ESTIMATION OF SOLAR ENERGY POTENTIAL OF BUILDING ROOFTOPS USING REMOTE SENSING AND GIS

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ABSTRACT

With about 300 clear sunny days in a year, India's theoretical incident solar radiation (insolation), just on its land area, is about 5 PWh/year (i.e. = 5000 trillion kWh/yr). The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 2,300–3,200 sunshine hours per year, depending upon location. This is far more than current total energy consumption. A significant portion of Chennai's electricity can be produced either by large utility-scale solar power stations or with small, distributed solar power systems installed in individual buildings. This study discusses the application of geographical information system (GIS) to map the solar potential of some of the individual building roof tops in Alwarpet region, Chennai.

Producing energy in large solar power stations requires vast tracts of land and may necessitate an extensive upgrade of the power grid. Distributed production using photovoltaic panels on rooftops, on the other hand, does not have these drawbacks and takes advantage of the omnipresence of insolation. Assessment of available rooftop area in these buildings, using a complete set of GIS and Remote sensing data and its photovoltaic potential has been estimated using Point Solar Radiation tool in ArcGis 9.3. This analysis provides a picture of the potential of individual buildings. Roof-mounted solar heating and photovoltaic systems are not only important technologies to decrease the emissions of carbon dioxide caused by domestic fuel consumption, but they also help saving energy and financial costs. Therefore, today the worldwide use of solar systems is increasing. Private investors as well as local authorities have a rising interest in identifying roof areas which are suitable for mounting solar systems. Thus a more economic, environment friendly and feasible scenario for the near future is derived, assuming PV installations only on large (>100 m^2) rooftops and with lower panel efficiencies (16%). It is found that even in this case, a substantial amount of today's electricity dem and can be met.

Key Words: Solar energy, Carbon foot print, GIS, Remote sensing

1. Introduction

Energy crisis is one of the most important challenges faced by many countries. Solar power in particular has increased in popularity due to its wide-ranging applicability and, in many cases, government-sourced financial incentives (Pragya and Tirumalachetty 2014, Ramachandra 2007). As solar power generation continues to grow, new methods for sitting this technology are being developed (Alstan et al 2013). Many of these sitting techniques use GIS software and remote sensing data to evaluate true solar potential for large-scale solar farms, distributed generation scenarios, and building- scale systems (Charith et al 2011, Alessandro et al 2014, Caiaffa et al 2014 and Esclapse et al 2014). No matter the scale of the analysis - from rural plains to individual rooftops - GIS and remote sensing play a pivotal role (Bareth et al 2005, Ben et al 2010, Melius et al, 2013 and Johan et al 2014).

Solar energy plays a vital role as a renewable energy because of its unpolluted nature and its reliability in tropical countries (Charith et al 2011). Tamil Nadu is one of the states located in the southern peninsular region of India lying in the sunny belt between 8.5 ˚ and 13.35 ˚ N. Its geographical location is advantageous for utilizing the solar energy. For effective and efficient utilization of solar energy, it is necessary to have a precise knowledge about the various components of solar energy available at the locations of our interest. Global radiation is the most important component of solar radiation since it gives the total solar availability at a given place. Everyone agrees in principle that solar energy is a good idea. But even metro cities like Chennai hasn't harnessed it for conversion to electricity as some barriers still exist that prevent solar energy entering the mainstream.

Tamil Nadu Solar Policy was introduced in October 2013. Till then, the State had solar power capacity of 7 Mega Watts (MW). Now, as a consequence of a tender floated by the Tamil Nadu Generation and Distribution Company (TANGEDCO), at least 226-MW worth of projects is very likely to be set up within a year. Apart from this there are many other private developers such as INDarya Green Power which intends to put up a 300-MW solar park. Given the level of interest among developers, it is not inconceivable that the State could end up with 1,000 MW in the next couple of years

It is only in the case of small rooftop plants on individual houses that the movement is yet to take off. A rooftop solar plant is still not economically attractive. However, the State government has announced a few sweeteners. One is a generation- based incentive of Rs. 2 a unit.

The other is the Rs. 20,000 subsidy which the Chief Minister announced recently for capacities up to 1 KW. But the rules are still being formulated. This study may help individual building owners to think about installing solar panels on their roof tops.

2. Study Area Description

Alwarpet is a mixed residential zone in central Chennai. The area has commercial, Residential and Institutional buildings with varying heights. The study area falls under the ward Alwarpet which is in Kodambakkam zone. The extent of Latitude and Longitude consider in this study is 13°02’07.58’’N to 13°02’05.01’’ N, 13°01’42.51’’ N to 13°01’45.13’’N , 80°14’55.27’’ E to 80°15’34.06’’E and 80°15’35.89’’E to 80°14’53.25’’ E respectively. Extent of the study area is 971583.870 m^2. Alwarpet is chosen as the study area since it has got more buildings with open roof tops and also the buildings in the chosen area has a decent height variation which can be considered as a parameter in analysis. . The district boundary of Chennai, The boundary of entire alwarpet region is shown in the Figure 1

Figure 1 Study Area

3. Methodology

The study area is narrowed down to a block in Alwarpet region. 26 buildings with varying heights from minimum 9m to maximum 30m were chosen in the selected block, the heights of 26 buildings was found using a device called Laser tape and the roof area of each building was found using ARC GIS 9.3 by digitizing them as vector shape files. The buildings were then extruded using Google Sketch up tool which is a plugin software for google earth. The Digital elevation model for the study area is generated using the interpolation technique Kriging. The DEM thus generated is used to find the solar radiation values for individual buildings using 3Danalyst tool in ARC GIS 9.3. The obtained raw radiation values which are in w/m^2 is converted into available solar potential in KWh using the roof area of each building. The available solar radiation values and the efficiency of solar panels are used to find actual solar potential of individual buildings. The actual solar potential value is used to estimate the amount of carbon footprint reduction. The complete methodology is described on a flowchart shown in Figure 2.

3.1 Calculation of Roof Area and Height of the of the Buildings

The roof area of all the 26 buildings are found using ARC GIS 9.3 by digitizing the roof areas using QUICKBIRD satellite imagery with 0.6m resolution which is PAN merged and Orthorectified. The roof areas are found using Calculate area tool which is available in SPATIAL STATICS TOOL in ARC GIS 9.3.

