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Assessment of Solar Energy Based on Various Meteorological Conditions in the Indian Climate

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ABSTRACT

India has the largest DNI rating network, with 51 weather stations pre-programmed with the highest commercial quality solar settings. Some stations are performing well, while others are in need of intensive improvement. We focus on specific difficulties and misconceptions observed in the operation of various solar stations in the field. Analysing Indian solar sites to make a weather measurement methodology is the prime motivation of this study. Weather stations can observe all common phenomena occurring under weather conditions and solar isolation conditions. The monitoring of various sites is done for a period of time to get a detailed analysis of the impact of changes in weather conditioning on the solar energy.

Significant differences in insolation were found when comparing satellite and ground-based measurements. At some sites, it was found that the average deviation of solar isolation for a period of 15 days was 40% from the satellite base observation but for the same period of time this deviation is less than 12% when measured from the ground base. The data on wind speed and direction also has been collected from the local weather station. All roofs are equipped with solar panels. The monthly and annual output of the solar system was modelled using various simulation processes. Using a variety of state-of-the-art technologies, a solar power plant with a peak power of 8.3 kW can produce 9.03 MWh per year, and with the addition of thin-film technology it can reach 9.67 MWh per year. It can be concluded that the use of environmentally friendly technologies can lead to low cost development. It has been concluded that sometimes multiple implementations are needed, such as simulating solar power performance. In this study, we also describe a set of measures for the procedure to bridge the gap in insolation installations.

Keywords: Solar Power Plant, PV-system, Weather Link, **Sensor Interface Module**

INTRODUCTION

India has proposed a separate and independent ministry for opportunity power sources. It is roughly calculated that the energy requirement will grow27% from 2022 to 2045. India also emits a huge amount

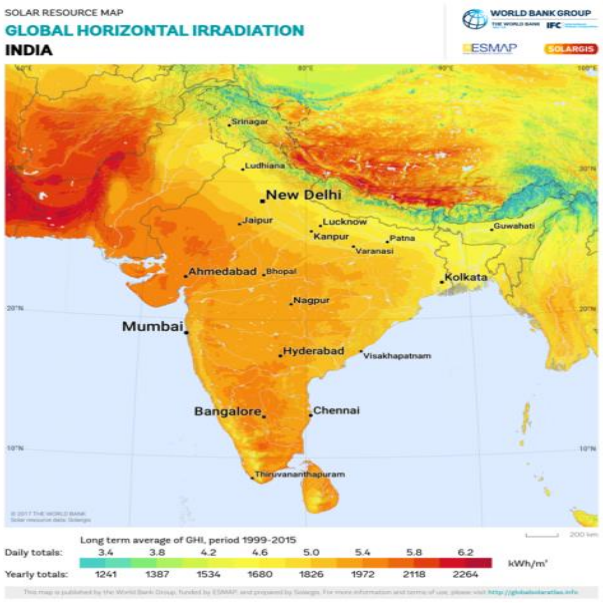
of greenhouse gases in comparison to its economy and industrial development. The highest increment in energy demand is found from Non-OECD nations having lower economic standard and higher growth rate in population, especially China and India. Average increment in use of fossil fuel 5.7% per year from 1950, due to which India in one of mostCO_2 emitting countries in top five **(Boden et al., 2011)**. As per recent data of Ministry of Environment, Forest and Climate Change the energy sector emit 71% of total GHGs emission in India. On 30_{th} June 2020, India has touch the milestone of 35.12 GW Solar installed capacity which is good share of total installed capacity of 371.977 GW, on other hand India has reached one more milestone to produce a clean energy by producing 35.7% of total installed capacity of 371.977 GW by the mean of renewable energy sources including hydro plant, this all shows that there is a great possibility to explore the solar energy production process if a tireless approach of researchers get a chance to explore it with the government's support. Indian lands get 5000 trillion kWh per year by solar radiation. Nearly 2.4 hectares area is needed for a solar power-plant to produce 1 MW power.

In Paris convention 2015 a promise was made by 187 countries (Contributing 97% of total pollution due to use of fossil fuel) to reduce 2 ^{0}C in the current increasing rate of global warming. To get this targeted achievement solar energy identify as a best option as an alternative to reduce the consumption of the current energy sources. Keeping in mind the global demand of solar energy, the various working in the field of solar energy expecting a huge growth rate of 24.6% and investment forecast is around 422 US dollar by 2023 **(Vedachalam, 2018)**. Very less amount of GHGs emitted due to use of solar energy when compared it to non-renewable energy sources. Future crises in availability of fossil fuel, increasing global warming and harmful impacts on environment due to the use of fossil fuel are the main driving force of emerging development in the field of renewable energy. Current available data of overall power generation by solar energy in India is 34627 MW shows a good opportunity of development in the field of solar energy utilization. The going on deployment of the solar power stations in India helping in decarbonisation, a huge amount has been invested in this sector due to which India become the emerging leader to implement the Paris convention.

A lot of possibilities are available to utilize the renewable energy in many poor and developing countries to fulfil their energy demand. Each country has an aim to produce 33% of total energy by the mean of renewable energy sources before 2040. To fulfil this aim Indian government is continuously working in this field and deploying solar energy. The use of alternative source of energy becomes essential for the prospective of less harmful impact on environment. For quick action a project Solar Radiation Resources Assessment has been started, mainly motivated by United Nations Development Program in which continuous improvement target for 2020-2025 has been decided.

It is nearly same as thermal power plant if we concluded the mining area, water storage area and the area which is used for ash disposal, the same area is also taken by hydropower plant if included submerged area of the water reservoir. There is much space in India which is currently unproductive like barren lands can be utilized by installing solar power plants. Plant which have total 1.33 million MW capacities, can be installed on .98% of the total land area of India, this area can be found many parts of the country as unproductive area, which are potentially fit for the solar energy production. To elaborate the

researches in the solar energy and starts an industry academia partnership by collaborating with Renew Power Ventures Pvt Ltd. This Centre of Excellence is also funded as sponsored project; one of these is centre of excellence in climate modelling, which is primarily focused on skilful simulation and projection of Indian climate.



