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An estimation of solar energy potential using point solar radiation tool in ARC-GIS: A case study of College of Engineering, Pune

Sardar A Patil, Sonal Khobrgade, Shweta Khandelwal, Harpreet Singh, Asfa Siddiqui

Abstract
In the day of energy crisis, fossil fuels becoming scare day by day due to limited reserves. Hence, the time has to come to depend on renewable energy, which is called as "Clean Energy", "Green Energy" as well as "Alternative Energy". Solar energy is one of the most important renewable energy available since the historical time. Now in this era of 21st century everyone is trying to establish solar PV plants. Most of the times educational institutes setup the renewable energy plants without taking into consideration of its viability.

The main aim of the present research work is to estimate solar energy potential employing point solar radiation tool in Arc- GIS, in CoEP Campus. The investigations are based on the primary data that are analyzed using point solar radiation tool in Arc- GIS. Google sketch-up along with excel and Open Data Tool for PV potential is also used.

The study reveals that the institution has slightly variation in spatio-temporal pattern of global solar radiation. It is estimated that 2282.4 KWp electricity can be generated by installation of PV plants in the CoEP campus.

Keywords: Arc-GIS, Renewable Energy, Green Energy, Clean Energy, Alternative Energy, Google Sketch-up, PV Plants, Open Data Tool

1. Introduction

Energy is elementary to the quality of our lives. Now-a-days we are totally dependent on an abundant and uninterrupted supply of energy for living and working. It is a key ingredient in all sectors of modern economics *(European Commission-Research Energy).* In the economic development of any country energy plays a significant role. Energy is defined as the ability or the capacity to do work (TERI, 2014) [23]. As stated by the Newton, energy is neither created nor destroyed; it is transformed from one form to another form (Singh, Savindra, 2001) [21]. After Industrial Revolution the demand for energy is increased all over the world. People are exploiting conventional resources to meet their needs of energy for the development in some extent, some are in the process but the present developmental process is not sustainable due to limited stock of the conventional resources.

In the day of energy crisis, fossil fuels becoming scare day by day due to limited reserves. Hence, the time has to come to depend on renewable energy, which is called as "Clean Energy", "Green Energy" as well as "Alternative Energy". Before the invention of fire, the Sun was only source of energy on the earth surface (Ghosh, G.K., 1991, p. vi) [7]. Solar energy is the most readily available source of energy which is free as well as pollution frees *(TERI).*

India is one of the few countries with long days and plenty of sunshine, intensity of solar energy increases from north to south. India in general and Maharashtra in particular is facing the problem of scarcity of electricity that ultimately affects the development process. By taking into consideration the demand of electricity and its scarcity, Ministry of New and Renewable Energy, Government of India is providing financial assistance to the educational institutions to setup renewable energy plants in the institutions *(www.mnre.gov.in).* Most of the times educational institutes setup the renewable energy plants without taking into consideration of its viability. Because of this such projects are not sustaining for more time.

Hence, here an attempt is made to estimate solar energy potential in the College of Engineering, Pune (CoEP) campus by using Geo-Spatial Technology (GST), as a case study.

The Study Region

For the present research work the College of Engineering Pune (CoEP) is selected as a case study. The College of Engineering, Pune (CoEP) is one of the leading educational institutes in the Maharashtra, which is located in Pune. It has annual consumption of electricity around 84 MVA in the year 2014. The latitudinal extent of the college is 18O 31' 42.472" north to 18O 31' 54.496" north and longitudinal extent of the college is 73O 51' 13.757" east to 73O 51' 31.891" east (Fig.1).