The height of the buildings is found using a device called LASER MEASURING TAPE (BOSCH DLE40). The working principle of laser tape is similar to that of a total station. Measurement of distance is accomplished with a modulated laser signal, generated by a small solid state emitter within the instrument's optical path and reflected by an object under survey. The distance is determined by emitting and receiving multiple laser pulses and determining the integer number of wavelengths to the target for each frequency. Thus the height measurement was made by sending laser beam from the terrace of each building to a dark spot on the ground floor (Red laser light is visible only in dark areas during day time) and observed till the instrument receives the return signal and the observed readings were noted down. The height measurements are obtained with an accuracy of 1.5mm. The buildings are extruded from google earth and raised based on relative heights using Google sketchup tool for calculating the shadow effect.

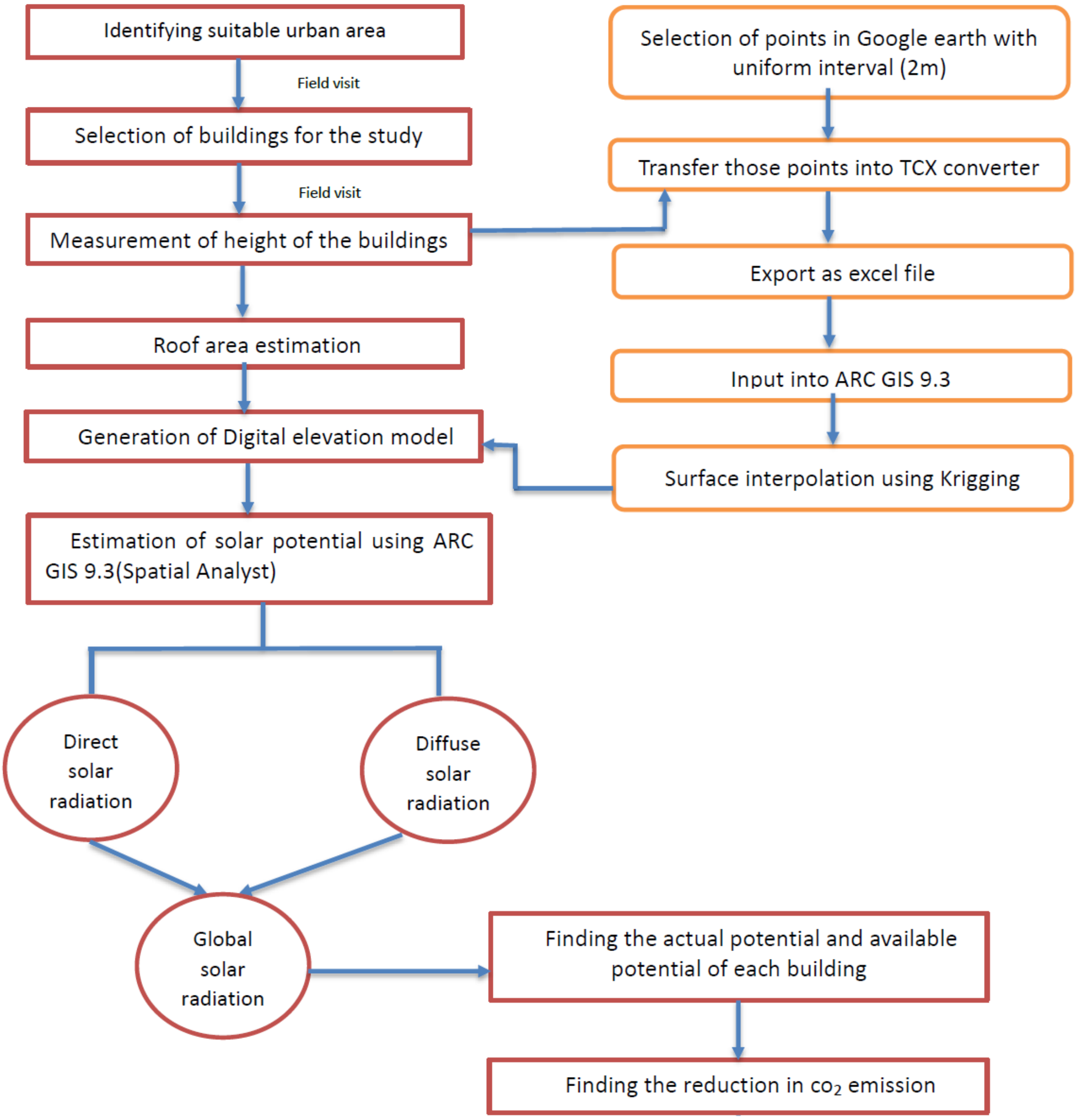

Figure 3 Methodology of the study

3.2 Generation of Digital Elevation Model

Digital Elevation Model (DEM) with 2m interval is generated from QUICKBIRD image using google earth imagery, TCX converter and ARC GIS 9.3 3D Analyst tools. Sample points are selected in Google earth image at a regular interval of 2m. The relative heights of the sample points are calculated using TCX converter. The DEM is prepared from the relative heights of the selected points by Krigging surface interpolation method using ARC GIS 9.3.

3.3 Estimation of Solar Radiation

The solar potential of the each building is found using a tool POINT SOLAR RADIATION which is available in the SPATIAL ANALYST tool in ARC GIS 9.3. Using this tool the amount of direct radiation, diffuse radiation, global radiation and the annual solar duration of each building is obtained.

3.3.1 Estimation of Direct Solar Radiation

The direct insolation from the sunmap sector ($Dir_{\theta,\alpha}$) with a centroid at zenith angle (θ) and azimuth angle (α) is calculated using the equation 1

$$Dir_{\theta,\alpha} = SConst * \beta^{m(\theta)} * SunDur_{\theta,\alpha} * SunGap_{\theta,\alpha} * \cos(AngIn_{\theta,\alpha} \quad \ldots\ldots\ldots\ldots(1)$$

Where,

SConst is the solar flux outside the atmosphere at the mean earth-sun distance, known as solar constant. The solar constant used in the analysis is 1367 w/m^2.

