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Analysis of Global Solar Radiation in Solar Sector: An Empirical Feasibility Study in India

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Abstract - *Most of the previous research focused on the solar radiation but they never paid much attention to the optimum radiation collection with the solar sector in India. There are so many other benefits also like prevention of climate change and nature procurement. This article concentrates on the factor of solar radiation that influences the optimum collection of solar radiation. This article is an attempt to Bridge the gap between previous researchers and new research. It is not possible to study or survey of entire research in a single research paper. So I have taken a district of South Region that is Coimbatore (Tamil-Nadu) and data analyses on the basis of factors such as wind speed, relative humidity, Sunshine hours, suspended particulate matter (SPM) and air pressure. The Methodology is quantitative Perspective. And the impact on the price of PV cell with the change in time and technology, which may be helpful for the government as well as the private sectors in India, because we think that the initial capital cost of solar panel installation is too high. This may be a source for selection of proper location and also proper PV cell. Nowadays, measurement of solar radiation is very essential for the different-different field of applications, such as meteorology, climatology, hydrology, pollution forecasting and also for agriculture. Also for the design and operation of solar energy conversion devices, solar radiation is considered as a most important parameter.*

Key Words: Global solar radiation, factors of radiation, non-conventional energy, distribution of incoming solar radiation, change in position of the sun with time, price variation of PV cell.

1. INTRODUCTION

In Today's era, there is a global energy crisis in India as well as in entire world and this will increase day by day due to the depletion of conventional energy sources. To overcome this problem, the demand for the development of alternative energies has also grown in past few decades. Therefore, to complete this energy demand, solar energy is one of the best elimination for conventional sources (such as coal, oil, wood etc.) because these are limited and also creates pollution due to high carbon content. As we know that entire India, as well as the world, is suffering from "Climate Change", for prevention of climate there is a lot of money expended by so many countries like the USA. This is due to high concentration of carbon and its oxides such as Carbon monoxide (CO), methane (CH_4) and carbon dioxide (CO_2) present in air, due to air pollution which results "Global Warming" and due to Global warming, the temperature of surrounding also increased and this increase in temperature will also utilize as a solar energy.

1.1 India Scenario of Area

India is one of the biggest countries in South Asia. India has 29 states and 7 union territories and the population is around 1.35 billion (in 2018), which is accounting for more than 17.74% of world's population. It is 7th largest country in the world with total land area 3,287,263 km square. It has a land frontier of 15,200 km and coastline of 7,517 km. India measures 3214 km from North to South and 2933 km from East to the west. The energy consumption of India is at 4th position in the world i.e. after China, USA and Russia.

1.2 Solar energy scenario in India

Renewable source of energy is the great opinion for the long-term view. Among the various renewable energy sources, India receives a very large amount of solar energy, which is about 300 clear sunny days (Pillai and Banerjee 2009) in a year. India receives approximately 5000 kWh/year and the daily average solar radiation incident over India varies from 4kwh/day to 7kWh/day. The Jawaharlal Nehru National Solar Mission (JNNSM) was launched by Prime minister of India in 2010, with a target of 20,000 MW solar power capacities by 2022. In January

2015, the Indian government expands this scheme and decided to achieve the target of 100GW and invest US$100 billion. In 2016 "Suryamitra" skill development program has also started by the government of India which is sponsored by Ministry of New & Renewable Energy and organized by National Institute of Solar Energy (NISE). The duration of this skill development program is 600 hrs. (Approximately 90 days). The aim of scheme "Suryamitra" is about to achieve the target of 175 GW which includes 100 GW from solar Energy by 2022.

These targets help not only to achieve green energy but also help to create millions of jobs in India. India also attains a target of having 70% renewable energy use by 2050. In India, the largest solar steam cooking system with capacity 15,000person/day has installed in Tirupati Tirumala Devasthanam (Southern part of India). To enhance the production of solar power in India, the government provides offers such as subsidies in a purchase of solar power-based technology and also decrease the price of equipment used in solar technology like PV cells etc.

1.3 Solar Radiation

Solar radiation is electromagnetic waves which are received from the sun, over a wide range of wavelengths at varying intensities. The wavelength comes from the sun are between the intensity of 300 nm to 3000 nm called shortwave radiation. If the wavelength is short then frequency must be high because the wavelength and frequency is indirectly proposal to each other. Therefore, these waves come to earth with very high energy. The total energy emitted by the sun is around 3.72 X 10^{20} MW. The solar radiation reaches at a rate of 1,367 W/m^2 to the upper surface of the earth.

1.4 Advantages of Solar Energy

These are the main advantages of solar energy,

- These are the Non-Conventional source, which means unlimited.
- Reduce the dependency on fossil fuel.
- If we eliminate the initial cost, then it is free of cost.
- No noise creates.
- No harmful exhaust such as carbon contained gases like other.
- Reduce the effect of Global Warming.
- Maintenance cost is also low.
- No any kinds of health issues.
- For operation no fuel required.

