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Solar Energy Potential Assessment in Madurai City, India

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ABSTRACT

Knowledge on solar radiation incident on horizontal or inclined surfaces is required for any solar energy application. This knowledge is useful for designing and performance evaluation of both solar thermal and photovoltaic systems. This study seeks to provide reliable information on the availability of solar energy resource in Madurai and to assess the potential of solar water heating and photovoltaic systems in the four zones of Madurai city. In this connection, solar radiation was continuously monitored at the four zones for a period of one year. From the study it is found that Madurai receives global solar radiation in the range of 3.37 – 6.25 kW/m². The analysis showed that global solar radiation is available in surplus throughout the year in all four zones of the city and that the city is ideally suited for harvesting solar energy. The potential of solar water heating in the domestic sector of Madurai city was assessed in the study. During the survey, the total roof area of the sample respondents in the four zones was calculated and was found to be 41,235 m². It was estimated that 4,123 systems of capacity 100 litres per day (lpd) could be installed on rooftops to meet the hot water demands of the population and could save upto 6.18 GW of electricity annually. The potential of solar photovoltaics was also analysed. It was found that there is an enormous potential for installing 3.61 MW photovoltaic system in the total available roof area of the sample households under study.

1. Introduction

Solar radiation data is a fundamental input for solar energy applications such as photovoltaic, thermal and passive solar systems. Solar radiation data should be contemporary, reliable and readily available for design, optimization and performance evaluation of solar technologies for any particular geographical location. Solar energy applications require a complete knowledge and detailed analysis about the potentiality of the site. Therefore, measurement of solar radiation at ground level is an important feature in solar energy conversion systems [1]. This calls for a complete study of solar radiation incident in any given locality. Many renewable energy technologies such as solar water heaters, air heaters and photovoltaic systems have been installed in some areas in Madurai. However, these systems have been installed using insufficient data or no data at all apparently because there is no detailed information on the solar energy resource in the city. The result has been that many of them have not performed to the owner’s expectations. For proper performance, the following need to be known beforehand – (i) The magnitude of the available resource and (ii) Temporal and spatial characteristics of the available resource. This information enables one to select or use a system that will operate well at all specific sites. This forms the basis for this study as it seeks to provide reliable information on the availability of the resource in the region [2].

2. Experimental Methods

2.1 Study Area

The study was conducted at Madurai, a major city in the state of Tamil Nadu in southern India. Madurai is the second largest corporation city by area and third largest city by population in Tamil Nadu [3]. The jurisdiction of Madurai Corporation has been extended to include the areas of the city corporation, 3 municipalities, 3 town panchayats and 11 village panchayats located around the Madurai corporation. Consequent

to this extension, the total area of the corporation has increased considerably from 51.82 km² to 147.997 km². The number of the wards has increased from 72 to 100, dividing into four regions - Zone I, II, III, IV [4]. The Zone-wise distribution of Madurai municipal corporation is shown in Fig. 1.

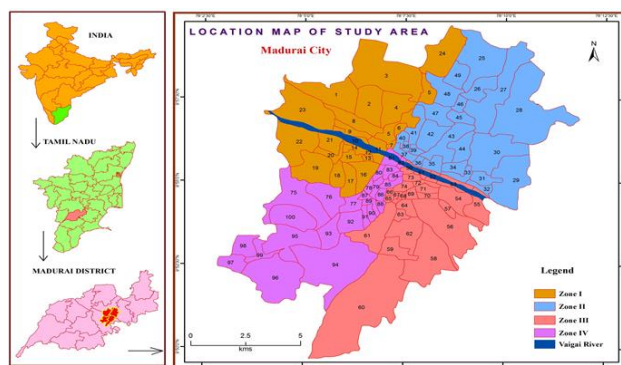


Fig. 1 Location map of the study area showing the four zones and 100 wards

2.2 Primary and Secondary Data Collection

Zone 1 (North zone) comprises of ward numbers 1-24. Zone 2 (West zone) comprises of ward numbers 25-49. Zone 3 (South Zone) comprises of ward numbers 50-74. Zone 4 (East zone) comprises of ward numbers 75-100. The study was based on both primary and secondary data and the questionnaire was so designed as to overcome recall bias to the possible extent with various checks [5]. The questionnaire was circulated in all 100 wards so that due representation is given to the whole city. The required primary data was collected from the selected households with the help of an interview schedule, accomplished through personal interview method. Due care was taken to avoid bias and to ensure accuracy of data [6]. The secondary data was collected from the Directorate of Economics and Statistics, the District Collector’s Office, the Taluk Office, various journals, books and websites.