β is transmisivity of the atmosphere (averaged over all wavelengths) for the shortest path (in the direction of the zenith)

m(θ) is the relative optical path length, measured as a proportion relative to the zenith path length

$SunDur_{\theta,\alpha}$ is the time duration represented by the sky sector. For most sectors, it is equal to the day interval (for example, a month) multiplied by the hour interval (for example, a half hour). For partial sectors (near the horizon), the duration is calculated using spherical geometry.

$SunGap_{\theta,\alpha}$ is the gap fraction for the sunmap sector.

$AngIn_{\theta,\alpha}$ is the angle of incidence between the centroid of the sky sector and the axis normal to the surface

Relative optical length (m(θ)) is determined by the solar zenith angle and elevation above sea level. For zenith angles less than 80^o, it can be calculated using the equation 2

$$M(\theta) = EXP(-0.000118 * Elev - 1.638 * 10^{-9} * Elev^2) / \cos(\theta) \quad \ldots\ldots\ldots\ldots (2)$$

Where,

θ is the solar zenith angle;

Elev is elevation above sea level in meters.

The effect of surface orientation is taken into account by multiplying by the cosine of the angle of incidence. Angle of incidence ($AngInSky_{\theta,\alpha}$) between the intercepting surface and a given sky sector with a centroid at zenith angle and azimuth angle is calculated using the equation 3

$$AngIn_{\theta,\alpha} = acos[Cos(\theta)*Cos(G_Z)+Sin(\theta)*Sin(G_Z)*Cos(\alpha-Ga)] \quad \text{.............(3)}$$

Where,

G_Z is the surface zenith angle.

Ga is the surface azimuth angle. (For zenith angles greater than 80° refraction is important).

Total direct insolation (Dir_{tot}) for a given location is the sum of the direct insolation ($Dir_{\theta,\alpha}$) from all sunmap sectors and is calculated using equation 4

$$Dir_{tot} = \Sigma Dir_{\theta,\alpha} \quad \text{................ (4)}$$

3.3.2 Estimation of Diffuse Solar Radiation

For each sky sector, the diffuse radiation at its centroid (Dif) is calculated, integrated over the time interval, and corrected by the gap fraction and angle of incidence using the equation 5

$$Difn_{\theta,\alpha} = Rglb * Pdif * Dur * SkyGap_{\theta,\alpha} * Weight_{\theta,\alpha} * cos(AngIn_{\theta,\alpha}) \quad \text{...........(5)}$$

Where,

Rglb is the global normal radiation.

Pdif is the proportion of global normal radiation flux that is diffused. It is approximately 0.2 for very clear sky conditions and 0. 7 for very cloudy sky conditions.

Dur is the time interval for analysis

$SkyGap_{\theta,\alpha}$ is the gap fraction (proportion of visible sky) for the sky sector

$Weight_{\theta,\alpha}$ is the proportion of diffuse radiation originating in a given sky sector .

$AngIn_{\theta,\alpha}$ is the angle of incidence between the centroid of the sky sector and the intercepting surface.

The global normal radiation (R_{glb}) can be calculated by summing the direct radiation from every sector (including obstructed sectors) without correction for angle of incidence, then correcting for proportion of direct radiation, which equals to 1- P_{dif} and it is shown in equation 6

$$Rglb = (SConst\ \Sigma(\beta^{m(\theta)}))/ (1 - Pdif) \quad \text{..............(4.6)}$$

For the uniform sky diffuse model, $Weight_{\theta,\alpha}$ is calculated using equation 7

$$\textbf{Weight}_{\theta,\alpha} = (\cos\theta_2 - \cos\theta_1) / \textbf{Div}_{azi} \quad \text{................(4.7)}$$

Where,

θ_1 and θ_2 are the bounding zenith angles of the sky sector;

$\textbf{Div}_{azi}$ is the number of azimuthal divisions in the skymap.

For the standard overcast sky model, $\text{Weight}_{\theta,\alpha}$ is calculated using the equation 8

$$\textbf{Weight}_{\theta,\alpha} = (2\cos\theta_2 + \cos 2\theta_2 - 2\cos\theta_1 - \cos 2\theta_1) / 4 * \textbf{Div}_{azi} \quad \text{................(8)}$$

Total diffuse solar radiation for the location (Dif_{tot}) is calculated as the sum of the diffuse solar radiation (Dif) from all the skymap sectors and it is shown in equation 9

$$\textbf{Dif}_{tot} = \Sigma \textbf{Dif}_{\theta,\alpha} \quad \text{............(9)}$$

3.3.3 Estimation of Global Solar Radiation

Global radiation (Global_{tot}) is calculated as the sum of direct (Dir_{tot}) and diffuse (Dif_{tot}) radiation of all sunmap and skymap sectors, respectively and it is shown in equation 10

$$\textbf{Global}_{tot} = \textbf{Dir}_{tot} + \textbf{Dif}_{tot} \quad \text{............... (10)}$$

3.4 Estimation of Actual and Available Solar Potential

The output from Point Solar Radiation tools is invariably a raster. Using equation 11 the raster output from point solar radiation can be converted into electrical units.

(KWh) = (Wh/m2)*[shape_area]/1000 ....(11)

After finding the available potential, Actual potential is obtained using equation 12.

Actual potential = KWh * Efficiency of Solar Panel .... (12)

The efficiency of solar panels are considered as 16% of the total solar radiation, hence the efficiency value is taken as 0.16.The efficiency of solar panels depends on the materials used in production. The average efficiency ranges from 16% to 20% (Piera, and Teller, 2014).

3.5. Estimation of Carbon Footprint Reduction

For producing 1 unit of electricity i.e. 1 KWh from coal 612.5 g of co_2 is emitted (Cranston and Hammond, 2010).The amount of carbon footprint emission that can be reduced by using solar energy as a power source instead of coal can be determined using equation 13.

Carbon footprint reduction (kg) = Actual Potential * 0.6125 ……….. (13)

4. Results and Discussion

4.1 Height and Roof Area of Buildings

The height of the buildings found using LASER MEASURING TAPE (BOSCH DLE40) and the roof area found using ARC GIS 9.3. From Table 1 it is observed that the elevation of the buildings varies from 9.83m to 30.0m with an average height of 15.36m.The buildings chosen vary between residential, commercial and institutional. The Ramaniyam towers, an apartment complex, are the highest in the study area. Larger the rooftop, more energy can be harnessed and in that regard, Park Sheraton, a popular hotel has the highest area value of 2101.315 sq.m The roof area is extracted from a PAN sharpened Quickbird image of 0.6m resolution. This can be seen in figure 3.The buildings fall within a maximum radius of 3km.

