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QUANTITATIVE ASSESSMENT OF CARBON EMISSION REDUCTION BY SOLAR PHOTOVOLTAIC PLANT AT KOLAR DISTRICT, KARNATAKA, INDIA

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ABSTRACT

Implementation of renewable energy technologies in Karnataka is a pioneer in the country as part of its commitment to reduce greenhouse gas emissions. Yelesandra Solar Photovoltaic Plant was established in semi-arid regions of Kolar District, Karnataka in 2010 and the area is rich solar insolations. The study was conducted to quantify the carbon emission reduction by a solar photovoltaic plant through its power generation performance over a period of five years in a semi-arid region where biomass accumulation is negligible. The results revealed that, out of 5 consecutive years of power generation, the plant achieved highest power generation of 3348437 KWh and 2012 being the lowest record due to shut down of plant for operation and maintenance. The total power generation during 2011-15 was 20757 MW resulting in reduction of 19607.06 tCO_2*. The total monetary benefit achieved from the carbon credit was 2.19 crores and the sale of electricity benefit was Rs. 89.25 crores at Rs. 4.36/KWh. Large scale solar projects on waste lands and irrigation canal can be considered by conducting environmental impact assessment studies throughout the state. The solar energy is the sustainable energy source for future generation having multiple environmental benefits and play crucial role in meeting energy demands of the state and country as well.*

Key words: Solar energy, Power generation, Environmental benefits, Carbon emission reduction

Introduction

Solar energy is an important renewable energy harnessed from sun using various technologies. The process of conversion depends on geographical location and rotation of sun and earth to the axis. Based on the solar insolation intensities, the solar hotspots will be identified for commercial harness. India has incredible scope for harnessing solar energy as most part of the country has 300-330 sunny days in a year. The country has potential of harnessing 20 MW of solar energy / Sq. Km [18]. With the current magnitude of climate change resilience, solar power is always an alternative source for the reduction of fossil fuel emissions. The power consumption for various activities during day time is always more and the solar power production during day time offset the demands satisfactorily [5] and [18].

The Ministry of Non-Renewable Energy (MNRE), Govt. of India launched an ambitious programme Jawaharlal Nehru National Solar Mission (JNNSM) in 2010 with an objective to harness 20000 MW by 2022 and providing 20 million solar lighting in rural areas [13]. The Ministry has launched several incentive programs to encourage the mission and in the year 2008, Govt. of India pronounced National Action Plan for Climate Change (NAPCC) initiative to combat greenhouse gas emissions. As a part of the programme, Generation Based Incentive (GBI) was introduced to promote grid connected solar power plants for the first time in India [16]. In the 21st Conference of Parties (COP) meeting of United Nations Framework Convention on Climate Change (UNFCC) held at Paris in 2015, India was committed to install 175 GW of renewable energy by 2022 and out of which 100 GW was solar energy contribution [12]. As a part of commitment to UNFCC agreement, Karnataka was committed to install 6000 MW of renewable energy BY 2022 [11].

As on 31.12.2017, the total installed capacity of solar power was 17052 MW across the country and 1800.85 MW in Karnataka alone. Apart from large scale stand alone solar power plants (7754 Kwp) in Karnataka, 7334 lanterns and lamps, 52638 home lights, 2694 street lights and 4118 pumps has been connected with solar power. As on March, 2018, Karnataka state has installed 4884 MW renewable energy projects and stands first in the country followed by Telangana (3378 MW) and Rajansthan achieved 2279 MW [13]. Karnataka has gift of high solar insolation ranging between 5.41- 6.02 Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) (KWh/m^2) respectively and thus the entire state is convenient for installation of large scale solar projects [10 & 11]. Importantly, it is crucial that the industry receives the right policy support to ensure that projects are executed and performed up to the mark to achieve the desired targets [19].