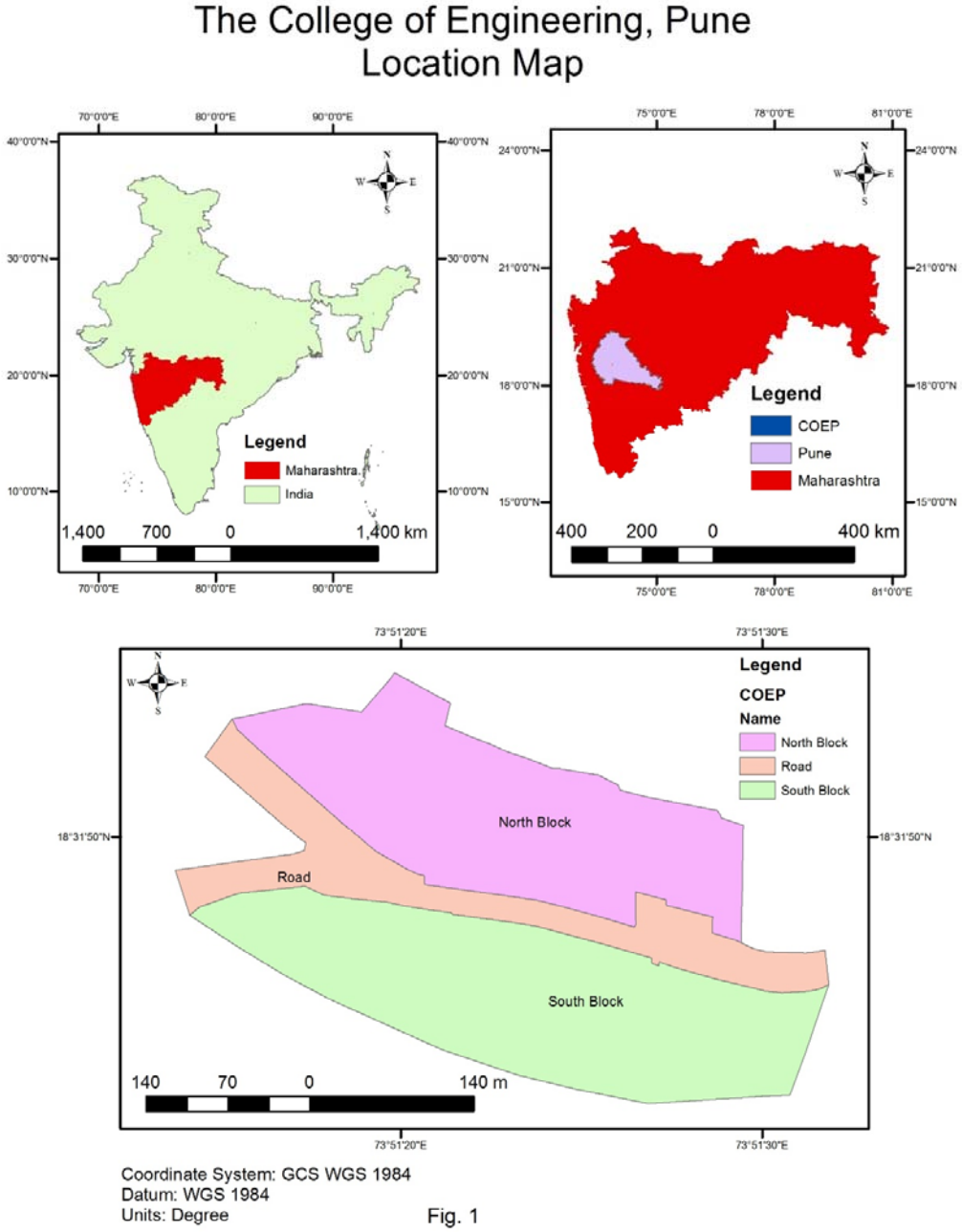


Fig. 1

Aim and Objectives

The focal point of the present research work is to estimate solar energy potential in an institutional campus of CoEP, Pune as a case study. The main aim of the present research work is to estimate solar energy potential employing point solar radiation tool in Arc- GIS, in CoEP Campus. However, the specific objectives of the present research work are as given below:

1. To calculate rooftop area available in in CoEP.
2. To analyze the spatio-temporal variation in global solar radiation in CoEP.
3. To calculate spatio-temporal variation in the solar PV energy output in CoEP.