Field Indian government and IIT Delhi collaborated with Renew Power Ventures Pvt Ltd, to set up a centre of excellence for renewable energy in the campus of IIT Delhi in September 2017. IIT Delhi was chosen because this campus is surrounded by many government offices, commercial building, Residential buildings and slums. Main purpose of this excellence set up is to facilitate young researcher from whole country who are interested in this field,

Fig. 1.1 Global Horizontal Irradiation in India. Source: Global Solar Atlas

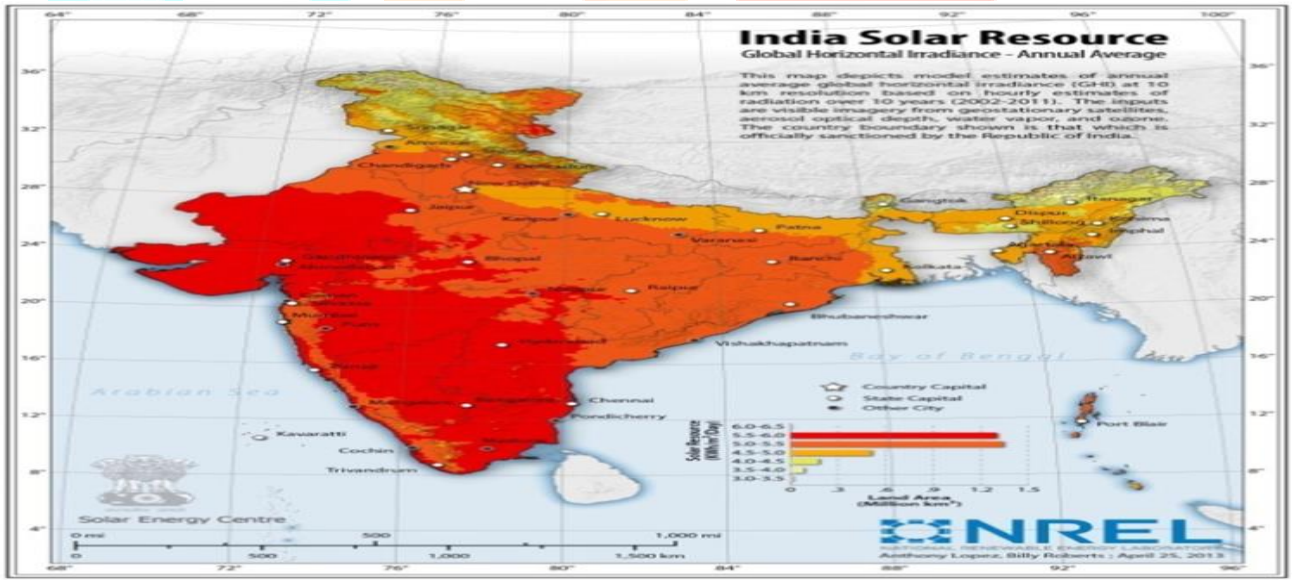


Fig.1.2 Global Horizontal Irradiance – Annual Average. Source: National Renewable Energy Laboratory, U.S Department of Energy.

The functions of the Centre of Excellence are to facilitate the benefits of solar energy to the common people of India and provide them the facility of latest development in the related field. Current power generation infrastructure in India mainly depends on the fossil fuel, which needs to be shift to renewable sources.

Fig. 1.3 Front View of Centre of Excellence for the renewable energy in the campus of IIT Delhi

Fig. 1.4 Top View of Centre of Excellence for the renewable energy in the campus of IIT Delhi

This centre provides research and development facility up to the world class level

(i) To assure all solution related to the renewable energy problems and a collective solution of the problems by experts of related industries, academy.

(ii) Faster adoption of the technique which are developed in this field worldwide.

(iii) Provide research and development facility as well as internship facility for young researchers from the related field.

(iv) Prepare research report for the various government agencies

Mainly photovoltaic (PV) is used to convert lights into electricity utilizing semiconductor material. This pandemic situation due to COVID-19 affects very badly the faster growth of the PV installation, Solar and weather assessments are required to evaluate and forecast the energy generation quantity by the installed PV. Data related to weather humidity, amount of solar radiation and fluctuation in temperature are taken from centre of excellence for non-renewable energy. The daily weather data like temperature, wind speed, wind direction and solar insulation are found from Indian Meteorological Department's surface observatory situated at the Safdarjung Airport terminal.