Table 1 Building information

BUILDING NUMBERS	HEIGHT (m)	TOTAL ROOF AREA (sq.m)	BUILDING NAMES	BUILDING TYPE
1	9.83	665.370	Sundara vihar	Independent house
2	10.58	362.945	Shreyas Adithi	Apartment
3	10.69	247.157	Sriranga	Apartment
4	10.72	238.411	Mansarovar	Institutional
5	11.50	300.594	Spencers Daily	Commercial
6	11.60	562.994	Ramaniyam Kalyani	Apartment
7	11.62	483.332	Bamini	Apartment
8	12.00	621.893	Chaitanya	Apartment
9	12.01	421.754	Shreyas Yogam	Apartment
10	12.46	584.424	Horizon	Independent house
11	12.48	116.072	Residency Kriya	Apartment
12	12.49	180.888	Rajendra	Independent house
13	12.52	187.163	Adiga Manor	Apartment
14	13.00	186.760	Legend's gym	Commercial
15	13.10	424.939	Western Union Bank	Commercial
16	13.17	585.093	Dev apartments	Apartment
17	13.46	447.770	Mehta Jewellery	Commercial
18	15.66	407.520	Swathi solutions	Commercial
19	17.50	885.713	Corporation School	Institutional
20	16.77	426.999	Srinidhi Apartments	Apartment

21	17.50	268.373	Coral classic	Apartment
22	18.30	300.911	State Bank of India	Commercial
23	23.32	2101.315	Park Sheraton	Commercial
24	27.20	824.582	Shanthi Haven	Residential
25	30.00	606.434	Ramaniyam abbotsbory1	Apartment
26	30.00	852.434	Ramaniyam abbotsbory2	Apartment

4.2 Extrution of Buildings

The buildings taken for the analysis are extruded based on their heights in GOOGLE SKETCH UP tool. This tool helps to view the buildings in 3D.The extruded buildings are shown in the figure 4. Apart from Visualization, GOOGLE SKETCHUP can also be used to determine the shadow effect of the buildings Here we see Ramaniyam abbotsbory with a height of 30m is surrounded by buildings whose average height is 15m Hence the amount of solar radiation received on these buildings will be lesser due to shadow effect from the taller nearby building . Solar simulation can also be done to determine the shadow effect on each building.

