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ESTIMATION OF THE ROOFTOP SOLAR PHOTOVOLTAIC POTENTIAL FOR ENGINEERING UNIVERSITY IN PAKISTAN

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ABSTRACT
Solar powered photovoltaic innovation has developed to turn into a feasible huge scale wellspring of supportable vitality. For utility arrangement, obliging framework limit, sending financing plans and detailing future versatile vitality arrangements, it is essential to understand the rooftop PV potential. This paper exhibits geographic data frameworks to decide the accessible housetop territory for PV deployment in Civil department of Mehran University of Engineering and Technology (MUET), Jamshoro, Pakistan. A four-step procedure has been developed for estimating total rooftop PV potential which involves high resolution satellite imagery; using GIS to calculate the existing rooftop territory of Civil department; extrapolation using roof area-population relationships; difference between rooftop area from GIS and physically measured sample; rooftop area reduction for shading, other uses and positioning; and change to power and energy outputs. It was found that MUET, Jamshoro hold the promising rooftop potential to fulfill its own needs. But we just extracted the rooftop area of the Civil department. The four types of higher efficiency solar PV panels has been used such as Mono-crystalline, Poly-crystalline, Amorphous and Cadmium-telluride solar PV panel can produce 70MWh, 56MWh, 37MWh, 53MWh respectively.

Keywords: Solar resources, Rooftop Solar Photovoltaic (PV), Potential estimation, Pakistan

1. INTRODUCTION

One of today's most important issue is the global climate damage as a result of the anthropogenic emission of greenhouse gasses (GHG_S). it is brought about by human exercises, and it introduces a genuine risk to nature and individuals (Solomon et al. 2007). Islamic republic of Pakistan is considered as an energy deficient country and it was affected by dreadful energy disaster with supply-demand gap of over 6,000 MW for over a decade. Pakistan is a developing country with a population of approximately more than 21 million. Pakistan was suffered from energy confine because of faulty planning and policy. Power shortages have affected all the sectors of economy adversely resulting in fragile economy, costing in recent years up to 4% of its GDP (Jamil and Ahmad 2010). Pakistan is considered as a country with least developed in terms of usage of renewable energy as majority of energy is generated using Hydroelectric Power, despite having all the factors. Pakistan has been blessed with many natural resources out of which, solar energy can be concluded as fundamental blessing. Studies suggest that Pakistan has technically highest values of insolation around the globe ranging 7 to 9 hours of sunshine throughout the day. Thus, this is ideal condition for generation of energy from solar power. Solar Power Systems are available throughout the country but at a slower pace due to ecological illiteracy among officials and people. Country possesses solar power plants in Kashmir, Khyber Pakhtunkhwa, and Sindh as well. Moreover, some considerable steps have been taken by mutual co-operation of International Renewable Energy Agency and Japanese Co-operation Agency. Recently, Quaid-e-Azam Solar Park has been inaugurated which is estimated to generate around 1 GWh by the end of 2017. These figures are enough to run around 3,00,000 houses at domestic level (Ebrahim 2015). PV cells are a demonstrated ecologically generous power source whose alluring attributes will keep on promoting photovoltaic research. Since current PV frameworks are still profoundly wasteful and extraordinary, they are not yet cost aggressive with petroleum product- based generators and are just normally utilized where there is no close by power source. PV developments in the arenas of thin film and nanocrystalline materials will continue to curl and rapidly increase PV efficiency to over 50%. As proficiency builds, PV innovation will draw in a more prominent number of individuals, bringing about decreased expense (Malik et al. 2013)