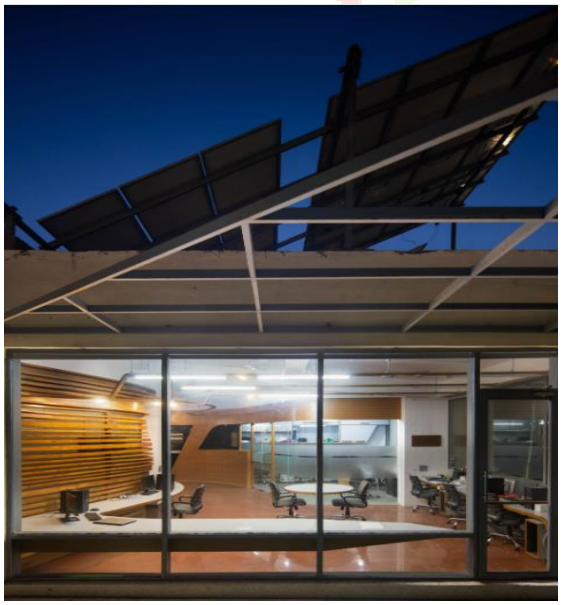


Fig. 1.5 Data Monitoring Room of COE Delhi

Fig. 1.6 Satellite View of Centre of Excellence for the renewable energy

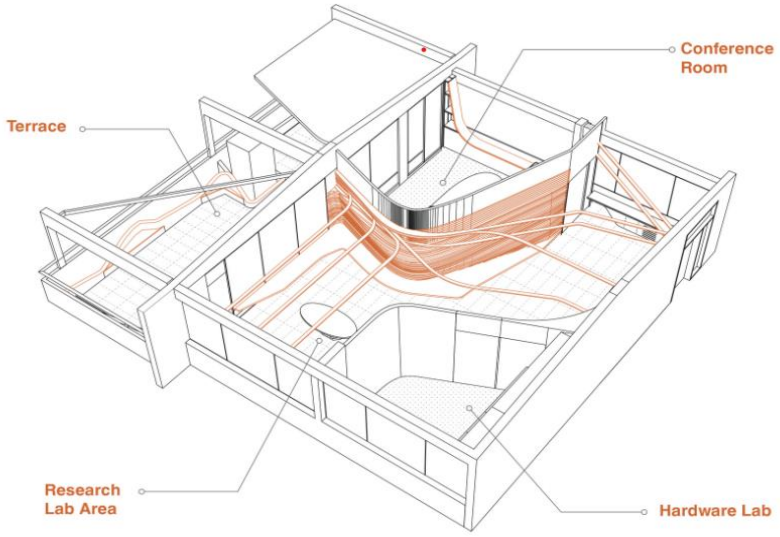


Fig. 1.7. Interior design of COE

However, the centre of excellence gives an access to provide measured data for the scholars and researchers who are willing to work in this field or still working. It was one of the MoUs at the time of establishment of this CoE, scholars from any Indian university can use data for the simulation purpose of their own set up of PV-system.

LITERATURE REVIEW

For maximum generation of solar power from a solar power station it is very essential to choose a location on which more solar radiation achieved. Location depends on many parameters like duration of solar radiation exposer, wind speed, wind direction, temperature, humidity, rain and some other environmental conditions. To increase the productivity of solar energy plant and reduce the cost of per MW generation many researchers are continuously going on. Installation cost of solar plant is high so it is also needed to make correct future weather information for the necessary measures, implementation of which is required for energy generation and process to fix the problems related to environmental issues. The solar cell productivity is depends on many factors like humidity, rain, temperature etc. that's why accuracy in forecasting of these parameters helps to get an idea about the season, and location to expand the solar energy production. Various studies to investigate the impact of many parameters on solar station and to find correct understanding of weather evaluation to decide the initiative which has been taken to increase the productivity of solar power station.

Gueymard and Myers[1] discovered that sun power region require help from radiometric measurements for lots statistics to installation a proper layout as well as for monitoring power stations and for assessment of set up model. It was also found that instruments uncertainties give a wrong data which affects the measurement process as well as radiation assessment. This study also assure that the previous studies in which it confirmed that majorly applied pyrometer underestimates global radiation, especially in winter season, till tan correct measurement done. The importance of forecasting from the transportation methods to errors in input radiation data is exhibit.

Purohit and Purohit[2] did a Techno-financial survey for concentrating sun strength era. They defined about The Jawaharlal Nehru national sun task of NAPCC introduced via Indian authorities with the intention to enhance

the growth and sell of solar strength for power production and other initiative with which the solar aggressive with fossil fuelled strength device. With many purposes as (i) Policies for power generation include that 20000 MW solar power units will be deployed till 2022. (ii) Provide funding and other government facility to the industry which are working in the field of solar power production (iii) Promotion of off grid system and cover a mile stone of 1000 MW, 2000MW till 2017 and 2022 respectively (iv) Identify 15 million m^2 and 20 million m^2 area of thermal collector has to be deployed by 2017 and 2022 respectively(v) establishing 20 million lighting systems based on solar system by 2022. A prior assessment in the aspect of technical as well as economical for concentration solar power technology is made in this study. Techno-economic effectiveness of concentration solar power technology for Indian climate is assessed by PS-10 and ANDASOL-1 becomes the base for present investigation. Simulation of these systems has been done for various Indian locations. It was found that the CSP technologies are beneficial in the north-western part of the country in the financial aspects. It concluded that the sites with yearly solar radiation 1800 kWh/m^2or more than it, mainly suitable for installing this CSP systems. The finding of this study can be utilized for deciding of location for short-term use of solar energy in the aspect of concentrating solar power production in India.

Pal and Devara[3] carried out wavelet-based spectral investigation for long length of optical characteristic of aerosols located via lidar and radiometer tracking in Western India. A detailed observation of statistic for yearly as well as inter annual of lidar and radiometer found from aerosol distribution was done to found the impact of various seasons and weather conditions at the location where investigation is performed in western India. The effect of urbanization at the long duration variation at the lider measurement of aerosol loading was also found. It was done by lidar observation and a set up made for Pune city, which considered population as well number of vehicles and industries of this city.

Shrimali and Rohra[4] mentioned the diverse tasks carried out thru JNNSM to evaluate the development which has been achieved in solar electricity discipline to reform the energy quarter. In this study the details of problems faced during the implementation is also discussed broadly.

Purohit et al.[5] assessment of concentrating sun electricity era effectiveness in North-western India, this region of the u.s.a. received biggest sun power with helping meteorological situations inside the thing of CSP, presently a massive waste region is likewise to be had in this part. Concentrating solar power (CSP). It was found that future sites having lower DNI magnitude will become economically feasible using new techniques, new materials.

Padmavathi and Daniel[6] perform evaluation to analyze 3 MWp grid connection of photovoltaic electricity plant in Karnataka country India in accordance IEC wellknown. using observed data. Seasonal and daily basis variation of SPV plant result is presented for observed data done at each five minute time interval. The SPV production according to load variation curve is observed. Standardized execution parameters of the plant and similar variables of other plants were compared. Finding of the power station is validating the report available for other countries.

Kumar et al.[7] performed subject evaluation of sun radiation stations in India, a detailed evaluation of total functioning energy stations for twelve months period prepare a listing of problems and inaccuracy observed for the duration of functionality**.** From the findings of 51 stations it concluded that many station working very well but rest are required serious improvement. Working of quality control system is very essential to find inaccuracy in performance of stations. A prime conclusion was made that continuous simulation is required to enhance the performance of a station. A basic gap filling procedure for solar energy is also described in this study. The procedure is applied on whose outcomes represent a mean bias of ca. 3 % over GHI, DNI and DHI over all types of gaps.