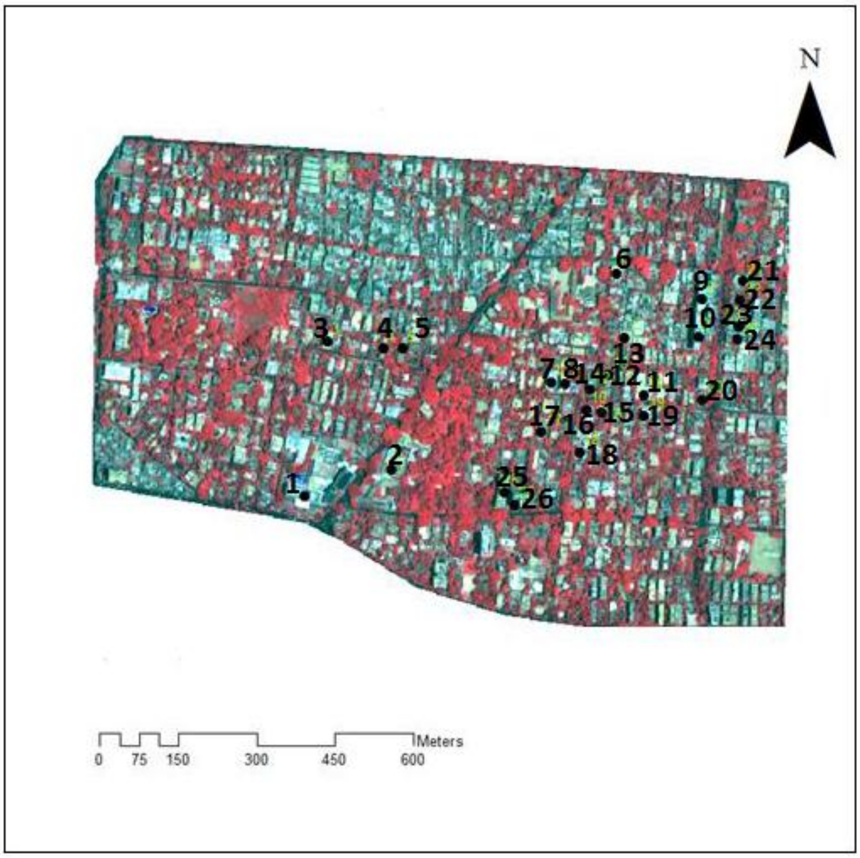

Figure. 3 Lay out of the Selected Buildings

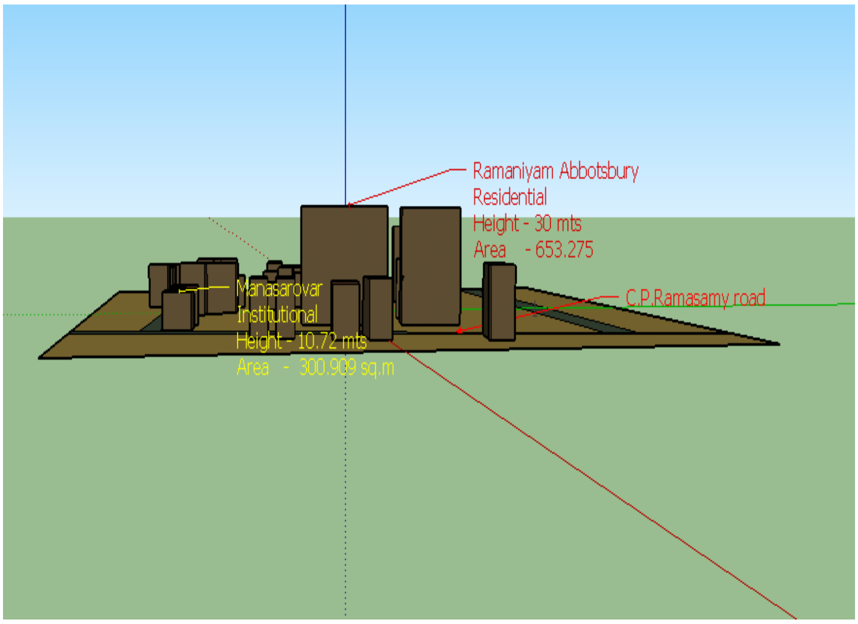

Figure 4 Extruded buildings view in google sketch up with their details

4.3 Digital Elevation Model

The DEM generated for the study area using the interpolation method krigging is shown in figure 5. In generation of DEM a number of sample points are taken at a 2m interval. These sample points includes the 26 buildings whose height are known. Then TCX convertor is to update the relative height values of all sample points. These height values are provided by Gramin, a GPS service provider. The accuracy of the altitude decreases with increase in height. For Sundara Vihar a building of height 9.83 m TCX value is 10 m, which is an error of 0.17m whereas Ramaniyam abbotsbory, a 30m high building has an error of 4m. In the North western part of the study area exists the taller buildings like Shanthi heaven and Ramaniyam. The western part of the study area has an average height of 15m. The shadow effect plays a major role in assessing the solar potential of buildings. Thus a DEM of very high accuracy is required. The DEM used in this study is generated from QUICKBIRD image is obviously having high accuracy.

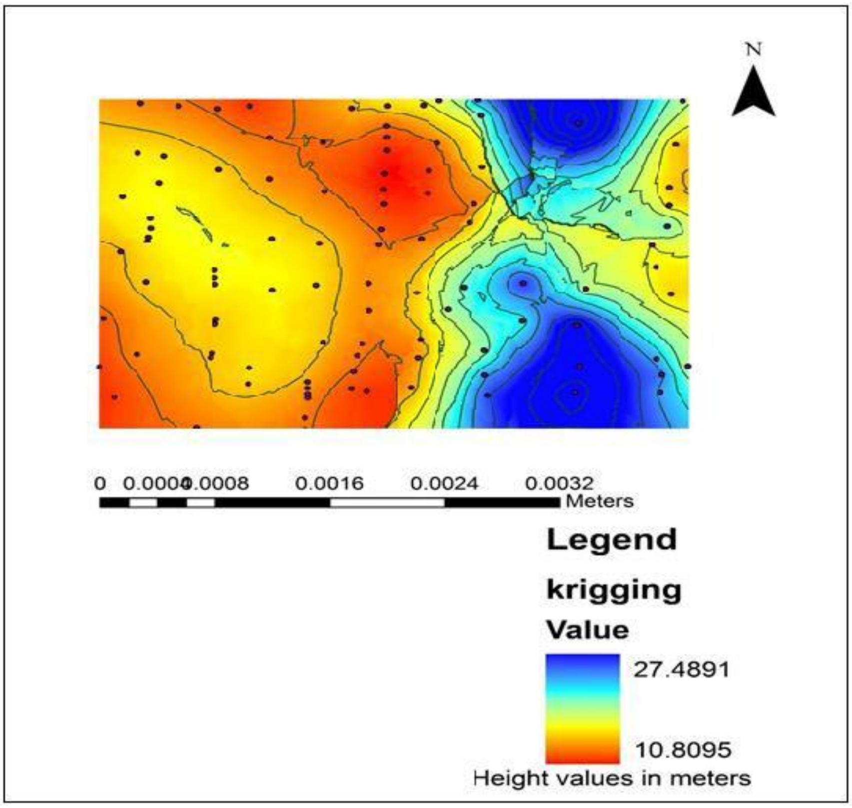

Figure 5 Digital Elevation Model

4.4 Point Solar Radiation

The radiation reaching the earth's surface can be represented in a number of different ways. Using the input of digital elevation model which in turn computes a viewshed raster from which the global radiation is computed. In this study area direct solar radiation values vary from 29020.788wh/m^2 to 1822598.043wh/m^2. Diffuse solar radiation varies from 66048.601 wh/m^2 to 657375.391 wh/m^2. The global solar radiation values vary from 98321.163 wh/m^2 to 2447551.188 wh/m^2.

4.4.1 Direct Solar Radiation

The Direct solar radiation values considers only the radiation that falls directly on the roof area is shown in Table.2. Direct solar radiation values vary from 29020.788 wh/m^2 to 1822598.043 wh/m^2. Mehta jewellery with a height of 13.46m and area 447.77 sq.m has the minimum value. This is due to the shadow effect, since it is situated right opposite to Ramaniyam which is having the height of 30m.

Table 2 Solar radiation values

Building No.	Height (m)	Roof Area (m^2)	Direct Radiation (Wh/m^2)	Diffuse Radiation (wh/m^2)	Global Radiation (wh/m^2)
1	9.83	665.370	1334318.923	654566.850	1988885.773
2	10.58	362.945	1489708.821	655822.745	2145531.566
3	10.69	247.157	1548164.994	657375.391	2205540.385
4	10.72	238.411	584225.012	654308.177	1238533.189
5	11.50	300.594	37721.749	66048.601	103770.350
6	11.60	562.994	1182446.602	649290.863	1831737.466
7	11.62	483.332	1700134.373	640396.858	2340531.231
8	12.00	621.893	868437.065	646636.330	1515073.396
9	12.01	421.754	1820505.369	627045.819	2447551.188
10	12.46	584.424	1795855.344	610119.747	2405975.091
11	12.48	116.072	1151735.539	613008.412	1764743.950
12	12.49	180.888	1635937.098	654516.229	2290453.327
13	12.52	187.163	73712.527	107581.779	181294.306
14	13.00	186.760	1103833.014	565763.341	1669596.354
15	13.10	424.939	55236.863	70868.776	126105.639
16	13.17	585.093	1815114.054	621050.679	2436164.733
17	13.46	447.770	29020.788	69300.375	98321.163
18	15.66	407.520	1043982.998	563058.722	1607041.720
19	16.77	885.713	1429864.568	346637.835	1776502.403
20	17.50	426.999	536317.726	335716.659	872034.385
21	17.50	268.373	146016.613	89622.754	235639.367
22	18.30	300.911	672588.767	472775.676	1145364.444
23	23.32	2101.315	1572656.283	586504.409	2159160.691
24	27.20	824.582	1822598.043	578321.011	2400919.054
25	30.00	606.434	799768.932	652325.504	1452094.436
26	30.00	852.434	1184446.195	649656.651	1834102.846

4.4.2 Diffuse Solar Radiation

The Diffuse solar radiation refers to the radiation that is scattered of from the surrounding buildings. Thus a building surrounded by more buildings is likely to have more radiation. The building with height 11.50 m and area 300.594sq.m, Spencers daily has the minimum value whereas Sundara Vihar, a building with height 9.83m has a higher value because of less surrounded buildings. Hence diffuse solar radiation values depend on the reflectance values from the surrounding features.

