_{inst} + EEOL) / (E_{agen}/nG - Ea_{oper})$$

Where:

E_{mat} = Primary energy demand to produce constituent materials for the PV system
E_{manuf} = Primary energy demand to manufacture PV system
E_{trans} = Primary energy demand to transport materials used during the life cycle
E_{inst} = Primary energy demand to install the system
EEOL = Primary energy demand for end-of-life management
E_{agen} = Annual electricity generation
nG = Grid efficiency, the average primary energy-to-electricity conversion efficiency at the demand side
Ea_{oper} = Annual energy demand for operation and maintenance in primary energy terms.

V. Emission Analysis

GHG emissions being the main cause of global warming leads to the death of thousands of people worldwide by causing serious health problems. The key reason to GHG emission is the incomplete combustion of Caron Dioxide.

It is also estimated that installation of standalone PV off grid system in Peshawar will lead to the reduction of $3.8tCO_2$[5]. Also, region with higher solar irradiance value would result in larger emissions reduction value [5]

VI. Challenges & Limitations

To achieve sustainable development in a country like Pakistan which is in the phase of getting developed, one needs to keep into account many factors. Both planning and implementation will be followed by equal hurdles and challenges some of which are listed below [8]:

A. Public Awareness: This is the first and foremost challenge that will be faced while implementing any sustainable change. Therefore, public and media should be taken into confidence while taking any such initiative. Proper guidance and necessary awareness should be provided so that they take this change as a positive one. For this purpose, specialized agencies and training organizations are of great help

B. Research & Development: Those countries that stand today successfully invest continually in research and development for their progress. For that, we need skilled manpower, proper technological infrastructure and

committed governmental regulations because the basic infrastructure that exists today is either not available anymore or in a very poor condition.

C. Proper Monitoring & Evaluation: In order to successfully develop a program, it is of utmost importance to continually monitor and evaluate the process for any modification or up gradation.

VII. Conclusion

A critical analysis over solar PV technology, after having analyzed the current energy situation of Pakistan, the emergence of renewable energy resources all around the world, it is very likely to say that Pakistan needs to undertake huge capital investment for not only its demanding future needs but also due to reduction of non-renewable energy resources from the globe.

An intensive cost calculation, technical analysis and GHG emission analysis reveals that even though the capital investment will be large but the future benefits of such installation would be unlimited and it would ensure a cleaner and greener environment. At the very same time, public awareness, research and development and proper monitoring and evaluation is deemed necessary to implement a large scale commercialized solar off grid power plant.

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