Research Methodology: Methods of Data Collection

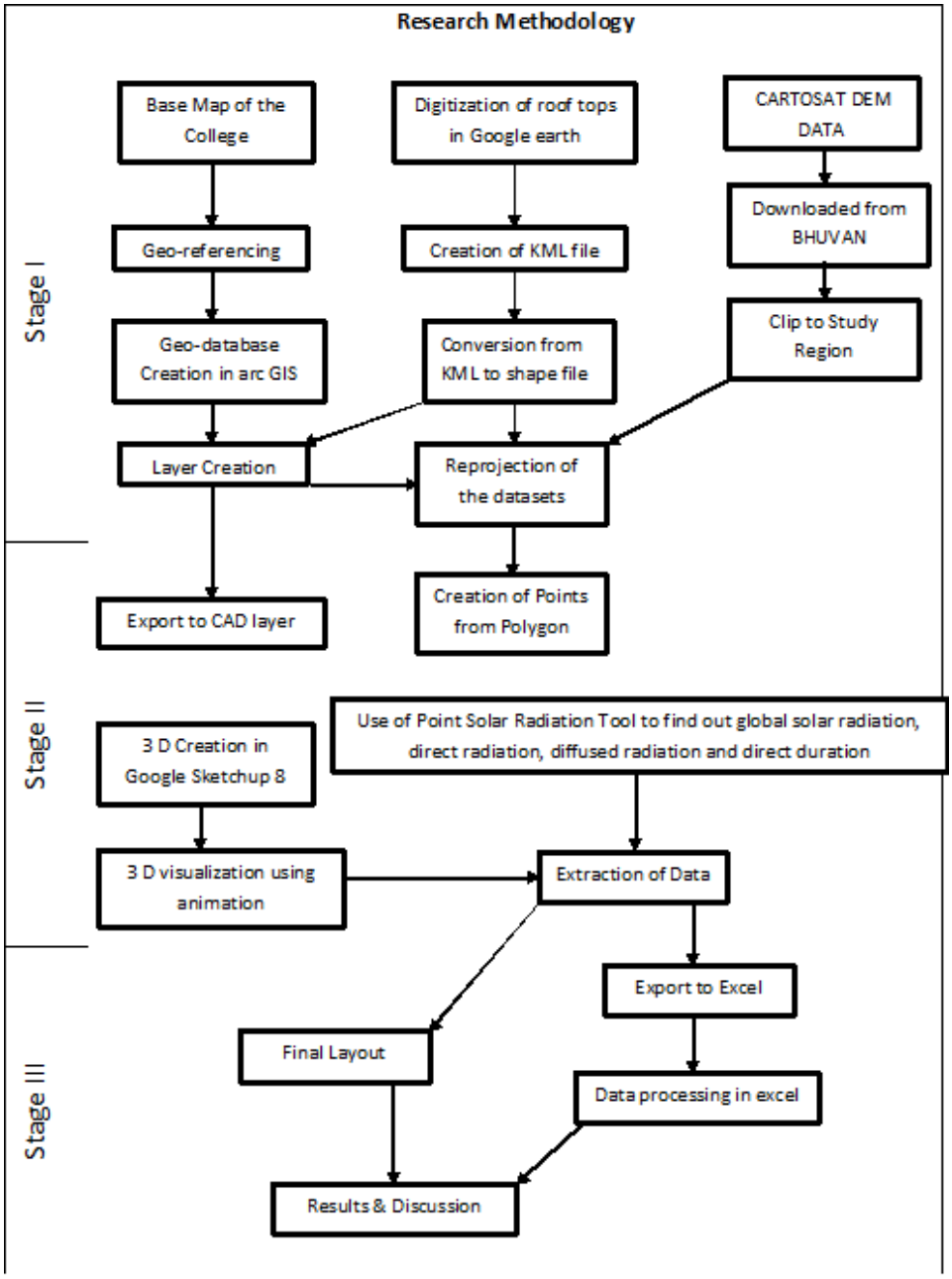
The present research work is based on primary as well as secondary data. The primary data includes remote sensing data. CARTOSAT DEM of 1 arc second resolution is

downloaded from Bhuvan website. The Google earth image is used as a supportive image to meet the objectives of the study. The base map of the study region is collected from the institution.

The secondary data related to energy consumption is taken from the institutional records. Other secondary data is collected from the books, journals, websites that are mentioned under references.

Methods of Data Analysis

The Arc-GIS 10.1 is the main software, which is used for the analysis of the data. The roof top area is selected as a spatial unit of investigation whereas the month is selected as a temporal unit of investigation. The accompanying flowchart provides in- depth information regarding research methodology used to carry out the present research work.