Solar PV system is that which convert solar energy in electricity by using photovoltaic effect. This installation is found in abundant in PV effect. They are termed as semiconductor devices which may be having enormous constituents of memory chips of computer (Wikipedia 2019). Every aspect no matter it is a home, industry or may be a commercial sector; it can setup self-generation by installation of PV Panels on Rooftop (Wikipedia 2019). Whereas, it is estimated that only 26% of area of roof is sufficient for the commissioning of PV deployments (IRENA 2012). Geographical Information System (GIS) has now become the built-in tool and technique. Many researchers have easily used it for analysis of renewable energy, as it appears in a literature review such as Singh and Banerjee (Singh and Banerjee 2015), Jamal (Jamal et al. 2014), Sun (Sun et al. 2013), Liu (Liu et al. 2011), Wiginton (Wiginton et al. 2010) and Izquierdo (Izquierdo, Rodrigues, and Fueyo 2008). The usage of Geographic information system tools for the assessment of photovoltaic potential in the rooftop is also related to the cost constraints like the availability of commercial software tools and the availability of high-resolution satellite images that are not publicly available in general (GIS 2019).

The Government of Islamic republic of Pakistan, a renewable energy policy has already been launched in 2006 by Alternate Energy Development Board (AEDB). Their performance was very slow and none of progress was made for several years. Fig 1 shows averaged direct normal irradiation of the months (DNI) at Jamshoro. As per the NASA's surface meteorology and sun powered vitality database, Jamshoro has a yearly normal direct ordinary radiation (DNI) of 6KWh/m2/day.

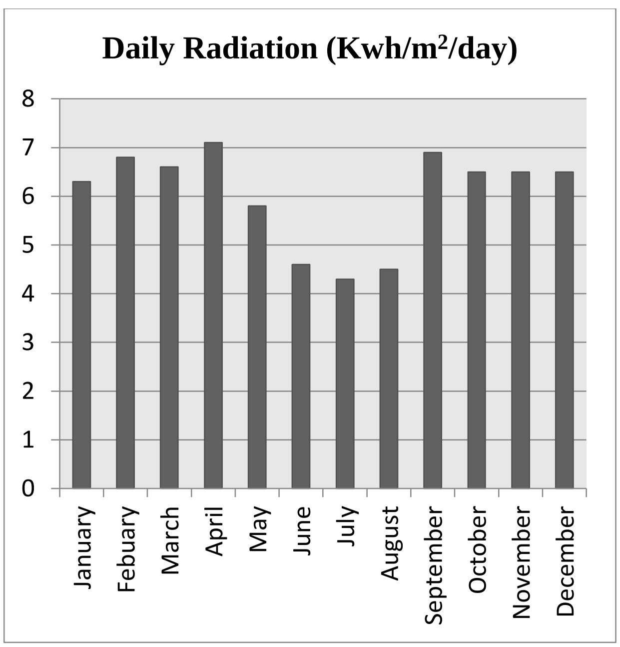

Fig 1: 12-Year monthly averaged DNI at JAMSHORO (NASA 2019)

Through this exploration work an innovation has been taken to conquer difficulties of power hole in MUET Jamshoro.

2. METHODOLOGY

The rooftop solar PV (photovoltaic) electricity system has large social and financial advantages barring some obvious environmentally friendly benefits such as electrical energy generation and water heating, it also has some extra income like enhancing water and air quality, lowering the city heat-island effect and making full use of urban space. The promotion of the new strength has turn out to be a harmony in many nation and cities, some cities started to enforce this inexpert energy program or even ratify some laws and guidelines to install solar PV (photovoltaic) structures on buildings. However, the biggest problem at present is the lack of information and strategies that can compute these advantages regarding available rooftop area, which in some medium and small cities even does not exist.

The objective of this research work study is to compute the available roof area of the civil department of MUET Jamshoro and estimate rooftop solar PV potential using GIS techniques. A four-step procedure was adopted to determine the rooftop solar photovoltaic potential of civil engineering department of Mehran University of Engineering and Technology (MUET) Jamshoro. This procedure shows the techniques and standards in a gradual manner that can provide information in the calculation of existing rooftop area for solar photovoltaic deployment in other creativities. However, the existence of background data and absence of assets is a significant problem in Pakistan. Therefore, the procedure was adopted with this study which employs GOOGLE EARTH^{TM} satellite images which are publicly available to calculate the solar photovoltaic potential on the roof of the relevant region (MUET Jamshoro). An almost identical type of proposal for rooftop solar PV (photovoltaic) analysis was acquired as confirmed through J. Khan (Khan and Arsalan 2016) and Wiginton (Wiginton et al. 2010) The process of estimation of rooftop potential as follows.