Adoption to solar energy is having multiple environmental benefits besides long term operational changes in reducing greenhouse emissions, micro climate, land use land cover, hydrology, etc. The environmental components must be integrating with the project objectives to achieve the sustainable benefits [8] and [3]. The studies revealed that, large scale solar plants has maximum environmental benefits and less impacts if it is planned in places such as deserts, high intense solar insolation areas and wildlife nil areas[4]. Hence, site specific analysis of environmental impacts and benefits assessments is essential to ascertain the least environmental impacts [6] and [7].

The solar energy is an ideal solution for mitigating greenhouse gases and to achieve this urban planning and decision making at the policy level is also essential [1]. The carbon sequestration in semi-arid areas is quite challenging in the absence of vegetation dynamics [15]. Under such circumstances, waste lands can be making use to harness solar energy to balance the ecosystem needs. Under such circumstances, the objective of this paper is to quantify the carbon emission reduction by a solar photovoltaic plant and its performance over a period of five years in a semi-arid region where biomass accumulation is negligible.

Study area

Kolar District is located in the southern plain region of the Karnataka State, India. It lies geographically between 77^0 21' to 78^0 35' east longitude and 12^0 46' to 13^0 58' north latitude (Fig 1). The land use of the district comprising of about 47% agriculture lands where as 42 % covered by wastelands. The ground water in the district is overexploited [2]. According to Census report of 2011, the population of the district was 15.36 lakhs. Kolar belongs to the semi-arid zone of Karnataka. The average fuel wood requirement of the district was 1.3 Kg/person/day [17]. Apart from, year to year fluctuations in the total seasonal rainfall, there are also large variations in commencement time of rainfall. The district depends upon the distribution of rainfall during the southwest and northeast monsoon seasons. Yelesandra Solar Photovoltaic (SPV) Plant of 3MW capacity located in Kolar District was the first of its kind plant in Karnataka implemented in large scale during 2009-10 was selected for the study. The plant starts its operation from 2011 and successfully running in the semi-arid zone of Karnataka [9]. The details of the plant are given in Table – 1.

Table – 1 Details of Yelesandra Solar Photovoltaic (SPV) Plant

Sl.No	Particulars	Details
1.	Latitude & Longitude of plant	12^0 53^I& 78^0 09^I
2.	Allotted Land Area	15 acres
3.	Nominal Capacity of the PV Plant	3 MW
4.	Date of Commission	December, 2009
5.	Commissioned by	Karnataka Power Corporation Limited(KPCL), Government of Karnataka
6.	Installed by	Titan Energy Systems Ltd., Secunderabad, Telangana
7.	Modules	Titan S6-60 series
8.	SCADA for diagnosing and monitoring	Yes
9.	PCU (Inverters)	250 kW (12 Nos.)
10.	HT Transformer and switchgear for evacuation	1.25 MVA for each MW
11.	Total project cost	60 Crores

Materials and Method

The study has taken up to understand the solar power generation and CO_2 emission reduction out of the unit. Meteorological data pertaining to the study area was collected from the Karnataka State Natural Disaster Monitoring Centre (KSNDMC), Bangalore. The data collected was analyzed for temperature and rainfall pattern of Kolar District. The district is known for high temperature and minimum rainfall in the state. This condition helps for harnessing of solar energy in a larger scale when compared to other districts.