4.4.3 Global Solar Radiation

The global solar radiation values are the sum of the Direct and Diffuse solar radiation and the values are shown in the table 2. Here the building Mehta jewellery which has a higher diffused radiation compared to Sundara vihar, a building of height 11.5m, has a lesser direct radiation of 29020.788 Wh/m^2 as compared to Sundara Vihar. Thus it has an overall lesser global radiation of 98321.163 Wh/m^2.The building Mehta jewellery as discussed in section 5.2, is surrounded by a lot of vegetation and other buildings which tends to create a shadow on its rooftop which inhibits the sunshine over the rooftop. Similarly areas with higher solar potential tend to not only have a larger roof area but also have lesser disturbances like building shadows and vegetation cover. Figure 6 shows a variation of global radiation with height of the buildings.

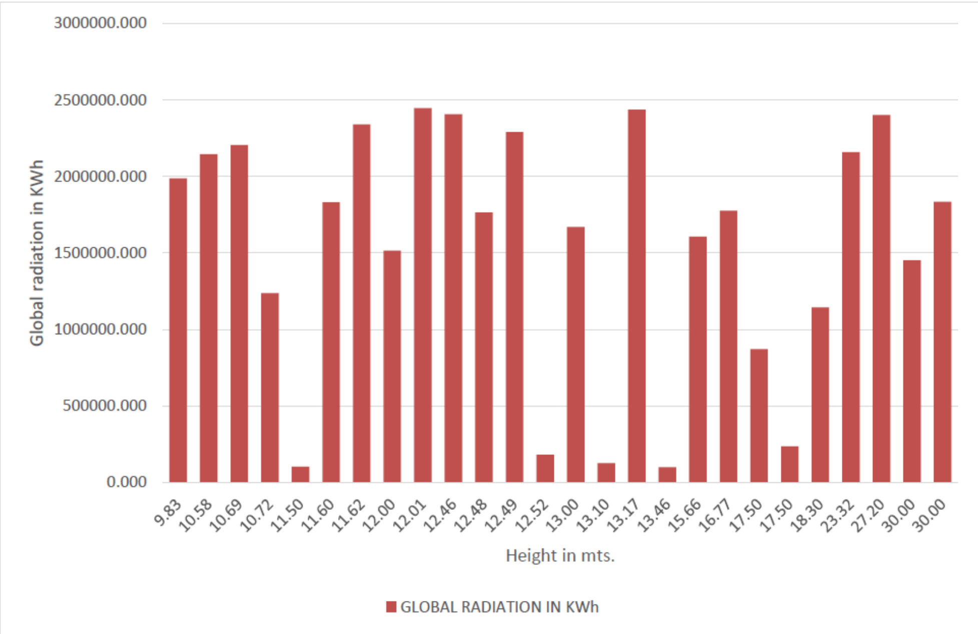

Figure 6 Variation in global solar radiation with respect to building heights.

4.5 Actual and Available Solar Potential

The actual and available solar radiation values found using the global radiation values and the efficiency of solar panels are shown in table 3.

Table 3 Actual and available solar potential of each building.

Building Numbers	Global radiation (Wh/m^2)	Area (sq.m)	Height (m)	Available potential (KWh)	Actual potential (KWh)
1	1988885.77	665.37	9.83	1323344.92	211735.19
2	2145531.56	362.94	10.58	778699.22	124591.88
3	2205540.38	247.15	10.69	545099.3	87215.89
4	1238533.19	238.41	10.72	295278.7	47244.59
5	103770.35	300.59	11.5	31192.33	4990.77
6	18311737.47	562.99	11.6	6593324.19	1054931.87
7	2340531.23	483.33	11.62	1131248.96	180999.83
8	1515073.39	621.89	12	941148.44	150583.75
9	2447551.18	421.75	12.01	1032254.71	165160.75
10	2405975.09	584.42	12.46	1406099.96	224975.99
11	1764743.95	116.07	12.48	204833.83	32773.41
12	2290453.32	180.88	12.49	414297.2	66287.55
13	181294.3	187.16	12.52	33931.04	5428.97
14	1669596.35	186.76	13	311813.81	49890.21
15	126105.64	424.93	13.1	53587.33	8573.97
16	2436164.733	585.09	13.17	1425375.62	228060.1
17	98321.16	447.77	13.46	44025.27	7044.04
18	1607041.72	407.52	15.66	654419.53	104707.12
19	1776502.4	885.71	16.77	758548.76	121367.8
20	872034.38	426.99	17.5	234027.87	37444.46
21	235639.37	268.37	17.5	63238.54	10118.17
22	1145364.44	300.91	18.3	344651.61	55144.26
23	2159160.69	2101.3	23.32	4537076.74	725932.28
24	2400919.05	824.58	27.2	1979749.83	316759.97
25	1452094.44	606.43	30	948609.73	151777.56
26	1834102.85	852.43	30	1477534.91	236405.59

Variation in solar potential with respect to height and area are shown in the figure 7 and figure 8 respectively. As we know, for every 1000m increase in height there is a 6.5 degree Celsius decrease in temperature. Thus for 20m there is a decrease of 0.13° C , which is negligible for our study area. Here standard temperature values have been taken on a monthly basis. In this case the solar potential is based on area. Hence Park Sheraton and Ramaniyam has more actual potential compare to other buildings in the study area.