According to Kunal Munshi, In Antarctica where extreme case i.e. six months of daylight and six months of the nightlight. In such an extreme condition solar panel works marvellously in diffused solar radiation. When the sun is not available properly and also solar panel covered with ice (in some cold areas like Leh & Ladakh and mountain reasons). Since it justifies that solar panel can work in all season. Which we can see in the picture (i.e. Fig-1) given below.

Fig-1: Solar Panel works on Antarctica even covered with ice partly.

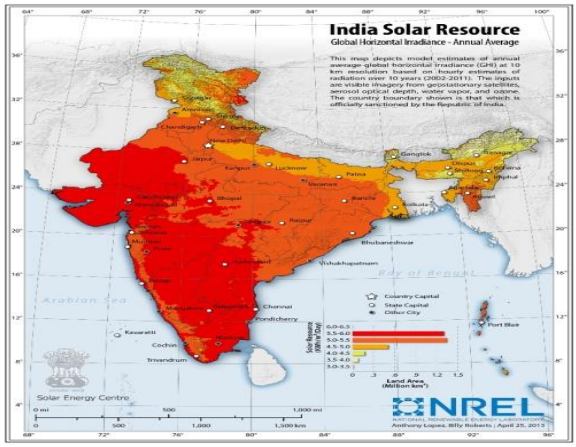


Fig-2: Indian geographical map showing area wise radiation. Source: NREL (National Renewable Energy Laboratory) Website.

"India blessed with solar radiation by nature" which we can see in the figure given below that is taken from Solar

Energy Centre. But we are still backward as compared with China and Germany (which are the superpower in solar the sector). So, this paper is based on the study of Global solar radiation, factors affecting its performance and appropriate locations for the installment of Solar panels.

As we can see in the above picture (Fig-2), most of the areas are covered with Red (i.e. excellent radiation) and Orange (i.e. Good radiation), therefore I said India blessed with solar radiation by nature and with the help of this God gift India can become a superpower in solar sector and can fulfill the most of the energy requirement itself and can be a self-depended country.

2. Literature Review

A Literature review is an important aspect in the field of research. A successful research can be carried out with the help of previous research and the current scenario. The summation of these two parameters always brings a researcher in a successful position. For planning of research, a researcher needs some tools such as books, dissertation, journals, thesis and some other sources of information (like the Internet) and a proper guide also.

2.1 Necessity of Global Solar Radiation (GSR) measurement

For enhancing the quality of life and for the progress of society we need the high amount of energy but the extensive use for fossil fuel creates bad impacts on the environment such as air pollution (due to combustion of carbon contained in fuel) and social and sustainability problems like the Greenhouse effect. So, to overcome the dependency on conventional fuels many researchers and some organizations are working on to get some alternative fuel, which should be a convenience to use, easy to store, also minimize the pollution and must be abundant in nature. In this direction, non-conventional energies like solar energy, wind energy, tidal energy, geothermal energy, and biofuels are more suitable than the conventional source of energy. India is blessed and honor with an abundance of higher potential and environment-friendly source of energy i.e. solar energy resource with entire year, which can be used for the domestic as well as industrial applications throughout the year. Therefore, it is very necessary to study the global solar radiation to analyses the atmospheric energy balance studies, thermal load analysis of buildings, agricultural studies and meteorological forecasting. The accurate knowledge of solar resources at any place also helps the Architects, Engineers and Agriculturist with respect to economic and efficient work.

2.2 Review of article in solar irradiation measurement

In this literature review, I have done a study on the intensity of radiation at a different location of India such as North, East, West, South and Central region in a different season. In several researchers, it was found that the intensity of radiation is excellent in the South region followed by west region and estimates the global solar radiation for Chennai (south region), quadratic equation gives a better result than the linear equation and the derived correlation is expected to estimate monthly average global solar radiation for Chennai location. This result can be also used for such location which has similar geographical characteristics at which solar data are even not available. The intensity of radiation also depends upon the location of the site (i.e. Urban or rural) and also upon season. According to (Robaa 2009) states that an urban area always receives the value of global radiation lower than that for the rural area. And monthly and seasonally mean values of calculated global radiation rise from minimum during the winter season (mainly December) to maximum during summer season (mainly June). The behavior of the sun in the different-different season can be understood with the help of the pictures given below and these pictures are as follows.