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3. Results and Discussion

3.1 Assessment of Solar Energy Potential in Madurai City

Solar radiation was continuously monitored at the four zones of Madurai city for a period of one-year in order to assess the potential of this renewable energy in the city. Solar radiation was measured using pyranometers (Kipp and Zonnen make) having a range of 0 to 1200 W/m² and a resolution of 0.1 W/m². Data were recorded at intervals of 1 minute using data loggers and the daily, monthly and annual averages were calculated. The monthly average solar radiation measured at the four zones of Madurai city are presented in Table 1.

Table 1 Global solar radiation in the four zones of Madurai city

Month	Solar radiation (monthly average) (kW/m ² /day)			
	North Zone	South Zone	East Zone	West Zone
January	3.98	3.88	3.79	3.70
February	4.97	4.90	4.84	4.82
March	5.25	5.28	5.34	5.36
April	5.97	5.85	5.95	5.99
May	6.25	6.20	6.19	6.23
June	5.82	5.88	5.92	5.88
July	5.64	5.71	5.67	5.70
August	5.51	5.42	5.50	5.49
September	5.48	5.40	5.50	5.46
October	5.31	5.28	5.30	5.29
November	4.66	4.76	4.71	4.73
December	3.58	3.37	3.53	3.42
Average	5.82	5.79	5.82	5.80

It was inferred that Madurai receives global solar radiation in the range of 5.25 – 6.25 kW/m² during summer, 5.42 to 5.92 kW/m² during south west monsoon, 4.66 to 5.50 kW/m² during north east monsoon and 3.37 to 4.97 kW/m² during winter. The analysis reveals that maximum global solar radiation is available throughout the year in all four zones of the city. The study identifies that this city is ideally suited for harvesting solar energy.

3.2 Assessment of Solar Water Heater (SWH) Potential in the Domestic Sector of Madurai City

Madurai has only a small market for solar water heaters (SWH). The estimate of SWH installations in the city is 100,000 lpd. Out of this only 30% are in domestic sector. On an average there is a 10% growth annually in SWH penetration [7]. Hot water requirement is less in the domestic sector. The awareness levels are also very low amongst the households. The installations of SWHs in the hospital sector have risen remarkably. The reason may be attributed to the increase in hot water requirements with the increase in the number of beds. All sizes of hospitals have a SWH installed to meet their daily hot water requirements [8]. Many installations were found in hotels located near the railway station. Small sized hotels are sceptical to change to solar water heaters, as they are not aware of its performance and the costs that would incur for its maintenance. Constraints for the hotel sector are space (which could be used as a roof top restaurant), large initial investment, loss of investment already made in acquiring electric geysers, and many disappointed users due to slow/non-payment of subsidies.

Based on the primary and secondary survey, the total SWH installation is estimated to be 4.2 thousand square meters in Madurai city. The sectoral share in the city is almost same as that for the state. The present scenario is summarized in the Table 2 given below.

Table 2 A comparison of the present SWH Scenario in Tamil Nadu and Madurai city (Cumulative m² of SWH)

Sector	Tamil Nadu	% to the total	Madurai	% to the total
Residential	74,000	64.3	2,700	64.3
Hotel	36,000	31.3	1,300	30.9
Hospital	3,000	2.6	100	2.4
Hostel/Others	2,000	1.7	100	2.4
TOTAL	1,15,000	100.0	4,200	100.0

Source: Report of global solar water heating project, MNRE, Gol (2011)

To assess the potential of solar water heating systems in the study area, the area available on the roof tops has to be assessed. During the survey, the total roof area of the sample respondents in the four zones was calculated and was found to be 41,235 m². Table 3 shows the total available roof area and the number of solar water heating systems that could be installed at the rooftops of the sample respondents at the four zones of Madurai city. It can be observed from the table that if 20% of this

area could be used for installation of solar water heating systems, the total available area for installation would be 8,247 m². This implies that 4,123 systems of capacity 100 litres per day (lpd) could be installed on rooftops to meet the hot water demands of the population taking into account the fact that a 100 lpd system occupies 2 m². A 100 litre per day capacity system suitable for 3-4 people can save up to 1500 kW of electricity in a year depending on the amount of hot water used. Therefore if 4,123 systems are installed, upto 6.18 GW of electricity can be saved annually besides reducing greenhouse gas emissions in the atmosphere.