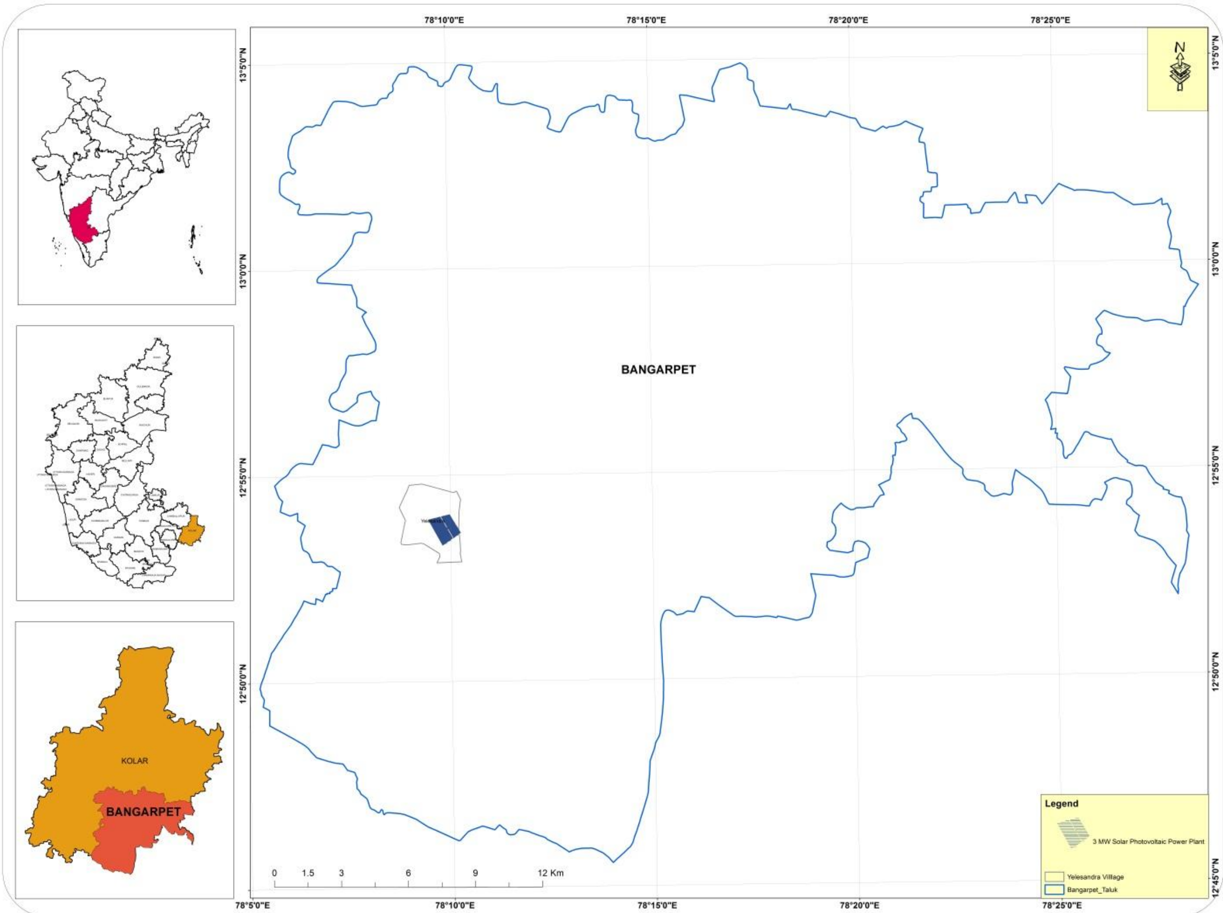

Fig 1. Study area map of Yelesandra Solar Photovoltaic (SPV) Plant

The area with high insolation radiation, semi-arid area was the priority with the focus mainly on carbon emission reductions with the non-renewable energy sources. Plan of visit to the study area was organized and discussed with the plant officials to obtain detailed information about the power generation for the year 2011-2015. The study area was frequently visited in 2016-17 to understand the geo-political characteristics. During the visit, discussion with site engineers of Karnataka Power Corporation Ltd (KPCL) were undertaken to understand the details of the pant and its functioning. Statistical tools were used to analyze the data collected during the study.

Results and Discussion

Rainfall and Temperature

Kolar district is located in the semi-arid climate zone with an uneven annual rainfall of 700-800 mm/year. During the period, the average rainfall was spread between June and October. In the year 2011, the average rainfall was recorded in 141.82 mm (Table-2) in October and whereas in 2012, 145.44 mm was recorded in the same month. Except in 2015, the average rainfall is recorded in the month of October in all the years between 2011 and 2014. However, in the year 2015, the rainfall was spread between August and November (353.09 mm) except in October.