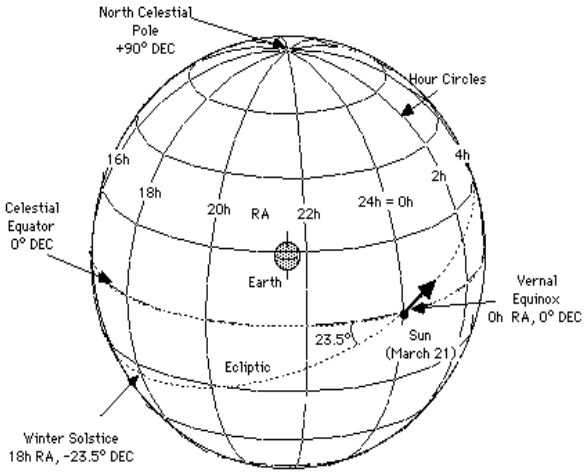


Fig-3: Position of Sun varies with respect to time.

(Braslaut, Thomas, and Heights 1976) and (Riordan et al. 1991) have pointed out the importance of solar radiation data for the optimal design and efficient operation of the solar energy system. In the design purpose, solar energy data are recognized as a very important but their acquisition is not easy due to its variation with time and space. Unfortunately, for many developing countries, solar radiation measurements are

not easily available for monitoring programs (Togrul, Togrul, and Evin 2000) and (Ibrahim et al. 2013) at different locations because of the expensive measuring equipment and technique required. (Elminir, Azzam, and Younes 2007) also discussed the information on the availability of solar radiation and also highlighted the main reason for the inadequacy of the current observation network.

Many researchers adopted various techniques for the measurement of global solar radiation. Angstrom type regression model was developed by (Veeran and Kumar 1993) this method correlating the relation between global solar radiation and sunshine hours to estimate to estimate the monthly mean daily global solar radiation at two different locations with the help of previous data of five years. (Besharat, Dehghan, and Faghih 2013) also used Angstrom type equation of first and second order for determining the monthly daily global radiation at Karachi. (Augustine and Nnabuchi 2007) developed a new equation of Angstrom to predict monthly mean daily global solar radiation incident on a horizontal surface in Warri, Nigeria. An empirical model was proposed by (Prieto, Martínez-García, and García 2009) in Asturias, Spain to estimate monthly mean daily global solar radiation with the help of temperature of the air.

(Besharat et al. 2013) reviewed the extensive global solar radiation models available in the historical literature. They classified the empirical model into four different categories on the different basis which are temperature-based, sunshine-based, cloud-based and last, is based on meteorological parameters. To evaluate the accuracy of monthly average daily global solar radiation on a horizontal surface, meteorological and geographical data of Yazd city, Iran was used. After evaluation and comparison of on the basis of statistical errors, the most accurate methods of each category were taken. Result revealed that all the proposed correlations have a good estimation of the monthly average daily global solar radiation on a horizontal surface in Yazd city. And finally, it was found by the El-Metwally that sunshine-based model predicts the monthly average global solar radiation with the highest accuracy among them.

(Quansah et al. 2014) proposed empirical model on the basis of the sunshine hour and temperature based to determine the global solar radiation in the Ashanti region of Ghana. Seven models were used in the evaluation method, by exploiting the Angstrom-Prescott model and Hargreaves-Samani model. Experimental analysis showed that the suggested Angstrom-Prescott underestimate the global solar radiation in the month of April to June and also in October-November. However, this also overestimates the August, September and December months. Further, it is cleared that the suggested model is not suitable for measuring the long-term solar radiation.

There are also some semi-empirical models which are obtained from satellite images; these images provide an alternative to expensive ground-based pyranometer measurements. These images help in the forecasting of irradiance present an environment where no any is available. But there are also some major difficulties which arise when comparing satellite and ground data measurement technique. These satellite data are instantaneous “snapshots” image of small solid viewing angle while ground data have been integrated over a large solid viewing angle (Noia, Ratto, and Festa 1993). Therefore, errors exist between the satellite images and the ground-based measurements. Some other research work has been developed for estimating solar radiation from satellite data. Regression techniques may be used in conjunction with satellite data to provide irradiance forecasts on time horizons ranging from an hour to a day(Schillings, Meyer, and Mannstein 2004; Martins, Pereira, and Abreu 2007; Janjai 2010).

Some of the method for deriving solar radiation from satellite observations employed meteorological geostationary satellite images. The geostationary satellites which are orbiting at about 36,000 km can offer a temporal resolution of up to 15 min and a spatial resolution up to 1 km but the satellites are not able to measurements accurately near mountains, oceans or other large bodies of water. Some limitations of satellite images limit the coverage and applicability of forecasting models (Inman, Pedro, and Coimbra 2013). In current days, more number of weather forecast models is used with spatial resolutions of a few kilometers. Some scientist and researchers are trying to concentrate on implement models with even higher spatial resolution to minimize the forecasting errors. To achieve the goal various soft computing models are reviewed, among this an artificial neutral network technique are selected to provide a large potential to improve the forecasts with high accuracy.