Chandel et al. [8] performed Wind energy evaluation of 12 specific positions in western Himalayan part of India for its effective utilization. This investigation is to be done for evaluation of effectiveness of wind in the Himachal Pradesh to find out effective location. WEPF technique is apply to evaluate the wind effectiveness of 12 different places at different territories and climatic regions utilizing wind data form 2008 to2012. Weibull and collective wind dispensation, Weibullfacts as well as Wind Power Density were found for these places. The maximum wind velocity is seen in hot season and minimum cold season in this location.

Ruiz-Arias et al. [9] correct size of the solar power aid is of fundamental importance for the multi-faceted development of a solar power plant. This assessment is mainly carried out by radiometric stations, but from the regional to continental scale, the satellite methods are the most suitable for you. The performance of this system was determined with the help of integral calculations made on the basis of these, with a 10-kilometre area of the world, and the direct monthly data on exposure for a period of 10 years. The results will provide you with advice that is, the average distance between the observation points, from 100 to 150 miles and can lead to the objective grid estimates.

Sivarasu et al. [10] A study in preparation for the implementation of the project on the basis of renewable energy sources in terms of the interests of consumers in India, taking into account the ability of the body. The results of this analysis indicate that the site will be taken as appropriate to the glass, and solar resources, and more resources to increase the power value, in MG. We will advise you of the potential for solar photovoltaic (SPV), a turbine, hybrid models and their suitability in relation to the empowerment of individuals in India, which is the empowerment of the country, and to reduce the use of fossil fuel-based energy. The results of this study show that the main problems and their solutions in the design, development, and implementation of the MG projects in India.

Chauhan and Saini [11]including the comments of the joint use of a small hydroelectric power plants, such as biomass, biogas, solar energy and small wind turbines, and by way of a single system of technology is aimed at summarizing the technology, which is based on the site in a given area. A methodology for the assessment of the level of demand and the resources available in a given area is being developed. We have also discussed the many obstacles and issues that shape the way in which the system is to be implemented..

Gherboudj and Ghedira[12] The innovative cards are used to describe the suitability of the land for the use of solar energy (PV and CSP) in the United Arab Emirates (uae). The proposed maps are produced by the

combination of solar radiation maps, taking into account the impact on the land, the limits and under the conditions. The obtained results show that the photovoltaic power stations are more convenient for the Uae, in comparison to CSP plants.

Mentis et al. [13] Geospatial exploration of wind energy technological and economic power in India. The current study focused on coastal wind power and concerns in providing techno economic power estimates based on wind energy technologies. Economics and geographical wind farms are structured and used as a major step-by-step guide for Geographic Information Systems (GIS) views. The cost of wind power is estimated geographically. In this study it was found that there are many areas with high wind yields every year, such as Rajasthan, Andhra Pradesh and Gujarat, while Goa and other areas showed very little or no energy. Electricity generation costs fall between 57 and 100 USD /MWh, making wind power competitive in India.

Murthy and Rahi[14]Did a preliminary assessment of wind power capacity in a coastal area in the north of Andhra Pradesh, India. The Wind Potential (WPP) . Currently, the plan is only in the low-lying areas, no attempt will be made to reach a higher altitude. Instagram allowances are used to calculate the value of SILVER to that of estrogen. This study provides an insight into the development policies pursued by the energy professionals along with researchers in the related field. This analysis makes use of the capacity factor (CF) method and the Weibull model. For a very long period of time, the daily wind speed information for the 32-year - (1983e2014), at a height of 10 m, and is derived from the NASA web site. Finally, the comparison of the wind power density (WPD), is located after the completion of these two models was statistically detected, monitored, and reported on in Chapters 5 and 6, respectively.

Müller et al.[15]Worked on the combination of a map and a thorough approach to creating a custom solar roof. In order to have a consistent set of data, the value of 51, on the basis of measurement stations in the country has been used to obtain the correction factor at this stage. At the same time, one of the other 61 stations was used to compare the long-term, search, maps, and the monthly baseline data. There are multi-year averages, the average of the values for each month of the year, as well as the standard deviations for the different radiation components.

Jamil and Akhtar[16]carried out a sociological study carried out to compare the performance of the diffuse solar radiation model, and the sky is the indicator, additionally the time in sunny humid-subtropical climatic zones in India. In this analysis, the solar radiation assessments have been carried out over a period of three years, from 2013 to 2016, in the city of Aligarh, Uttar Pradesh, India (27.88°n, 78.08°east longitude). According to the data and the global mean value is 21.01 MJ / m2, and the beam is 13.40 MJ / m2, and the scattered light from the sun 7.61 MJ / m2 per day. It has been found that a good agreement is observed in the ground-based measurements and satellite data. Modelling of diffuse solar radiation has been carried out depending on to the sky, and the index is the relative time from the rays of light. In this study, 42 of the new models, up to and including category 6 were modelled. The proposed models are also supported by the models are available in the literature. The models were evaluated in terms of efficiency and in terms of the top ten most commonly used statistical indicators. It

was concluded that a model with two input variables, which results in better performance compared to a model with only one variable.

Vedachalam[17] carry out the assessment for decarbonisation limits of sun electricity for the strategic Indian strength production place. The y described that emphasizing exploitation of solar energy can reduce hydrocarbon imports and emissions, this is need huge investments. A clear and sustainable approach requires executing the strategies need for long period decarbonisation.

Pereira et al.[18] This research is mainly done in order to improve the value and the value of the sun's rays, as well as the differences in the results due to the Weather Research and Forecasting (WRF) model with the help of the new forms of Autonomous Communication Process (OCP). OCP has the facility of clear-sky environments, including the effects of the atmospheric composition. The measurements were carried out over a period of up to one year.