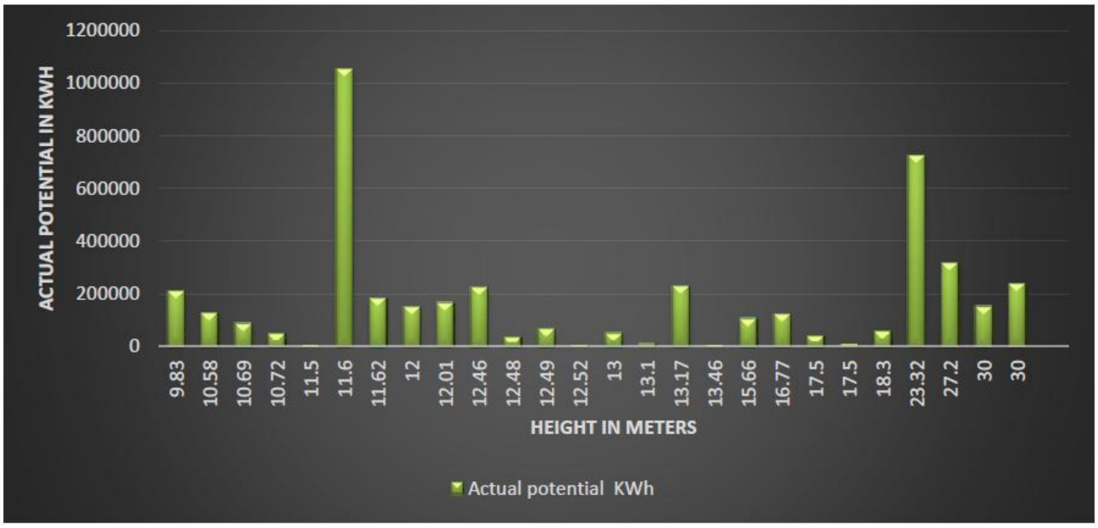

Figure 7 Variation in actual potential with respect to height

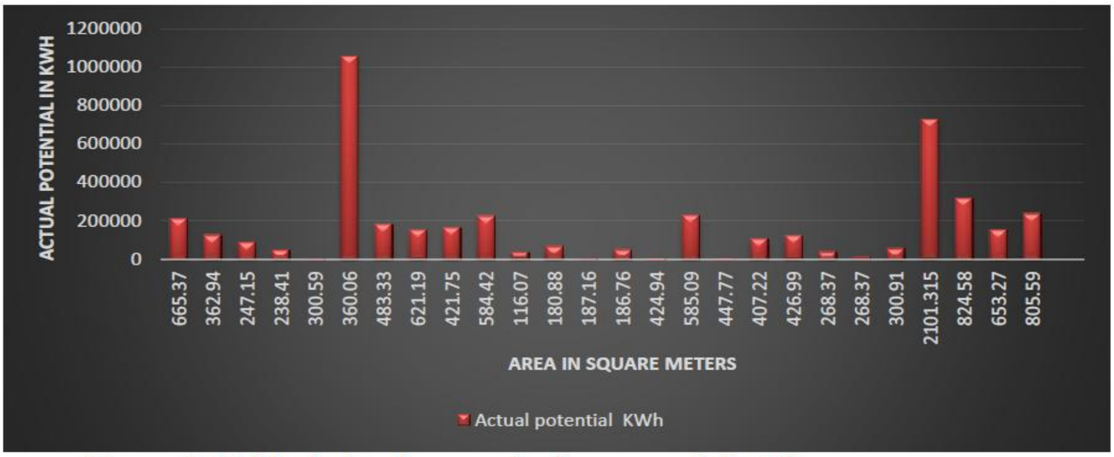

Figure 8 Variation in actual solar potential with respect to area.

4.6 Reduction in Carbon Dioxide Emission

The amount of carbon footprint reduction found using the actual potential and reduction value (0.6125g) for all 26 buildings is shown in table 4.

Table 4 Amount of carbon footprint that can be reduced using solar energy

BUILDINGS NUMBER	AREA (m^2)	HEIGHT (m)	ACTUAL SOLAR POTENTIAL IN (KWh)	CO2 REDUCTION (Kg)
1	665.370	9.83	181000.583	110862.8571
2	362.945	10.58	121367.802	74337.77873
3	247.157	10.69	87218.006	53421.02868
4	238.411	10.72	47244.592	28937.3126
5	300.594	11.5	4990.823	3056.879088
6	562.994	11.6	725932.28	444633.5215
7	483.332	11.62	165162.321	101161.9216
8	621.893	12	124593.593	76313.57571
9	421.754	12.01	151777.557	92963.75366
10	584.424	12.46	211735.188	129687.8027
11	116.072	12.48	32773.978	20074.06153
12	180.888	12.49	66290.85	40603.14563
13	187.163	12.52	5429.025	3325.277813
14	186.760	13	49890.21	30557.75363
15	424.939	13.1	8573.953	5251.546213
16	585.093	13.17	224977.534	137798.7396
17	447.770	13.46	7044.027	4314.466538
18	407.520	15.66	104706.868	64132.95665
19	885.713	16.77	105525.663	64634.46859
20	426.999	17.5	37444.459	22934.73114
21	268.373	17.5	10118.241	6197.422613
22	300.911	18.3	55144.258	33775.85803
23	2101.315	23.32	316760.742	194015.9545
24	824.582	27.2	236406.466	144798.9604