(Al-Alawi and Al-Hinai 1998) developed an ANN (Artificial Neutral Network) model for study the relationship between the Global radiation and climatological variables in and around the locations in north Oman. The ANN model prediction produces a mean absolute percentage error of 7.30% for training data sets and 5.43% for testing datasets. Kalogirou (2001) reviewed and presented about the applications of neutral networks mainly in non-conventional energy problems. ANN has also been used in diverse application such as robotics, forecasting, medicine, power systems, manufacturing,

optimizing, control, pattern recognition and signal processing. Once ANN models trained, it can perform prediction at high speed. They are particularly useful in wind speed prediction as well as solar radiation prediction.

(Rehman and Mohandes 2008) presented an outcome of ANN (Artificial Neutral Network) model for forecasting solar radiation. This forecasting has been done in Abha City in Saudi Arabia. The data has taken for forecasting between the years of 1998-2002. This data was divided for training and testing the neutral networks in such a way that, the testing data was not used in training of neutral network. The obtained results show that the developed ANN model able to estimating the solar radiation in the Abha city of Saudi Arabia. It also proposed a newly combined model, which is a combination of the nonlinear artificial neutral network model base for with incorporating the linear autoregressive moving average method. The result of the study revealed the improvement of the combined model over the ARMA and ANN model used in isolation.

(Pandey and Katiyar 2013) presented a brief account of solar energy principle, experimental techniques, and measurement of solar energy radiation and literature review of empirical solar radiation models and try to describe the present trend of solar energy measurement on tilted surface and also on horizontal surface with the help of meteorological data and geographical parameters for India. In this they found major interest to solar energy engineers.

(Sharma, Chauhan, and Kumar 2012) carried out a review of artificial intelligence techniques, which are used in the solar energy system. From this analysis, he concluded that the use of artificial intelligence techniques results in achieving improvement in efficiency and predicting the optimal set of design and operating variables for unknown data. Further, from the analysis of result, it was clearly concluded that there is a lot of scope for using a combination of artificial intelligence techniques with other optimization techniques in solar energy system; this improves the efficiency of the system.

Most of the solar power stations are generally fixed surface, tilted at a certain fixed angle for all season, which is approximate angles toward the equator. There are several methods to find the optimum collection, which are based on maximum solar radiation availability. All methods are based on the fraction of the load supplied by the solar system. But if the collector surface able to follows the sun moves from sunshine to sunset then obviously more radiation can be able to collect. Sun can be followed by two ways i.e. either single axis tracking (partial tracking) or by the double axis tracking system (complete tracking). In single axis tracking collector surface revolve about an only vertical axis and follows sun's movement. But in double axis system collector plate placed always normal to the incident rays. An experimental investigation and analysis have been done by Khalifa & Ibrahim (2010) with a basin type solar with internal and external both reflectors at tilt angle 0^0 (vertical), 10^0, 20^0 and 30^0 for still cover angles of 20^0 ,30^0 and 40^0. The result of this investigation was the revealed that the most of productive solar radiation in winter has a coverage angle of 20^0 and internal and external reflector with an inclination of 20^0. The efficiency of absorption of radiation depends upon two factors mainly i.e. angle of incident rays and length of pipe used in collecting plate. For maximum efficiency, the incident rays should be always perpendicular to the collecting pipe and if rays are parallel to the collecting pipe then the efficiency will minimum. And also, as the incident energy flux rises, the average absorption energy of pipe can approach to the minimum. As the pipe length increases, the average absorption efficiency of pipe drops and incident energy intensity also decreases.

A thickness of Photovoltaic (PV) plate also plays a vital role. Khalifa & Hamood (2009) tested a solar still with an insulation thickness of 0.03, 0.06, 0.10m to insert the storage of absorbed thermal energy. The result was observed that thickness of 0.06m insulation improved the productivity.

A new hybrid desalination unit consisting of an evacuated solar water heater, jutgeo textile and solar still was designed and tested by Omara et al. (2013). It was concluded that water productivity was increased by 114% over conventional solar still for an average efficiency was found to be 71.5%.

Yaici & Entchev (2016) found the applicability of adaptive neuro-fuzzy inference system for predicting the performance parameters solar thermal energy system. The predicted values are in good agreement with respect to experimental result.

According to Olatomiwaet al. (2015) try to find the accuracy of a soft computing technique for forecasting solar radiation based on monthly mean, minimum and maximum temperature and sunshine duration. The result revealed the efficiency of the proposed model.

According to Faith Onur Hacaoglu (2011), proposed method does not take into consideration by solar radiation data, this analysis was based on time series

method and some other mathematical models. Instead, a dual-parameter approach is considered with the augmented information of temperature data. This model inherent dependency between daily ambient temperature and solar radiation in a form of hidden Markoo model using the optimization technique called as Viterbi decoding algorithm. Therefore, an accurate modeling result indicates that temperature data is dependent on solar radiation data. This model is open for improvement. Several other combinations of geographical data such as air, pressure, humidity, cloudiness, sunshine duration can also be taken into consideration for future analysis or study.