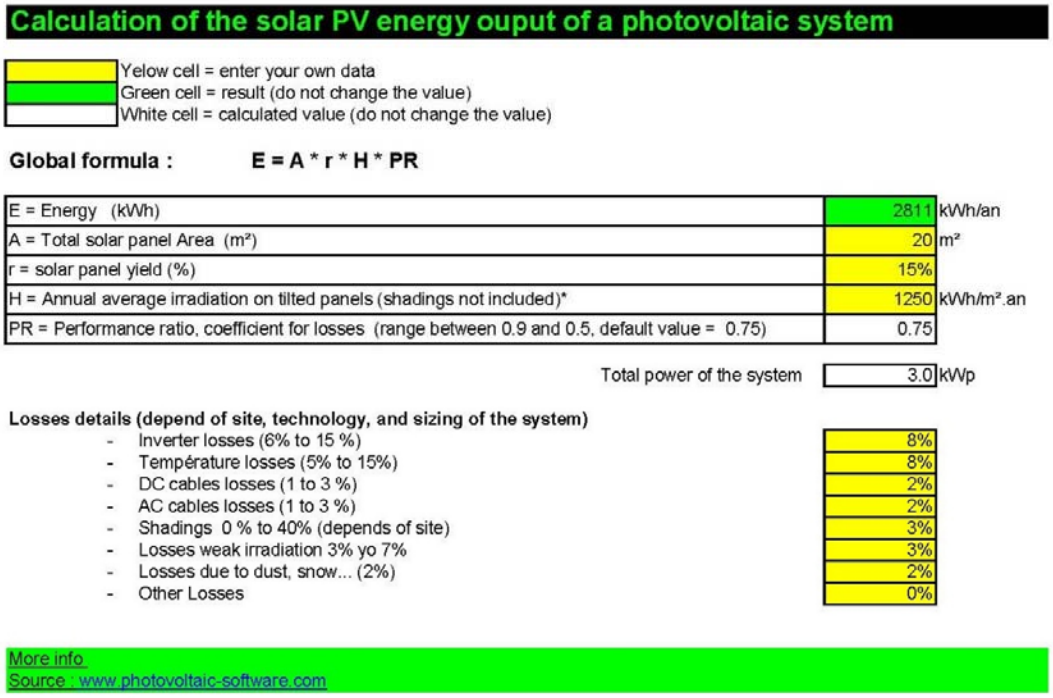
For the calculation of solar PV energy output of a photovoltaic system, the following formula is used.

E = A*r*H*PR Where,

E = Energy (kWh)

A = Total Solar Panel Area (m2) r = Solar panel yield (%)

H = Annual average irradiation on tilted panels (Shading not included)



Calculation of the solar PV energy ouput of a photovoltaic system

Yelow cell = enter your own data
Green cell = result (do not change the value)
White cell = calculated value (do not change the value)

Global formula : **E = A * r * H * PR**

E = Energy (kWh)	2811	kWh/an
A = Total solar panel Area (m²)	20	m²
r = solar panel yield (%)	15%	
H = Annual average irradiation on tilted panels (shadings not included)*	1250	kWh/m².an
PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75)	0.75	
Total power of the system	3.0	kWp

Losses details (depend of site, technology, and sizing of the system)

- Inverter losses (6% to 15 %)	8%
- Température losses (5% to 15%)	8%
- DC cables losses (1 to 3 %)	2%
- AC cables losses (1 to 3 %)	2%
- Shadings 0 % to 40% (depends of site)	3%
- Losses weak irradiation 3% yo 7%	3%
- Losses due to dust, snow... (2%)	2%
- Other Losses	0%

More info
Source : www.photovoltaic-software.com

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Review of Literature

Possibly the first attempt to focus on the use of solar energy is practiced in 7th Century B.C. *(US Department of Energy).* Humans started out concentrating the sun's heat with glass and mirrors to light fires. Today, human have everything from solar- powered buildings to solar powered vehicles. But in the developing countries like India very few studies have been conducted to find out potential solar energy.

At international level John Byrne and *et al.* (2015) [18]; Annie Chow and *et al.* (2014); James B. Pick and *et al.* (2014); The International Renewable Energy Agency (IRENA) (2014) [25]; Matej Brumen and *et al.* (2014) [20]; E. Doris and *et al.* (2013) [2]; Jacinto Estima and *et al.* (2013) [17]; Stuart Iler (2012) [22]; G. Agugiaro and *et al.* (2012) [4]; L. K. Wiginton and *et al.* (2011) [19]; and Ghita LAHLOU and *et al.* (2011) [6] have tried to analyze the various aspects of solar energy using geo-spatial technology.