25	606.434	30	150754.166	92336.92668
26	852.434	30	228061.269	139687.5273

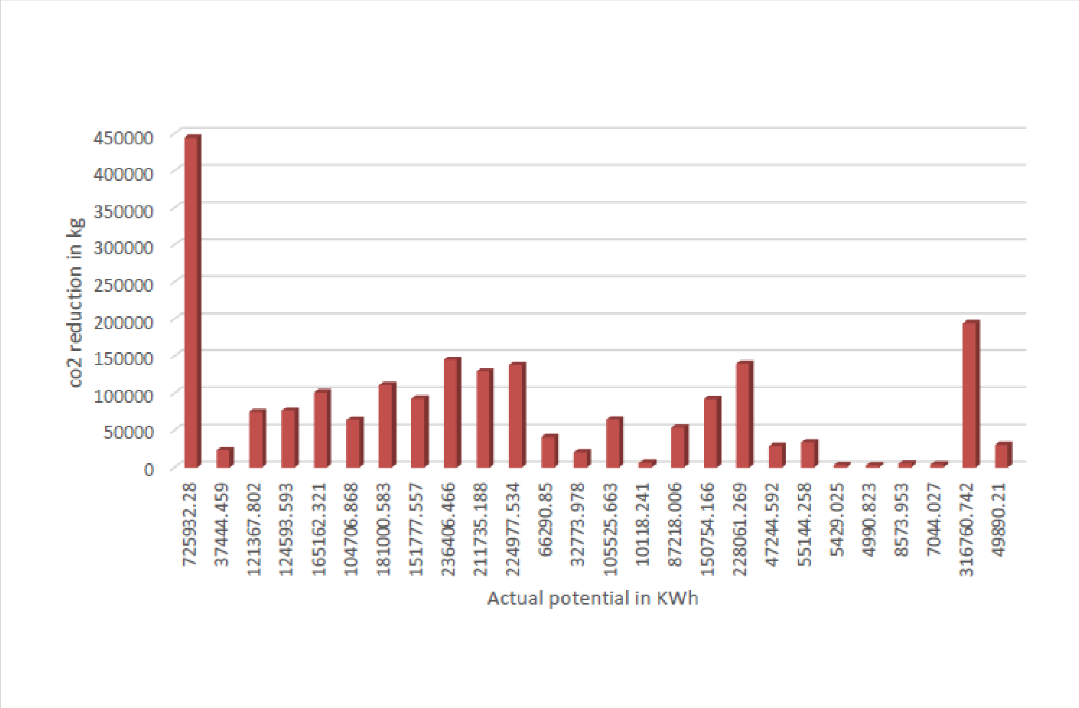

Figure 9 Variation in CO_2 reduction with respect to actual potential.

The average Co_2 reduction is 81,531 kg per annum. Evidently, from table. 4 the more the surface area of rooftops, more is the potential of the building rooftops hence more carbon emissions can be reduced. Solar energy if even implemented to a marginal extent can greatly reduce CO_2 emissions. Here the building Park Sheraton with a potential of 725932.28 KWh has the highest reduction in CO_2. Commercial buildings like Park Sheraton can invest more on solar energy. The building with least actual potential, Spencers daily has the least amount of CO_2 reduction of 3056.879 kg per annum. Variation in Co_2 reduction with respect to actual potential is shown in figure 9.

5 Conclusion

In this study the heights of the buildings which are measured with an accuracy of 1.5mm using a laser tape and the roof area of the buildings found using Quickbird data are used as analysing parameters. The results analysed reveal that the solar radiation has more dependency on area than height. Buildings which are short and large in area also has good amount of solar radiation.

This study has been carried out to find the solar potential in roof tops of individual buildings. The results reveal that there is a good amount of solar radiation available in the study area. The total amount of solar radiation that can be obtained from 26 buildings are 3460924.454 KWh. The total amount of carbon emission that can be reduced using solar energy in the study area is 2119816.23 kg.

The utility of solar potential is not an issue that is not anymore. It carries the answer to the ills ailing the present world with regards to climate change and depletion of conventional resources. Anyhow, the efficient and economical use of solar energy is essential. Chennai being the capital of Tamil Nadu has immense potential being in the tropical zone too.

References:

1. Alessandro Marucci, Emanuela Caiaffa, Flavio Borfecchia, Luigi De Cecco, Luigi La Porta1, Maurizio Pollino1 and Sandro Martini1 (2014), “Remote Sensing and GIS in planning photovoltaic potential of urban areas”, European Journal of Remote Sensing , 47: 195-216.
2. Alstan. J, Christoph F. Reinhart and Jakubiec. 2013. “A Method for Predicting City-Wide Electricity Gains from Photovoltaic Panels Based on LiDAR and GIS Data Combined with Hourly Daysim Simulations.” Solar Energy, 93: 127–143.
3. Bareth. G, Kassner. R, Koppe. W, Schüttenberg. T (2005), “analysis of the solar potential of roofs by using official lidar data”, GIS & Remote Sensing Group, Department of Geography, University of Cologne, Germany

4. Ben Ryan, Elisabeth Long, Leslie Libby, Steve Wiese (2010)" Solar Rooftop Assessment for Austin", American Solar Energy Society, published in the SOLAR 2010 Conference Proceedings.
5. Caiaffa, Flavio Borfecchia, Luigi De Cecco, Luigi La porta, Maurizio, Marucci, Sandro Matini (2014) "RS & GIS in planning photovoltaic potential of urban areas", European Journal of Remote sensing, volume 47: 195 – 216.
6. Charith Tammineedi, Choi, Jeffrey Rayl, Jeffrey R.S. Brownson and Yosoon. 2011. "PV Analyst: Coupling ArcGIS with TRNSYS to Assess Distributed Photovoltaic Potential in Urban Areas." Solar Energy 85 (11): 2924–2939.
7. Cranston.G.R and Hammond.(2010), "Egalite, fraternite, sustainable: evaluating the significance of regional affluence and population growth on carbon emissions", International journal of Global warming, 2(3): http://www.sciencedaily.com/releases/2010/10/101026141445.htm(21- 03-2015)
8. Esclapés, J., I. Ferreiro, J. Piera, and J. Teller. 2014. "A Method to Evaluate the Adaptability of Photovoltaic Energy on Urban Façades." Solar Energy 105 : 414–427.
9. John Byrne , Job Taminiau a,n, Lado Kurdgelashvili , Kyung Nam Kim (2014), "A review of the solar city concept and methods to assess rooftop solar electric potential, with an illustrative application to the city of Seoul", Elsevier volume 41: 830 – 844.
10. Melius, Margolis and Ong (2013), "Estimating rooftop Suitability for Photovoltaics : A review of methods, Patents and validation techniques", NREL,NREL/TP-6A20-60593. http://www.nrel.gov/publications. (23.1.2015).
11. Pragya Sharma, Tirumalachetty Harinarayana (2014)," Solar energy generation potential along national highways", Sharma and Harinarayana International Journal of Energy and Environmental Engineering, volume 4(16): 1-13
12. Ramachandra T. V. (2007), "Solar energy potential assessment using GIS", Energy Education Science and Technology, volume 18(2): 101 – 114.