In India, there is a wide network of some main organization which provides a variety of data relevant to solar radiation. The main organizations are Indian meteorological department, National Renewable Energy Laboratory (NREL) they also provide data of beam and diffuse radiation of various cities in India. However, still these are not sufficient to observe the solar radiation at each and every location. These are limited due to its initial cost, maintenance and requirement of skilled manpower. That's the reason that Global solar radiation measurements are usually made in few locations, which may or not be the same as the actual site of solar energy department.

In order to consider the behavior of solar radiation at the site of interest, long-term data from a nearby location along with empirical model, soft computing (artificial neutral networks, support vector machines, wavelength etc.) and satellite imaging (semi-empirical) techniques are used.

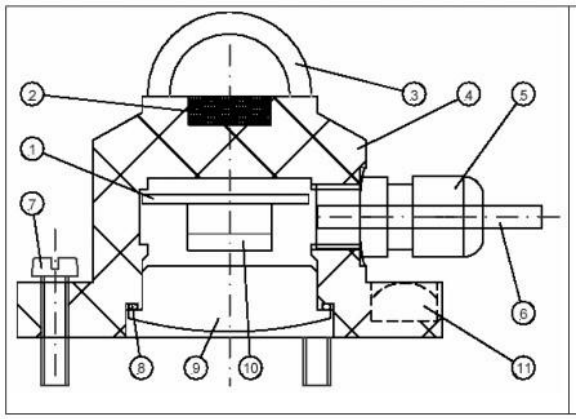
3. Research Methodology:

To accomplish the objective, survey and analysis play an important role. Data of survey provide a basis for research and analysis verify that data in real practice or not, and the summation of both help to understand the theoretical as well as the practical impact of solar radiation and factors affecting its intensity. There are mainly two types of equipment used to measure Global solar radiation and Sunshine hour of Agro Climate Research Center.

1. Pyranometer
2. Sunshine recorder

3.1 Pyranometer

A pyranometer is a type of actinometer used for measuring solar irradiance on a planar surface and it is designed to measure the solar radiation flux density (W/m^2) from the hemisphere above within a wavelength range 0.3 µm to 3 µm. When the sensor is kept under shade by a shading device, it measures diffuse solar radiation. In the inverted position, it measures the solar irradiation reflected by the underline surface.



1-Printed circuit board
2-Solar radiation sensor
3-Glass Dome
4-Body
5-Electrical cable connector
6-Electrical cable
7-Screw for horizontal level fixing
8-fixings
9-Access for cable connection
10-Screw electrical collector
11- Water babble.

Fig-4: Solar irradiance measuring device pyranometer.

3.2 Sunshine recorder

Sunshine recorder is generally associated with the energy received from the Sun in the visible part of the spectrum. The methodology requirement for Sunshine is primarily for relating to climatologically cloudy conditions.

Fig-5: Sunshine recorder

Sunshine duration is the time (hours or minutes) during which the sun rays able to cast a shadow. Sunshine duration measured continuously for about 140 years. At present, in India, there are more than 121 stations available for measuring Sunshine duration. Sunshine duration is recorded mainly by two types of recorders.

1. Focusing type
2. Photovoltaic type

The focusing type includes Campbell-Stokes sunshine recorder, which has been used universally. In dry atmosphere burning may begin at about approximately 70 watt/m^2, for very moist atmosphere, the burn may start at approximately 280 watt/m^2. The average threshold value is approximately 210 watt/m^2. There are some sunshine recorders; Foster sunshine switch is most popular in the USA, which is designed by Foster and Foskett of US weather bureau in 1953. It is consisting of two Selenium photovoltaic cell, in which one cell is exposed to direct radiation where other cell being shaded by a shade ring. In India also, R.D.Vashist has developed an automatic digital sunshine recorder at Instrumental Division, Indian Meteorological Department, Pune.

3.3 Current energy scenario in India

India has achieved tremendous success in developing its electrical system. when India got independence in 1947, installed capacity was about 1360 MW but after last 6 decades on 31st October 2010 installed capacity is 1,67,278.36 MW. Out of total installed generation capacity, 65% is Thermal,22% hydro,3% nuclear & only 10% renewable (solar and wind). Consider that 59% of rural households are yet to get access to electricity and the government aim to provide electricity to all household by 2022.

Indian Meteorological Department (IMD) has six centres. There are different kinds of radiation station, that measure solar radiation and daily duration of sunshine. Rajasthan and North Gujarat experience the highest annual Global radiation. According to the National action plan on climate change, if India were to convert 1% of 5000 trillion-kilowatt hour of solar energy that it receives in a year into energy, the country would have enough to meet its energy needs, which is now a growing concern.