Wate, P. S. (2014); Deepak Kumar and Sulochana Shekhar (2014) [1]; and T.V. Ramachandra and B.V. Shruthi (2007) have analyzed the aspects of solar energy potential in India. The Energy and Resources Institute (TERI) has developed a first-of-kind cloud based open-source Web-GIS Tool for estimating Rooftop Solar Power potential for Indian Solar Cities.

Results & Discussion

The CoEP is located in the central part of India having high amount of incoming solar energy. The solar energy potential is truly enormous in the campus due to the geographical position of the institution. The solar energy potential is estimated by using rooftop area and global solar radiation.

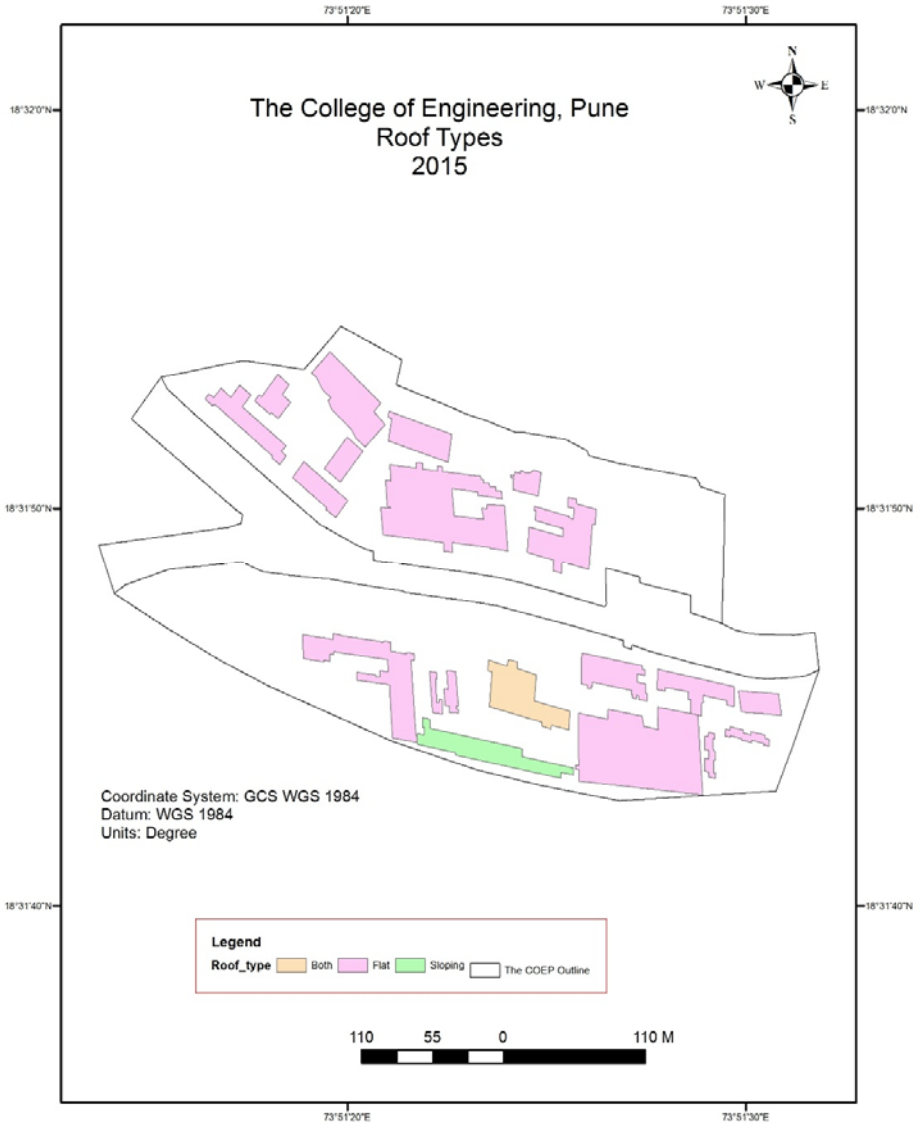
A) Rooftop Area and Roof Types

Roof-top layer has been created in arc GIS by using the base map of the institution. After creation of layer, the layer has been re-projected to the UTM projection for the area calculation of the roof-top area. The production department has the largest roof area i.e. 5046 m2 which is almost 20% of the total roof area (25360 m2). It is followed by mechanical department roof area with 4221 m2 and further more followed by the electrical department with 2295 m2 area and mechanical department drawing hall 1768 m2. These four buildings contribute more than 50 per cent of the total roof-top area of the college. The Table 1 and Fig. 3 give in-depth information regarding the rooftop area and roof types of 19 buildings in the institution. The roof types of the buildings available in the campus consist flat (17 buildings), sloping (1 building) and both type of roof (1 building). But during the course of investigation it is assumed that all the buildings have flat roof-top.