Yeom et al.[19]the Study of solar energy and wind power in North Korea is in the details. To estimate wind resources, means of production, the model statistics (MOS) have been integrated with the post-processed variables of the Local Data Assimilation and Forecasting System (LDAPS). In the estimation of wind energy, the wind speed is provided by a digital weather. It was found that the various regions of North Korea, it can be an obstacle for the further development of the infrastructure, renewable energy sources, this is the big mean and solar energy, and energy is the results explain the significance of the potential of renewable energy sources in North Korea.

Rehman et al.[20] Did the evaluation for solar capability for public bus routes of solar buses. The clear sky and systems close to to the street allotted by using automatic image processing set of rules that turned into using on this study. After this process the images deployed for solar assessment to found the information of the average solar irradiation on this route. Then a comparison in the energy requirements for an electric bus and available energy from solar radiation is made to find out that what part of this demand can be utilized by available solar energy. For this purpose a public bus route in Invercargill (New Zealand) was investigated. A fisheye camera was setup at the roof of a bus to take the images. It was concluded that 8.5% of total electric demand to run the bus can be fulfilled by solar panels which was installed on the rooftop.

Pinto and Stokkermans[21] Investigates various floating sun technology on the premise of diverse case examine. want of Floating sun generation (FPV) got here in the photograph due to scarcity of land, lower of performance at excessive mobile temperature, particularly due to intention of decarbonize. The purpose of this investigation was to fill the gap between the expected performance for FPV systems and the outcomes from simulations of production of power. It was found that high efficiency is depending on technologies as well as on the location.

Sumair et al.[22] evolved a way for Weibull parameters estimation and evaluation for wind efficiency. in this statement a technique named modified technique of moment (MMOM), compared with distinct techniques first strength sample element technique (EPFM) and method of moment (mom) for the evaluation of wind ability in Punjab has been executed.

Kumar [23] Explore solar energy from satellites, in neumerous regions of India. The manifestations of solar variations are analyzed in this study. In this study satellite imagery was used for solar data retention. Observations of solar panels including generalized irradiance (DNI) and global horizontal irradiance (GHI) provide an opportunity for information on energy efficiency. This view shows the map of the southern states of India in resolving the 100 km2 grid. The Karnataka and Tamil Nadu regions have been found to be the best applicants. The findings of this study have a bearing on the future of local distribution at the national level. These studies might be of fantastic assist to better making plans in this field.

Kapen et al.[24]made a comparison of ten-digit strategies to calculate Weibull's parameters for exploring wind energy which is a different high-potential (AMLM) method, the equitable energy method (EEM), a highly modified alternative (MMLM), high-potential (MLM) , energy pattern factor (EPFM) method, Mabchour method (MMab), graphical method (GM), timing method (MoM), Lysen art form (EML), and Justus (EMJ) art form, Weibull flexibility by the power of the wind. Made with the help of wind speed data downloaded from the weather department. Statistical observations show that MLM exhibits the best strength in all simulation tests, with reduced order EEM, EPFM and EMJ. According to the error number EEM has a small error.

Scope and AIM

The ultimate aim of this study is to yield weather data for solar energy evaluation with the help of solar radiation sensors. There is a prime question whether the data are correct or not, which also to be check. This is useful to find the best location for a solar power installation.

There are various available methods to provide weather data and solar data like weather station working on satellite reports and ground measurement. A major interest of this research is to find the comparison in the data which was found from the own station and from various ground report as well as satellite report, and find the reason of differences in data.

How can fit a PVs system which is suitable for the better production of electricity? What is the best way to combine the weather data and PV installation?

WEATHER CONDITIONS

To have a good idea of the many challenges and situations encountered at the time of this review.

Centre of Excellence for renewable energy

The association setup and calculations were performed at the CoE located in New Delhi. The synergistic effect of different parameters on force generation is also detected here with different instruments inside the golden average of excellence. In the below figures it inside and outside views of Center of Excellence is shown in fig 4.1. This is also facilitating the research support to researchers who has area of interest in same field. A proper support is provided to explore this area with provide all the facility which is available there as well as a proper guidance to trickle any problem.

Fig. 4.1 Center of Excellence for Renewable energy in New Delhi

This is also facilitating the research support to researchers who has area of interest in same field. A proper support is provided to explore this area with provide all the facility which is available there as well as a proper guidance to trickle any problem.

Regulatory procedure for grid linked PV in India

India's TPV installed capacity reaches 34627 MW (April 2020). maximum set up became presenting facility to affect the rural regions or diverse government reliable buildings. That's why we have faced a lot of problems to get a information related component cost, regulation process, tariff feeding, long term evaluation.

Table4.1 PV hooked up capability in MW For diverse applications

Utility	31st july 2021
Terrestrial solar power	27945.29
rooftop Solar power	2,230.10
Standalone Solar power	920.20
TOTAL	31,112.41

There are various companies provide PV systems in India like Tata Power Solar Systems Ltd, Amplus Energy Solutions Private Ltd,Icomm Tele Ltd etc. There is seen the cost different in production of electricity in various states of India, prime cause of this increment in the cost is transportation of Diesel and gasoline. Below the graph is shown the cost difference in the production of electricity.

Table4.2 fee of energy of various place from grid gadget

Location	Electricity cost per KWh

J. & K.	1399 USD/ KW
H. P.	1326 USD/ KW
U. P.	797 USD/ KW
Bihar	1020 USD/ KW
M. P.	794 USD/ KW
Karnataka	782 USD/ KW

Renewable electricity tariffs are determined using a variety of pricing players based on the ease of grid location flexibility. **Pricing additionally relies upon on voltage intake**. If government apply any official feed for tariff in PV it may be around 1005 USD/KWh. Below the table 4.3 provide an unofficial records for tariffs if PV installation is done in 3 phase

Table4.3 Pricing factor in different regions of India for PV feed and tariff

Feed Voltage (For 3 phase)	Feed Tariff (Voluntary payment)	Price Factor
At Low Voltage 450V	$F \times R_p$ 1020/KWh	F= 1 for New Delhi F= 1.4 for Uttar Pradesh
Medium Voltage 25kV	$F \times R_p$ 680/KWh	F= 1.6 for Himachal Pradesh F= 1.5 for Jammu & Kashmir

Today, a generation of polycrystalline and monocrystalline solar systems has developed. but we are not using a very important generation in this field to install skinny films in India because there is a problem. cost of a panel trip **RS10000/ W_{peak}.** This cost reduction also increases our volume. The cost of the inverter depends on your needs. The DC to AC converter with 2300W is almost Rs 15000. Even around RS 7 / W. For the convenience of calculations, we have considered that the network is connected using an inverter of equivalent cost. Below, Table 4.4 provides an estimate of the overall price.