Demand for solar products has been rapidly rising for the recent years,
Especially in rural areas which are forecasted in a period of (2014-2017). Solar Street lighting system, home lighting system, solar water heater, solar lamps, solar pumps, solar charging points are the most popular application in India. Some states such as Gujarat & Rajasthan also promoting it by giving tax relaxation and incentives because they are non-consumable and also environment-friendly.

In Tamil-Nadu, total installed capacity was 14,774.06 MW on 2010. This comprises generation from the thermal, hydro and renewable source of energy. Tamil-Nadu is the only state in India where 35% shares of installed capacity are coming from renewable source i.e. solar energy.
The contribution of power sector-wise in Tamil-Nadu,

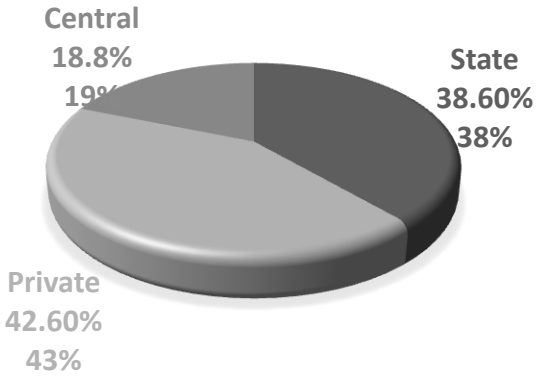


Fig-6: Contribution of power sector wise

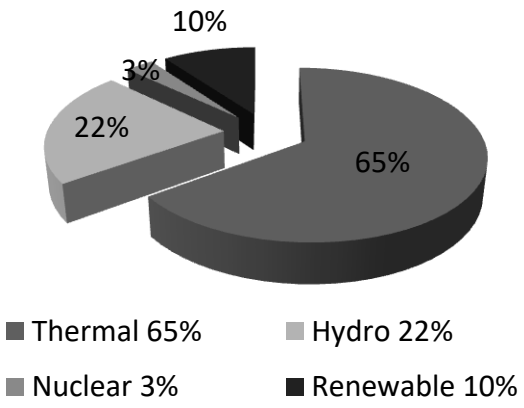


Fig-6.1: Contribution of power technology wise

Research Centre: ACRC
Latitude: 11^{0}02' N
Longitude: 76^{0}59'E
Altitude: 426.72m
These are the following factors influencing global solar radiation.

- Relative Humidity
- Suspended Particulate Matter (SPM)

These are the above factors which influencing the Global solar radiation of 2017 in Coimbatore.

In Coimbatore (Tamil-Nadu),
The location of Coimbatore, Tamil-Nadu is considered for the global solar radiation analysis. Data recorded (2009, 2010, and 2011) from the Agro Climate Research Centre.

Geographical Details:
Location: Coimbatore, Tamil-Nadu

- Sunshine Hours
- Air Pressure
- Wind Speed

RESEARCH TOOLS:
These are the following tools which are used to evaluate the condition.

- Mean
- Coefficient of Variation
- Standard Deviation
- Coefficient of correlation
- T-test
- Multiple Regression

Seasons	Months	Global Solar Radiation(cal/ cm^2/Day)	Average Temperat ure (^{0}C)	Relative Humidity (%)	Wind Speed (Kmph)	Atmospheric Pressure (hPa)	Sunshine hours (hrs)	SPM (µg/m^3)
Winter	December	372.1741	24.1855	70.5806	4.7484	963.1387	6.354	174
	January	409.161	24.4952	66.4194	4.9000	960.2387	7.612	240
	February	437.1178	25.0018	63.4643	4.5679	960.8214	8.796	225
Pre-Monsoon	March	428.2032	27.0613	61.5484	4.2484	962.0290	9.229	186
	April	378.2066	28.1800	68.8000	4.0400	961.0667	7.576	194
	May	391.1645	28.4258	71.8710	4.1742	960.3710	8.325	233
Monsoon	June	345.4833	26.8050	70.2833	9.2500	928.5067	5.053	156
	July	338.3064	27.1048	69.5645	10.009	898.9419	5.025	103
	August	315.7451	27.0790	71.8226	8.5032	959.9452	4.632	169
	September	356.1933	26.2200	73.3000	8.1533	961.2133	7.193	100

Post-monsoon	October	356.851	27.0952	74.9677	4.4226	931.2484	6.525	143
	November	329.2533	24.7483	75.3167	4.6967	962.9933	5.440	152

Table-1: Global solar radiation captured in Coimbatore

With the help of the above data Mean, Standard deviation (S.D) and Cumulative Variance (C.V) are calculated in different seasons.