Table 1: The College of Engineering Pune Roof-top area in m2

S. No.	Department	Roof-top area (m2)
1	Production department	5046
2	Mechanical department	4221
3	Electrical department	2295
4	Mechanical departmental drawing hall	1768
5	Academic block	1752
6	Main Building	1613
7	Civil department	1543

8	Library and Auditorium	1025
9	Computer department	1009
10	Boat club	1017
11	Metallurgy department	885
12	ENTC department	654
13	Workshop Building	477
14	ENTC department	457
15	IT Building	454
16	Mathematics department	319
17	Administrative Block	249
18	Residential Block-1	211
19	Residential Block-2	198
20	Establishment cell	167



B) Spatio-Temporal Variation in Global Solar Radiation

The global solar radiation is calculated using point solar radiation tool in Arc- GIS. During the course of investigation it is assumed that all the buildings have the same height of nine meters, which is slightly vary from the reality, in case of some buildings.

It is interesting to note that the Library and auditorium building receives the maximum and Boat club receives the minimum global solar radiation. It is 1771271.53 WH/m2 and 1673282.76 WH/m2 respectively. But if we consider the roof-top area of the buildings, the production departmental building is at the top and it receives 440590105.04 WH global solar radiations. It is due to the maximum roof area of the building. Table 2 furnishes the facts regarding Global Solar Radiation in CoEP

Table 2: The College of Engineering Pune Global Solar Radiation (in WH/m2)

Name	Monthly Global Solar Radiation in WH/m2												Annual Total
	January	February	March	April	May	June	July	August	September	October	November	December	
Boat club	91896.6	103636.0	144985.8	163850.6	181760.6	178798.4	183414.2	174481.8	152951.6	119220.0	93454.9	84832.3	1673282.8
Academic block	93809.6	105277.6	146386.9	164524.9	181768.6	178516.8	183275.7	174944.6	154171.8	120901.8	95299.8	86740.2	1685618.3
Computer Department	99166.9	109924.9	150470.2	166685.3	182168.5	178129.4	183284.1	176556.5	157782.7	125690.3	100475.9	92069.4	1722404.0
Residential Block-1	101975.3	112304.5	152432.2	167515.7	181961.4	177484.5	182851.9	177051.6	159458.9	128112.2	103178.4	94878.7	1739205.2
ENTC Department	101802.5	112184.3	152398.7	167619.8	182196.8	177763.9	183113.6	177203.4	159463.3	128004.6	103017.1	94699.1	1739467.1
Residential Block-2	102563.6	112793.1	152812.6	167638.2	181847.6	177275.0	182687.7	177095.9	159773.0	128604.3	103742.6	95470.0	1742303.6
IT Building	102839.6	113009.3	152954.5	167640.8	181726.0	177107.5	182540.7	177055.4	159877.3	128815.5	104004.6	95751.4	1743322.4
Workshop Building	103069.5	113190.2	153068.1	167623.4	181584.8	176920.3	182373.8	176995.1	159956.2	128991.8	104223.2	95984.8	1743981.3
Mechanical Department	102963.3	113145.1	153138.3	167842.3	181944.4	177320.3	182760.0	177268.1	160069.5	128970.4	104129.6	95866.5	1745417.8
Mathematics Department	103200.1	113327.6	153246.3	167814.2	181790.7	177121.2	182580.7	177196.0	160140.9	129146.3	104354.0	96108.4	1746026.4
Production Department	103408.9	113484.1	153325.3	167758.0	181607.5	176893.0	182371.6	177094.7	160183.3	129294.4	104551.1	96322.5	1746294.5
Electrical Department	104255.2	114176.6	153840.4	167880.9	181370.9	176514.6	182059.1	177096.8	160596.2	129986.2	105360.6	97176.0	1750313.4
ENTC Department	105546.7	115129.2	154297.7	167508.6	180233.9	175113.0	180768.4	176450.7	160826.4	130880.0	106575.8	98506.9	1751837.1
Establishment cell	105038.0	114796.1	154253.1	167889.9	181011.3	176016.9	181623.3	176978.7	160901.4	130593.8	106105.2	97971.4	1753179.2
Admin Building	105038.0	114796.1	154253.1	167889.9	181011.3	176016.9	181623.3	176978.7	160901.4	130593.8	106105.2	97971.4	1753179.2
Metallurgy Department	107330.7	116458.5	154980.1	167096.0	178815.9	173345.1	179148.6	175679.6	161209.2	132136.8	108256.7	100342.1	1754799.4
Mechanical departmental drawing hall	107268.2	116620.6	155606.3	168202.0	180367.1	174995.8	180777.2	176969.5	161983.6	132415.8	108238.6	100220.3	1763665.0
Civil Department	108005.1	117202.4	155984.7	168184.3	179982.5	174474.3	180316.7	176824.9	162256.7	132985.0	108939.6	100968.8	1766125.0
Main Building	108414.2	117559.3	156309.7	168382.8	180071.0	174511.0	180380.4	176990.4	162550.9	133354.6	109334.9	101375.9	1769235.2
Library and auditorium	109128.4	118114.1	156649.7	168322.6	179641.5	173946.5	179875.2	176801.2	162783.6	133892.3	110012.4	102104.0	1771271.5