2.1 Sampling

It is essential to perform sampling to obtain the rooftop area of the ROI. It is apposite to mention here that the ARCGIS software has been used for finding out the rooftop area in this research work. ARCGIS has now developed as an recognised software tool and technique and it has been commonly utilized for study. Sampling process has been done in next section.

2.2 Rooftop Area from GIS using Polygon Tool

To obtain the available rooftop area, the rooftop of the ROI has been hand-digitized utilizing high resolution satellite images in geographic information system (GIS) software as done previously by researchers like J. Khan (Khan and Arsalan 2016) and Wiginton (Wiginton et al. 2010)

2.3 Field Validation and Error Estimation

After finding out the rooftop area, it was essential to perform field validation to check the accuracy. There are two purposes for the field validation survey: first to check the precision of the removed rooftop areas as compared to the physically calculated actual rooftops. Next, examine the shading factors, orientation of each building within the ROI and other uses on rooftops such as water tanks and outers of air-conditioner. Therefore, to check the accuracy of the rooftop area, field validation survey of the ROI (Civil department MUET Jamshoro) was made. Then these physical measurements taken by the hand were compared to the removed roof areas bore from ARCGIS environment software. The extracted rooftop area 0f rooftop (Civil department) was found as 2660 m^2. The actual roof area of the sample building was found as 2850m^2 during field validation work. Two overhead water tanks, outdoor air conditioners and some different roof usages were originated on the model roof. The overhead water tanks were of 28m^2, outdoor air conditioner was of 5.2m^2 and different roof uses on the sample structure were of 17.8m^2. The area held in reserve on the roof of the sample was 50m^2. Therefore, it was determined that the area available on the rooftop of sample building was 2800 m^2. J. Khan (Khan and Arsalan 2016) used the same kind of approach for the assessment of potential space for roof in Phase 7 Karachi.

2.4 Reduction

After total unpolished roof area of the region was obtained, it was essential to decrease total area to that which was accessible for rooftop solar PV installation considering shadow effect, water reservoirs, space entrances and different roof uses to calculate the total power potential and energy output. Building orientation is also very important factor what's more, should likewise be represented decrease to get the actual accessible rooftop area for PV applications. The essential focal point of this exploration work is to gauge the all-out housetop zone of the ROI; decrease elements was outside the extent of this undertaking and subsequently related writing was used to acquire precise territories accessible for PV establishment. During field validation process, it was discovered that area covers small and large flat building (R_f=1) which do not endure for reduction in area. Flat buildings are unaltered by structure orientations (B_f=1) because they do not have peaked rooftops. Thus, fraction of roof area (f_{ROF}) could be calculated by using same technique which is used previously by (Khan and Arsalan 2016) and (Wiginton et al. 2010)

$$f_{ROF} = R_f * B_f \quad (1)$$

$$f_{ROF} = 1 * 1 = 1 \quad (2)$$

Therefore, the fraction of oriented roof area has been calculated as shown in equation 2. Then shadow effects, different rooftop utilization, PV installations and servicing should be considered for the reduction in the rooftop area. The non-shadowy vicinity & structure orientations together form the fraction of actual existing rooftop area that can be used for photovoltaic installations. Table 2 shows the Fraction of available rooftop areas used by different researchers in their research initiatives such as (Izquierdo, Rodrigues, and Fueyo 2008; Khan and Arsalan 2016; Wiginton et al. 2010) and Peter (Lehmann, Peter, and innovations : Aachen 2003) utilized the value 0.35, 0.34, 0.30 & 0.90 respectively. Field validation investigation of ROI exposed that 25-30% of the total rooftop area is booked for overhead water tanks and different rooftop uses. The division for concealing and other rooftop uses in the wake of considering the concealing impact from close by trees and structures is taken as:

$$R_S = 0.36 \quad (3)$$

Table 1. Fraction of available rooftop area used by other researchers

References	Location	Fraction of available rooftop area
(Khan and Arsalan 2016)	Pakistan	0.35
(Wiginton et al. 2010)	Canada	0.3
(Izquierdo, Rodrigues, and Fueyo 2008)	Spain	0.34
(Lehmann, Peter, and innovations : Aachen 2003)	Germany	0.9
(Scartezzini and Courret 2002)	Switzerland	0.95