Variables		Global solar Radiation	Average Temperature	Relative Humidity	Wind speed	Atmospheric Pressure	Sunshine Hours	SPM
Seasons \ Units		Cal/cm^2/day	^{0}C	%	Kmph	hPa	hrs	µg/m^3
Winter	Mean	406.20	24.56	66.82	4.73	961.39	7.58	222.88
	S.V	32.58	0.41	3.57	0.16	1.53	1.22	42.96
	C.V	8.02	1.67	5.35	3.50	0.15	16.09	19.27
Pre-monsoon	Mean	399.19	27.88	67.40	4.15	961.15	8.37	204.33
	S.D	25.94	0.72	5.30	0.10	0.83	0.82	25.40
	C.V	6.49	2.60	7.86	2.54	0.08	9.87	12.43
Monsoon	Mean	338.93	26.80	71.24	8.97	937.15	5.47	132.33
	S.D	17.11	0.41	1.66	0.82	29.62	1.16	35.63
	C.V	5.05	1.53	2.33	9.19	3.16	21.19	26.92
Post-monsoon	Mean	343.05	25.92	75.14	4.55	947.12	5.98	147.5
	S.D	19.51	1.65	0.24	0.19	22.44	0.76	6.36
	C.V	5.68	6.40	0.32	4.25	2.37	12.83	4.31

Table-2: Analysis of captured data with SPSS software

From the above data, it is found that during winter season solar radiation is maximum i.e. about (406.2 cal/cm^2/day) and minimum at (338.93 cal/cm^2/day) during monsoon season.

4. DATA COLLECTION

For modeling convenience, radiation falling upon a sloping surface can be divided into 2 categories. These are as follows

Direct radiations, which are coming straight from the sun,

1. Diffuse radiations, which are coming to earth with the infraction of sky.
2. Diffusely reflected radiation, which is reflected from the ground onto the sloping surface.

The above diagram explains the proper distribution of Global solar radiation. According to this budget out of total 100% solar radiation, only 48% of total radiation is able to collect on ocean and land. And among rest of 52%, 18% are absorbed by water vapor, Dust particles and ozone (O_3), 3% absorbed by clouds and rest are reflected back.

The target of MNRE (Ministry of New and Renewable Energy) we can see in the diagram given below, which is designed with the help of two factors i.e. Rooftop solar and Ground mounted solar. This is a target of Ministry of New and Renewable Energy, which is a forecasted to obtain solar energy up to 2022.

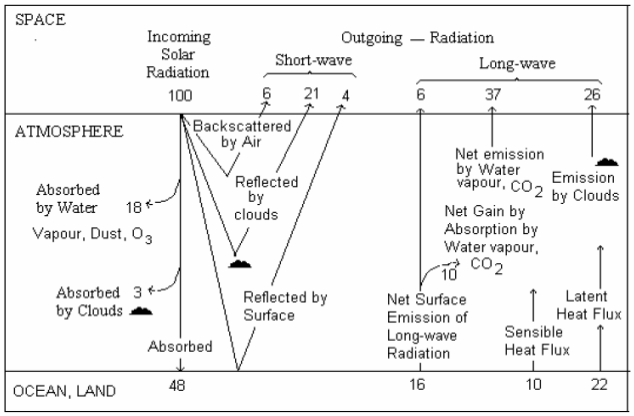


Fig-7: Radiation Budget of the atmosphere (Radiation Manual, WMO 1985)

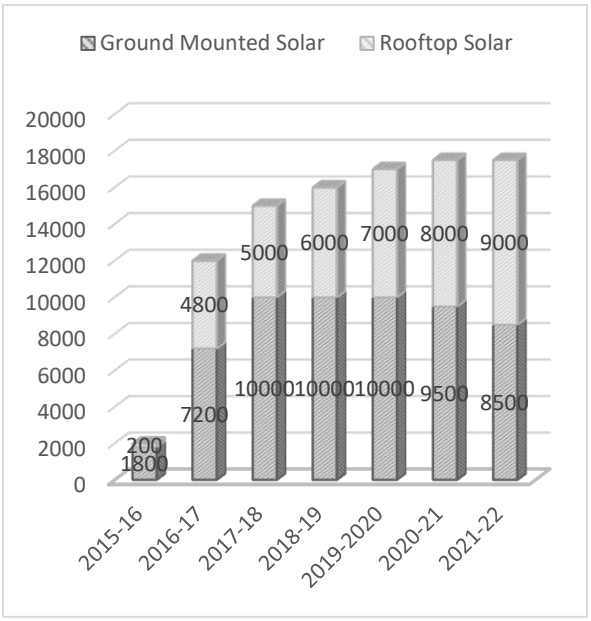


Fig-8: MNRE Year-wise Solar Targets (in MW)

But the current scenario of installed capacity of solar power in India till 30th April 2017 is presented in the graph given below.