Source: Estimated by the researchers using CARTOSAT DEM and Arc-GIS 10.2 software.

C) Estimation of Solar Energy Potential (Electricity)

For the calculation of solar energy (electricity) potential using global solar radiation data, an open source tool developed by photovoltaic and solar electricity design is used. During the course of investigation, it is assumed that only 60 per cent global solar radiation is available for PV plants as well as only 60 per cent roof-top area can be utilized for installation of PV plants. Table 3 provides exhaustive information regarding solar energy potential that can be generated by installation of PV panels. It is clear that in the CoEP campus, maximum 2282.4 KWp electricity can be generated. In building wise variation, production unit stands first in potential solar energy production and an establishment cell is at the end.

Table 3: The College of Engineering Pune Estimation of Potential Energy (Electricity)

Name	KWh	Rooftop area	60% Rooftop area	Power (KWp)
Mechanical departmental drawing hall	155907.99	1768	1060.8	160.3
Mathematics department	27849.12	319	191.4	28.7
Boat club	85086.43	1017	610.2	91.5
Mechanical department	368370.44	4221	2532.6	379.9
ENTC department	57285.07	654	392.4	58.9
ENTC department	39746.82	457	274.2	40.9
Academic block	147660.16	1752	1051.2	157.7
IT building	39573.42	454	272.4	40.9
Computer department	86895.28	1009	605.4	90.8
Electrical department	200848.46	2295	1377	206.6
Civil department	136256.54	1543	925.8	138.9
Establishment cell	14639.05	167	100.2	15
Admin building	21827.08	249	149.4	22.4
Main building	142688.82	1613	967.8	145.2
Library and auditorium	90777.67	1025	615	92.3
Production department	440590.11	5046	3027.6	454.1
Workshop building	41593.95	477	286.2	42.9
Residential Block-1	18348.62	211	126.6	19
Residential Block-2	17248.81	198	118.8	17.8
Metallurgy building	77649.87	885	531	79.7
Total	2210182.87	25360	15216	2282.4

Source: Estimated by the researchers using CARTOSAT DEM and Arc-GIS 10.2 software.

Findings

Followings are the major findings of the present research work.

1. Geo-spatial technology plays a significant role in the estimation of solar energy potential but the quality of output depends on the quality of 3 D data (DEM).
2. The CoEP has the total roof top area of 25193 sq. m.
3. The study reveals that the institution has slightly variation in spatio-temporal pattern of global solar radiation. The building wise analysis depicts that the Library and auditorium, Main Building, Civil Department, Metallurgy Department, Admin Building, Establishment cell, ENTC Department, Electrical Department, Production Department, Mathematics Department, Mechanical Department, Workshop Building, IT Building, Residential Block-2, Residential Block-1, Computer Department, Academic block and Boat club are in descending order.
4. It is estimated that 2282.4 KWp electricity can be generated by installation of PV plants in the CoEP campus. By taking into consideration roof top area and production of electricity the six building rooftops namely Production department, Mechanical department, Electrical department, Mechanical department & drawing hall, Academic block and Main building are more suitable.

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