Therefore, the existing rooftop area for photovoltaic installation (A_{pv}) is gross rooftop area $A_{rooftop\ (gross)}$ reduced by the product of f_{ROF} and R_S:

$$A_{PV} = A_{rooftop(gross)} * f_{ROF} * R_S$$

$$A_{PV} = A_{rooftop(gross)} * 0.36 \quad (4)$$

This area characterizes the total rooftop existing area for PV installation in the ROI.

2.5 Calculation of Solar Rooftop PV Potential

Rooftop photovoltaic Power Potential

The rooftop solar PV power potential may be computed as:

$$P = I_g * eff * A_{PV} \quad (5)$$

Where I_g is the solar global insolation measured under global AM 1.5 spectrums of $1000W/m^2$ and eff is the efficiency of the solar PV panel and A_{PV} is the total rooftop area available for PV installation.

Annual Energy Output

Annual energy production depends on the daily global average (Imdh) in a horizontal connection, the efficiency of the photovoltaic solar panel and the total area of the roof available for the propagation of photovoltaic energy. (Imdh) 5.35kWh / m^2 / day for Jamshoro (according to NASA database). Therefore, annual energy production can be calculated as follows:

$$E = I_{mdh} * 365 * eff * A_{PV} \quad (6)$$

The four PV panels have different efficiencies and characteristics (summarizes in Table 2) and are used to demonstrate many installation scenarios of solar power generation of ROI.

Table 2. Synopsis and assessment of four different types of PV technologies

PV technology	Module efficiency	Panel output (W/m^2)
Mono-crystalline si (c-si)	22.90%	229
Poly-crystalline si (p-si)	18.50%	185
Amorphous si (a-si)	12.20%	122
Cadmium-Telluride Cells (CdTe)	17.50%	175

3. RESULTS AND DISCUSSION

After sampling of RER, the rooftop area has been obtained ARCGIS software using polygon tool as 2850 m^2. This area has been compared with other research initiatives and it was found that it is the reasonable result. The physically measured area has been obtained as 2660m^2. Before obtaining the rooftop PV potential and energy output of the ROI, this area has been abridged to discover the accessible rooftop for PV deployment. The accessible rooftop area of the PV deployment has been estimated as 957.6 m^2 by using equation 4. This area is the actual rooftop area of the ROI without shades and different uses of roof and is concerned usually in south. Rooftop area obtained from ARCGIS = 2850 m^2 Rooftop area obtained from physically measurement = 2660 m^2. Percentage of accuracy = 93.4%

After obtaining the actual rooftop area for PV deployment, this area has been used in equation 5 and 6, in order to estimate the PV potential and energy output of the RER considering four different types of panels i.e. Mono-crystalline, Poly-crystalline, Amorphous and Cadmium Telluride. According to thumb rule, the 10m^2 area is required for the 1kw capacity solar system. But by considering shadow effects, building orientations and different roof uses, the area and power potential has been reduced. However, according to thumb rule, the results have accuracy of 98%. This study revealed that Mono-crystalline is the best PV panel because it has the potential to produce more PV power and energy output from others as shown in table [4.1]. But its capital cost is high. Due to high efficiency, high panel output and ability to work at 25^0C, Mono-crystalline PV panel has been used for energy modeling and solar sizing as well.