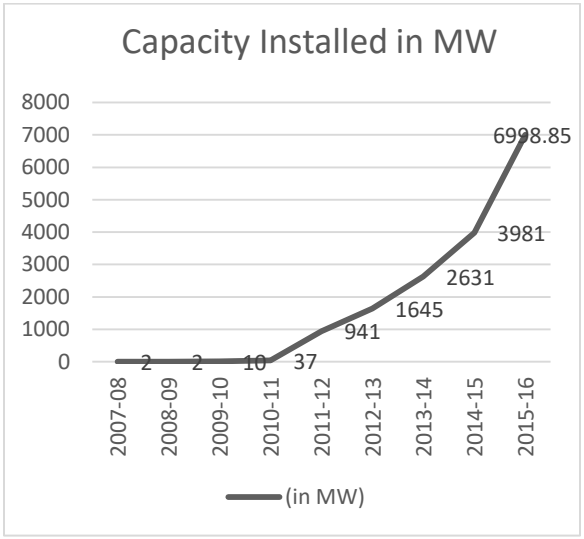


Fig-9: Capacity installed in Chennai till 2017

And we should also analyze the revolution in the efficiency of solar cells; these cells are made up of different material with the change in time and always try to improve the efficiency of the cell. A record-breaking efficiency is achieved in the past year of 2014, which is 46%. The efficiency variation is able to see in the graph given below.

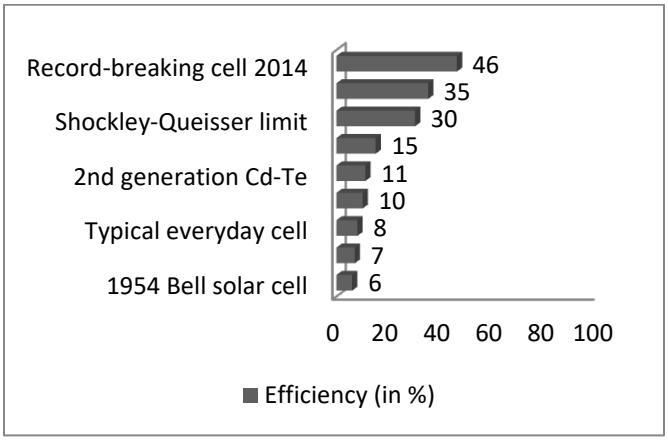
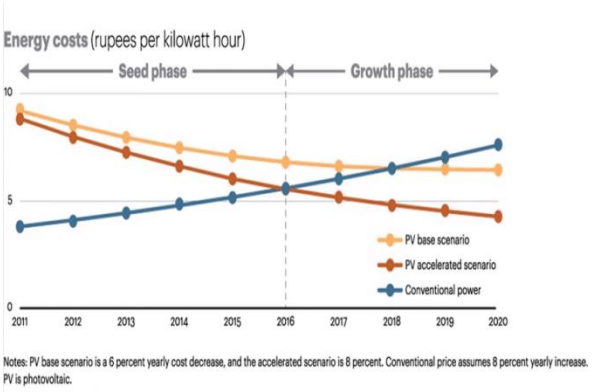


Fig-10: Bar chart represents the efficiency of the different solar panel on basis of material.

The prices of PV (Photovoltaic) cell which is generally made up of silicon are also decreased day by day. The price history of silicon PV cells (in US$ per watt) also mentioned in the graph given below.

Source: Bloomberg New Energy Finance & pv.energytrend.com

And finally, it should discuss that the final cost of solar power in rupees per kilowatt hour (per kWh). To analyze the energy cost difference between conventional power sources and PV accelerated scenario, the entire cost is divided into two categories i.e. Seed phase and Growth phase. Then after proper analysis by A.T.Kearney analysis, it is observed that in Seed phase PV based scenario is high but in Growth phase, it is continuously decreasing.



Source: A.T.Kearney analysis.

5. RESULT

The result may be very useful for Government of India. In this study, there is tried to study the suitable locations entire India (which are colored by deep Red or Orange in Map, which is enclosed in Introduction part) for solar power stations. These locations are able to collect a very high amount of solar radiation and this solar energy can use for the compensating of the requirement of conventional energy in India. This may also be the best option for compensate the main problems from which India is suffering, which is a prevention of Climate control with help of pollution control and also help to overcome with the problem of increasing the rate of Petrol & Diesel.

6. DISCUSSION

From the above study of global solar radiation in India, it was concluded that in winter season the solar radiation is minimum when we compared throughout all season. Relative Humidity has a significant correlation with air pressure and Temperature has a significant correlation with Sunshine hours. It generally observed that the collector solar plate is generally fixed at a certain angle for all season, but when earth revolves with respect to the sun then the collector plate not able to collect optimum radiation. So if all solar collectors are double axis tracking system then it will able to collect the solar radiation at optimum quality with some changes in the angle of collector plate.

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