Table4.4 Pricing factor in different regions of India for PV feed and tariff

Component	Price: RS/W_{peak}
Panel	75-100
Converter/ Inverter	70
Cable, Transport and Installation	75

Technical Arrangements

Weather Station

Principal recognition in this have a look at is primarily based at the raw association of the weather station "Vantage Vue" of "Davis contraptions". that is combination of numerous sensors for measurements

- Radiation sensor
- Rain Outlet
- Temperature Sensor
- Humidity Sensor
- Wind Direction Sensor and Anemometer
- Barometer

Fig. 4.2 Set up Weather station has been installed at the top of the Buiding (top most left)(DAVIS INSTRUMENTS VANTAGE VUE)

This unit is taken because it is latest model of 2022 which gave a result with a good accuracy and in an affordable cost at RS 28000 in Indian market. A good feature of this setup is that it is having a big range of wireless transmitter. To get the data a free radio band (872.0-880.8) is used on which this station send the data. Its range can be expanding up to 350 m in the line to side. The range from the wall is set up 70m to 140m by the DAVIS INSTRUMENTS which is manufacturer of this weather station.

The data is collected to a Sensor Interface Module (SIM) from the entire sensor, where collection of data then the transmission of this data is send at required place. All sensors should be in single setup like the top left figure of 4.2.

The data is send to the PC which is connected to the receiver to get all the data. The data can be taken in seven different timings, due to some reason if the PC get off then receiver can store the data this receiver can be store up to 3000 data. Data is maintained and observed at 32 variable parameters like (Date, time, humidity, wind direction, atmosphere temperatur). Table 4.4 depicts the correlation of sampling intervals and record timing.

Table 4.5 Sampling gap and recording timing at the receiver

Sample Interval (minute)	1	10	20	40	80	160	320
Record Time	45	15	20	31	56	207	250
	Hours		Days				

Solar radiation sensor

It is a major part of this weather station that has important applications for this station. It is located next to the rain gauge. It must be in a horizontal position; it has layers of air in this shell that provide convection cooling.

Fig. 4.3 Solar Radiation Sensor

It has photodiode having the cell, in this setup a amplifier situated which convert the current into the voltage upto the 2.5 volt. Table 4.5 depicts data of this sensor

Table 4.6 statistics of the solar radiation sensor

Technical Data for Solar radiation sensor	
Resolution and Units	1 W/m^2
Range	0 to 2000 W/m^2
Accuracy	10 % of total scale
Drift	Up to ± 4% per year
Cosine Response	±3% for angle of inclination from 0^0 to 75^0
Temperature Coefficient	-0.15% Per^{0}C (-0.067% per ^{0}F) Temperature reference is 25^{0}C
Interval for Update	60 Second to 120 Second
Current Graph data	Instantly, Hourly, Daily, Monthly
Historical data	Hourly Average, Daily
Alarm	High Threshold from Instant Reading

Temperature sensor

It is located under the rain collector. it is based entirely on PN junction diode, sampling every 10 to 12 seconds**, can be degree -40^{0}Cto +60^{0}C**. In Fig. 4.4 the temperature variation is shown

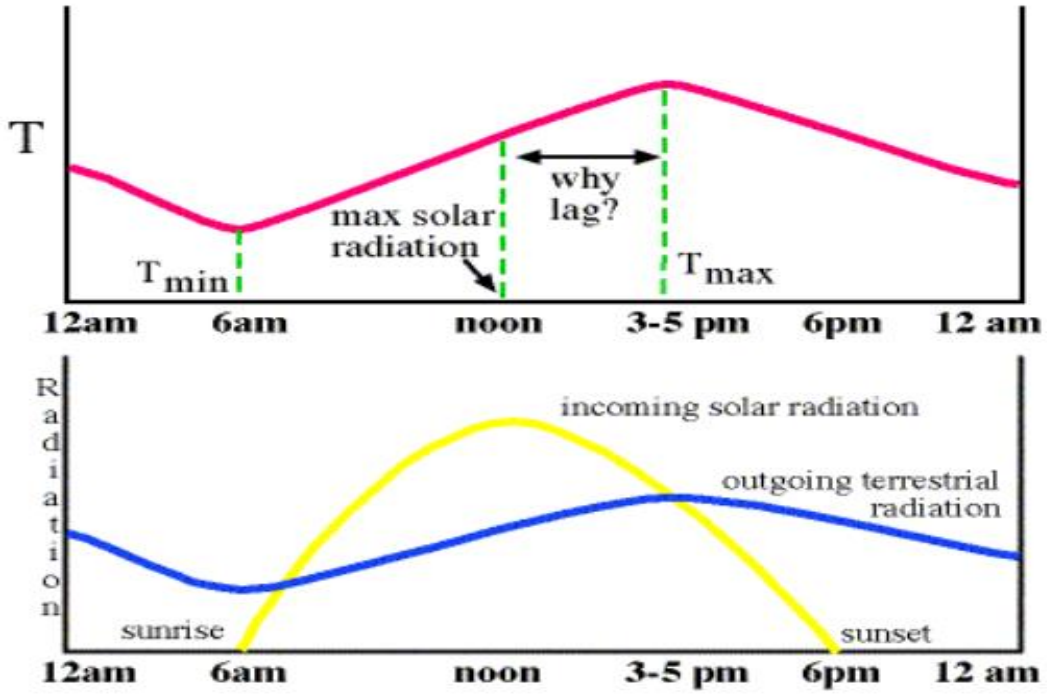


Fig 4.4 Accuracy over temperature trend for Davis temperature sensor

Moisture sensor: Relative humidity is measured with this sensor. This sensor can measure up to 100% RH. The time it takes to update is 50 seconds to 1 minute.