Table 2. The average rainfall (mm) recorded during 2011-2015 in Kolar District

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2011	0.16	12.0	1.0	89.6	62.82	36.4	102.44	130.33	48.51	141.82	42.76	16.27
2012	3.90	0.14	3.56	65.6	102.26	36.37	141.44	91.98	44.27	145.44	106.26	27.96
2013	0.14	13.91	4.48	49.71	61.61	54.66	52.13	70.49	18.38	128.44	29.33	3.94
2014	0.00	0.06	15.49	4.05	78.23	86.15	50.56	47.40	78.13	138.94	32.11	10.45
2015	6.90	0.40	35.11	104.63	86.43	75.35	39.42	105.92	153.24	72.60	353.09	15.71

The average temperature in the district is between 35^o-38^oC. The maximum temperature was recorded during April-May in the range of 39^o- 40^oC in all the years. Interestingly, even during the monsoon season, the average maximum temperature recorded in the region was 34^o-47^oC.

Power Generation

In the year 2011, the power generation for the month of March was the highest and October being the lowest. In the month of October there was continues yield loss due to inverter failure and rainfall. The total yield loss due to inverter failure recorded was 45355 KWh. The power generation in the month of March was 470800 kwh, and in the month of October it was 272400 kwh, whereas in 2012, the highest power generation was in the month of March followed by February and January. There was no data of failure in the inverter and the yield loss from the gird was comparatively very less. There was no error in data logger as well. In the month of November, the power generation was very less since the plant was shut down for about 5 days due to technical maintenance. The power generation for the month of March was 419101 KWh (Fig 2) and for the month of November was 114376 KWh.

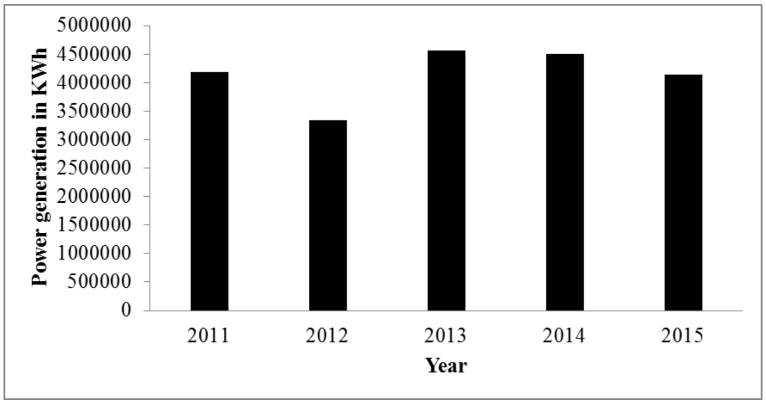

Fig 2. Power generations recorded during 2011-2015

The month of January (459600 KWh) recorded the highest power generation during 2013 which is followed by the month of March (446200 KWh). Of all the years between 2011and 2015, the maximum power generation was recorded in the year at the range of 4561400 KWh (Fig 1) and the lowest power generation recorded was 310200 KWh. The lowest recorded was in the month of July. There was inverter failure which results in yield loss. There was also yield loss due to grid failure recorded as 5916.96 KWh. Yield loss due to switch yard failure was also high (1338.12 KWh) during the period.

In 2014, the highest power generation was recorded in the month of March whereas the lowest was recorded in the month of December. March being the hottest month with an average temperature of 38.9^o C produces more energy. There was no yield loss recorded as no inverter failure. But, there was yield loss due to grid failure which was about 9661.68 KWh. In the month of December there was several problems related to power generation. Often there was Grid failure in most of the days, data logger error occurs for 1st, 2nd and 3rd MW and sometimes voltage trip was occurred. Yield loss due to Grid failure in the month of December was 10788.12 KWh. The power generation recorded in the month of March was 477168.7 KWh and for the month of December 310881.3 KWh was recorded.