4. CONCLUSION

This paper has verified the usage of Google Earth™ satellite imagery and geographic information system (GIS) tool to upsurge understanding of building assembly and dissemination in a ROI (Civil department) MUET Jamshoro for determination of calculating potential for rooftop solar photovoltaic (PV) distribution. The objective of this research work was; To decide the genuine accessible housetop zone for PV body and evaluated the PV potential and vitality yield of the ROI. A four-step procedure has been developed for estimating total rooftop PV potential which involves high resolution satellite imagery; using GIS to calculate the available roof area of the Civil department; extrapolation using roof area-population relationships; difference between rooftop area from GIS and physically measured sample; rooftop area reduction for shading, other uses and orientation; and conversion to power and energy outputs. It was found that the Mono-crystalline solar PV panel has the potential to produce more PV power than other solar PV panels. Therefore, the Mono-crystalline is the best suitable solar PV panel.

REFERENCES

Ebrahim, Zofeen T %J Dawn news. 2015. 'World's largest solar park to light up Pakistan's future'.

GIS. 2019. 'GIS Software - Geographic Information Systems - GIS Mapping Software', *https://www.caliper.com/maptitude/gis_software/default.htm.*

IRENA. 2012. 'Photovoltaic (PV) systems'.

Izquierdo, Salvador, Marcos Rodrigues, and Norberto %J Solar Energy Fueyo. 2008. 'A method for estimating the geographical distribution of the available roof surface area for large-scale photovoltaic energy-potential evaluations', 82: 929-39.

Jamal, Taskin, Weerakorn Ongsakul, Jay Govind Singh, Sayedus Salehin, and SM Ferdous. 2014. "Potential rooftop distribution mapping using Geographic Information Systems (GIS) for Solar PV Installation: A case study for Dhaka, Bangladesh." In *2014 3rd International Conference on the Developments in Renewable Energy Technology (ICDRET)*, 1-6. IEEE.

Jamil, Faisal, and Eatzaz %J Energy policy Ahmad. 2010. 'The relationship between electricity consumption, electricity prices and GDP in Pakistan', 38: 6016-25.

Khan, Jibran, and Mudassar Hassan %J Renewable energy Arsalan. 2016. 'Estimation of rooftop solar photovoltaic potential using geo-spatial techniques: A perspective from planned neighborhood of Karachi–Pakistan', 90: 188-203.

Lehmann, Harry, Stefan %J Institute for sustainable solutions Peter, and Germany innovations : Aachen. 2003. 'Assessment of roof & façade potentials for solar use in Europe'.

Liu, Guangxu, Wenxiang Wu, Quansheng Ge, Erfu Dai, Zhiwei Wan, Yang %J Environmental Engineering Zhou, and Management Journal. 2011. 'A GIS method for assessing roof-mounted solar energy potential: a case study in Jiangsu, China', 10: 843-48.

Malik, Naresh Kumar, Jasvir Singh, Rajiv Kumar, and Neelam Rathi. 2013. 'A Review on Solar PV Cell', *International Journal of Innovative Technology Exploring Engineering*, 3: 116-19.

NASA. 2019. 'Surface Meteorology and Solar Energy Database', *https://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?skip@larc.nasa.gov+s01#s01*.

Scartezzini, Jean-Louis, and Gilles %J Solar energy Courret. 2002. 'Anidolic daylighting systems', 73: 123-35.

Singh, Rhythm, and Rangan %J Solar Energy Banerjee. 2015. 'Estimation of rooftop solar photovoltaic potential of a city', 115: 589-602.

Solomon, Susan, Martin Manning, Melinda Marquis, and Dahe Qin. 2007. *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Cambridge university press).

Sun, Yan-wei, Angela Hof, Run Wang, Jian Liu, Yan-jie Lin, and De-wei %J Energy Policy Yang. 2013. 'GIS-based approach for potential analysis of solar PV generation at the regional scale: A case study of Fujian Province', 58: 248-59.

Wiginton, LK, Ha T Nguyen, Joshua M %J Computers Pearce, Environment, and Urban Systems. 2010. 'Quantifying rooftop solar photovoltaic potential for regional renewable energy policy', 34: 345-57.

Wikipedia. 2019. 'Photovoltaic systems', *https://en.wikipedia.org/wiki/Photovoltaic_system*.