Pressure sensor: It measures pressures up to 1200 mbar with an accuracy of ±2.0 mbar with an update interval of 50 seconds.

Wind direction sensor: With the help of the spoiler, the path of the wind can be determined. Using a potentiometer, resistance is formed in the path of the wind. It updates in 2-3 seconds, due to its quality it becomes the fastest sensor in the whole system.

Wind speed sensor: Wind speed is calculated using a magnetic suction cup and suction cups. The shaft rotates once when receiving an impulse. This sensor also has the same 2-3 second update time as the wind route sensor

Rain sensor It measures precipitation using an inclined bucket and a rain-collecting cone with an area of 250 cm2. every 0.2 mm of precipitation suggested reading, all stats are sent to SIM. update time is 20-25 seconds**.**

Fig 4.5 Rain Gauge

Changes in the accuracy of rainfall are shown in the table. 4.6.

Table 4.7 Rain sensor accuracy

Rain Rate	Accuracy
Up to 60 mm/h	±5% or 0.3 mm
60 mm/h – 120mm/h	±5% or 0.4 mm

Limitations

Since semi-experts are not as accurate, long-lasting, and powerful as are used by many meteorological services as they may use very expensive and very specific equipment that is not feasible in weak financial conditions without we use.

"WeatherLink" Software used for weather measurement

Better analysis requires programs that complicate any analysis system. The USB connection is provided by the DAVIS manufacturer of the receiver station and a Windows computer with WeatherLink software installed. The software lets you know real-time scenarios where data can be saved. It has important features to import data and allows manual export of NOAA standards and geolocation reports..

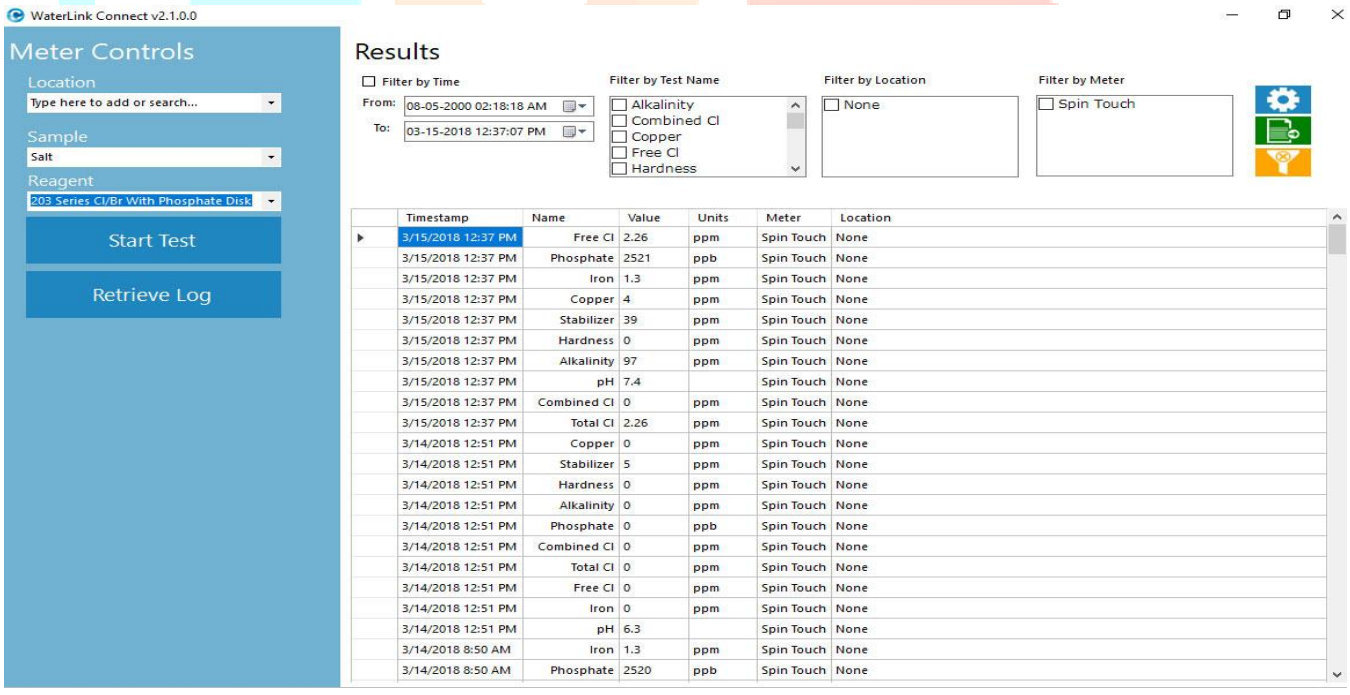


Fig 4.6 WaterLink software for analysing measurement data

An advantage of this software is that we can back up the data regularly, because it save data as a project folder in the hard drive. Cloud storage facility is also available in this software, which facilitate the worldwide downloading facility at any location.

Limitations

Only solar radiation can be measured using the WaterLink software. This software can only provide daylight calculations for the last 15 days. There is no mechanism to store solar energy according to sample time values. Detailed analysis and calculations require the use of various mathematical tools.

Installing the Weather Station

Due to different needs, you should consider installing your own weather sensor. The advantages are:

1. At any time the real time data is available
2. data of various parameters such as barometric pressure, temperature, humidity, wind direction, wind speed, and amount of solar radiation are always available. In general, we find that wind speed and direction data are not available in satellite data array setups..
3. The interpolation is not needed as the information given by it is always correct.
4. Purchasing of data from any external agency is quite costly and we cannot find it for any particular location.
5. Verified data can be send to many research organisation for facility them to do research at an advance level

Methods

Identify a proper location: Various considerations need to be made in selecting the appropriate location to install the weather station. The advice in the "Installation Manual" can be consulted from which we have an idea of the environment to avoid for installation and the proper location to install this station.

We have selected 5 locations to install it and the conditions have been classified for all sites. Identifying weaknesses is also important in discerning the optimal situation as well as the current situation.