Table 3 Total available roof area for installation of solar water heating systems in the sample households of the four zones of Madurai city

S. No.	Zone	Total roof area available (m ²)	No. of 100 lpd systems that can be installed	Cost of installation (in lakhs of Rupees)	Cost of electricity saved (in lakh of Rs.)
1	North Zone	2326.3	1163	98.9	17.4
2	South Zone	2325.1	1162	98.8	17.4
3	East Zone	1691.8	846	71.9	12.7
4	West Zone	1903.9	952	80.9	14.3
	TOTAL	8247.1	4123	350.5	61.8

3.3 Assessment of Solar Photovoltaic (PV) Potential in the Domestic Sector of Madurai City

A photovoltaic system comprises a solar panel, storage system, charge controller, and maximum power point tracker (MPPT). MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. However, different types of these components are made from various technologies which in affect the performance of a PV system [9]. Knowledge of the performance of each component is vital in the design of a PV system. Secondly, the performance of the PV modules and other components varies from place to place depending on the weather conditions at the site. Outdoor tests performed over a period of time are the best way of evaluating the components, and hence, the system performance. Poor workmanship also affects the performance of photovoltaic systems [10].

From the preliminary survey, the total available roof area in the sample households is estimated to be 46,152.7 m². If 70% of this area could be used for installing solar photovoltaic technology for electricity generation, the total available area would be 28,864.5 m². The area occupied by a 1 kW photovoltaic system is 8 m². Therefore, 3608 systems of capacity 1 kW can be installed in the available area. There is an enormous potential for installing 3.61 MW photovoltaic system in the total available roof area of the sample households under study.

Table 4 Total area available for installation of solar photovoltaic system in the four zones of Madurai city

S. No.	Zone	Total roof area available (m ²)	No. of 1 kW systems that can be installed	Average cost of installation (in lakhs of Rs.)	Cost of electricity saved (in lakh of Rs.)
1	North Zone	8142.05	1018	1221.3	25.6
2	South Zone	8137.85	1017	1220.6	25.6
3	East Zone	5921.16	740	888.2	18.7
4	West Zone	6663.51	833	999.5	20.9
	TOTAL	28,864.57	3,608	4,329.6	90.8

Table 5 Photovoltaic systems required to meet the existing demand of the sample households

S. No.	Zone	Annual consumption of electricity (MW)	Cost of purchase of electricity (in lakh of Rs.)	PV systems required to meet the demand (kW)	Average cost of installation (in lakhs of Rs.)
1	North Zone	1453.1	29.1	576.6	691.9
2	South Zone	1425.1	28.5	565.5	678.6
3	East Zone	1363.5	27.3	541.1	649.3
4	West Zone	1374.3	27.5	545.4	654.4
	TOTAL	5616.0	112.4	2,228.6	2,674.2

From Table 4, it can be observed that the approximate cost of installation of these systems would be 43.29 crore and the cost of electricity saved is around 0.91 crore. The capacity of photovoltaic

systems required to meet the existing demand of the domestic sector in the four zones of Madurai city is furnished in Table 5.

It is estimated that a total of 5,616 MW of electrical energy is consumed annually by the sample respondents in the four zones. The total cost of purchase of this energy is Rs. 1.12 crore. To meet the existing demand of 5,616 MW of electricity in these zones, 2.23 MW system would be required, which would cost Rs. 26.74 crore. To install systems having a total capacity of 2.23 MW, an area of 17,840 m² is required. But the total available roof area is more than the required area. Therefore, the potential for harvesting more solar energy than the demand is higher in these four zones of Madurai city.

4. Conclusion

Solar energy is a clean, pollution free, and renewable source of energy. Development of this source of energy requires an accurate detailed long-term knowledge of the potential taking in to account seasonal variations. Madurai city is ideally placed to take benefit from what solar energy source can offer. The study identifies that the four zones of Madurai city with abundant global solar radiation throughout the year are ideally suited for harvesting solar energy.

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