In 2015, the highest power generation recorded was in the month of March followed by February. Whereas, the lowest power generation recorded was in the month of November as continued grid failure and data logger not recorded data for the 1st and 2nd MW. This problem leads to lowest power generation. The power generation for the month of March was

449272KWh (Fig 2) and for the month of November the power generation recorded was 237600 KWh.

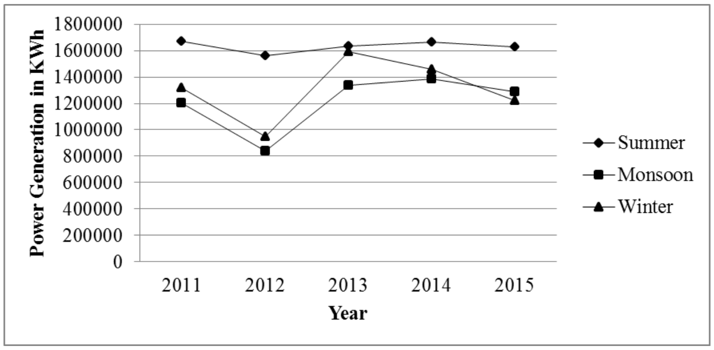

Fig 3. Power generations in different seasons during 2011-2015

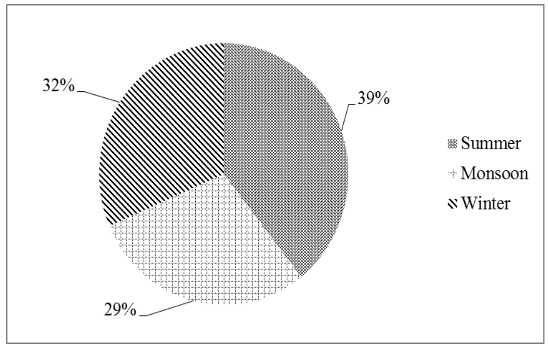

Fig 4. Power generation contribution in different seasons

The power generation during summer appeared to be high (39%) in the months of February to May (1667510 KWh) in 2014. Whereas, in Monsoon season (June-September) was being the lowest (29%), the power generation was during 2014 at the range of 1382676 KWh. Similarly, 1589800 KWh power generation was recorded during winter season (October – January) in the year 2013 followed by the year 2014 (1458995 KWh). The season contributes 32% of the total power generation (Fig 3 & 4).

Carbon Emission Reduction

As per the Project Design Document (PDD) submitted to avail Clean Development Mechanism (CDM) benefits by the project authorities in the year 2012, the average projected emission reduction designed for the project was 4220 tCO_2/Year (0.9446tCO_2/MWh). However, as agreed the target was exceeded slightly in the year 2013 (4308tCO_2/Year) and 2014 (4259 tCO_2/Year) and was not able to reach the target in 2011, 2012 and 2015 due to switchyard failure, grid failure, error in data logger and inverter failures (Fig 5).

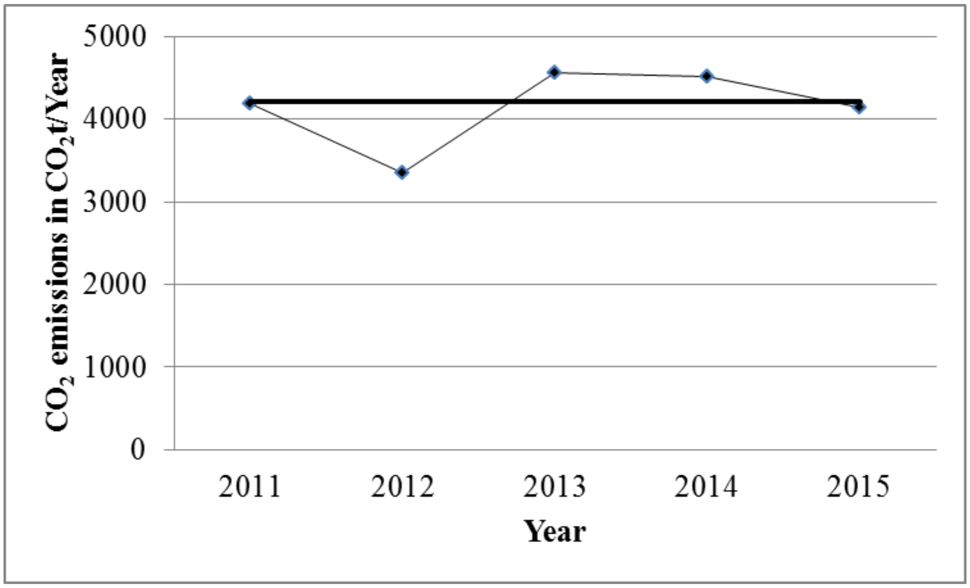

Fig 5. Carbon emission reduction tCO_2 /Year achieved during 2011-2015

The carbon emission reduction in terms of monetary benefits is calculated as given below.

The total power generated during 2011-2015 at Yelesandra Plant - 20757516 KWh (20757 MW)

The projected carbon emission reduction designed for the plant – 0.9446tCO_2 /MWh

Total carbon emission reduction in the last 5 years – 20757 MW x 0.9446tCO_2 /MWh = 19607.06tCO_2.

Present trade of per tCO_2= 13.92 € (as on 11.05.2018)

Thus, 1967.06 tCO_2 x 13.92€ = 2, 72,930 € (Rs. 2, 19, 68,160/- @ 1€ = Rs. 80.49 INR as on 11.05.2018)

Conclusion

The analysis of meteorological data indicates that, monsoon being the lowest power generation period and reduce by 10% and 12% when compared to summer (39%) and winter seasons (32%) respectively. However, rainfall and temperature has no significant impact on power generation reduction. Out of 5 consecutive years of power generation, 2012 being the lowest record due to shut down of plant for operation and maintenance. Apart from that, the common problems associated with the plant causing power generation reduction was due to repeated switchyard failure, grid failure, error in data logger and inverter failures. Hence, KPCL and project authorities shall have to concentrate on these aspects to improve the power generation without interruption [14]. The total power generation during 2011-15 was 20757 MW resulting in reduction of 19607.06 tCO_2. The total monetary benefit achieved from the carbon credit was 2.19 crores and the sale of electricity benefits was Rs. 89.25 crores @ Rs. 4.36 / KWh (KERC, 2017). Thus, the plant was already recovered its expenditure and makes it sustainable for future electricity needs of the state.

Kolar district has recorded 42% of wastelands in the district and the suitability of these lands for large scale implementation of solar power projects may be considered by adopting win-win approach with local self-authorities towards achieving the target negotiated at UNFCC in the 21st COP meeting held at Paris. Many researchers opined that, solar power projects have least environmental impacts but this would be studied with greater attention to site specific details. Presently, Government of India exempted preparation of environmental impact assessment studies for solar power projects and kept out from the purview of obtaining statutory environmental clearance under the Environment (Protection) Act, 1986. But, this needs to be re-examined keeping in view of operational phase impacts on land use/land cover, surface hydrology, local biodiversity, soil biota, etc.

Nevertheless, Karnataka is gifted with high solar insolation range for the entire state, the agricultural lands, forest areas, wildlife corridors and areas with ecological significance shall not be considered for large scale solar installations [20]. However, in order to make the project techno-economically sustainable and to achieve the desired targets by 2022, the canal top solar projects shall be encouraged which is having multiple benefits adding to zero land acquisition, checks evapo-transpiration of canals and also reduces regular canal maintenance. A pilot project of 1 MW capacity was installed on Almatti Right Bank Canal of Upper Krishna Project in Bagalkot District, Karnataka which is running successfully in the state. Now, the MNRE in 2017 approved 10 MW canal top solar projects on Narayanpur Left Bank Canal of Upper Krishna Project in Raichur and Yadgir Districts under Public Private Partnership (PPP) paved way for such projects in the near future.

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