We get an idea from literature survey for identify the proper location. It should be assure that there should not be shading at the timing of solar measurement from stating the day timing to the end of shining hours. From literatures we have find the idea that near the equator chosen location should be high. Various points and table 5.1 is found from Campell Scienentific.

Table 5.1 Sensors location instructions

	Association	Elevation from floor
Wind	A.A.S.C.	3.9 m ± 0.2 m
	E.A.P.	12.0m
	W.M.O.	12.0m
Temperature with relative	A.A.S.C.	2.1m ±1.26m
Humidity	W.M.O.	1.4m to 2.4m
	E.A.P.	3.0m
	A.A.S.C.	1.4m ± 1.4cm
Rain	W.M.O.	44.0 cm min
	E.A.P.	44.0 cm min
	Non objects ≥ 7^0 from the horizontal	
Solar Radiation	≤ 5m from floor for cleaning purpose	
	Horizontal set up	

It was found from survey of various weather stations that the location should be for away at least eight times of the building height, or other hurdles which situated near the weather station. The location should have proper floor area which should be covered with grass and cutting of this is required time to time. One more prime things should keep in mind that weather station should be away from heat exhaust area of any industrial or roof tops, steep slops, agricultural land shaded place, snow fall area etc.

Offset correction measurement

The data taken after a complete installation should match the official data taken from the nearest government weather station that only works professionally for it. IGI Weather Station (Indira Gandhi International) The airport took from the weather station to verify our data was taken in the early stages. There is a slight difference in the data that can be discarded.

Set up is installed according to the WMO standard which is mentioned in table 5.1. In fig. 5.1 depicts the wind direction sensor installation of IGI Airport.

Compared to where our weather has been configured, the IGI airport is less dense in population and forest, so there are slight data differences both in terms of location. We have compared the data to IGI Airport data only for an idea that we are taking proper decision to start measurement and we get that an positive indication found because the differences in both was in a limit.

Fig. 5.1 Wind speed and Direction sensor installation at Airport

Sample Timing

It is prime requirement to choose a proper timing for this evaluation with the consideration of the dynamic nature of solar radiation. Sample timing of weather station depend on solar insolation. In present study the minutes and hour data compared at various air masses.

The sampling needs to be done rapidly to avoid the data lost. This sampling timing should be very rapid in cloudy weather and maybe slow in the shining weather condition.

To begin with, we need to focus on one-day Ct clearance over the entire sampling period. It is the ratio between the current solar insulation G and the maximum possible insulation G0 (when there is no disturbance in the atmosphere) $C_t = \frac{G}{G_0}$ (5.1)

As we know that the sensor has placed horizontal the elevation angle α is also came in to picture. G0 calculated using external radiation H0 is 1400 W/m2 for a positive angle, which can be expressed as$G_0 = sin(\alpha) * k_0$ (5.2)

Elevation angle can be found in different time slot and it changes location to location

Next step to find frequency of Ct for different time slices from 0 to 1 in xi(Ct). where n is the quantity and i is the frequency interval is Xi and X0

$X_i = \sum_{i=0}^{i} x_i(C_t)(0 \leq i \leq n)$ (5.3)

Then next plot is done at a clearance index ($f_i(c_t)$) after deviding the interval X_n

$f_i c_t = \frac{X_i}{X_n} (\ 0 \leq i \leq n)$ (5.4)

A rapid sampling is done at the binging, which indicate a cloudy situation or sky is not clear

Wind Evaluation: Once the sampling rate is decided and measurements have been made, wind direction and speed must be evaluated. In this section, we will evaluate the relevant points.

Wind direction: To fully understand the wind direction, the direction data is divided into 16 directions, each of the 23^0. To get a wind diagram a collective data of direction frequency is needed, which then divided by total amount of valid direction for finding the relative value. If the setup is correct in position and installed properly then it will give similar direction as nearby weather station which is situated at IGI Airport.

Wind Speed: Wind speed analysis was performed using Weibull and Rayleigh distribution. From this we have the form factor k and the scale factor c, which explain the details of the wind at a particular location. Small value of c depicts the low speed of wind and higher value describe the higher velocity, where G factor describe the degree of stillness of the wind. The Weibull-distribution describe by

$t_{weibull}(v) = \frac{G}{c}(\frac{v}{c})^{k-1}.e^{-(\frac{v^k}{c})}$ (5.5)

Calculation of the coefficients k and c will be calculated using mean wind speed $\bar{v}$ and standard deviation σ.

$\bar{v} = \frac{1}{n}(\sum_{i=1}^{n} v_i)$ (5.6)

$\sigma = [\frac{1}{n-1}(\sum_{i=1}^{n}(v_i - \bar{v})2)]^{\frac{1}{2}}$ (5.7)

$k = (\frac{\sigma^{-1.086}}{\bar{v}})$ (5.8)

$c = [\frac{1}{n}(\sum_{i=1}^{n} v_i^k)]$ (5.9)

Taking a shape factor of 3 the Rayleigh distribution curve applied Weibull equation.

Solar Evaluation: To get the amount which reached the ground can be calculated by this solar evaluation. This solar isolation converted into the solar energy in the weather station to get a measurement, which depends on sampling time as well averaging of data. One month data is required to get a clear understanding.

$H_{month} = (\sum_{i=1}^{n} I_i).12.678[\frac{Wh}{m^2}]$ (5.10)

Solar irradiation data are found from satellite based system which provide its data to the Center of Excelllence for renewable energy at New Delhi.

Data according to ground base is available fron weather station at IGI Airport New Delhi.

Installation of weather station

Observation to the locations : Keep in mind the obstacles and limitations in order to perfect the installation installation location. Proper visual inspection allows visualization to decide on location. All the set up was installed at the roof to avoid the shading on the pyrometer and to avoid the damage of anemometer as well as wind vane. This entire situation would not recommend installing it at the ground. The location was chosen at the top of the building of center of excellence for renewable energy with a proper permission by the inspection of concern authority. All places are in the range of radio wavelength

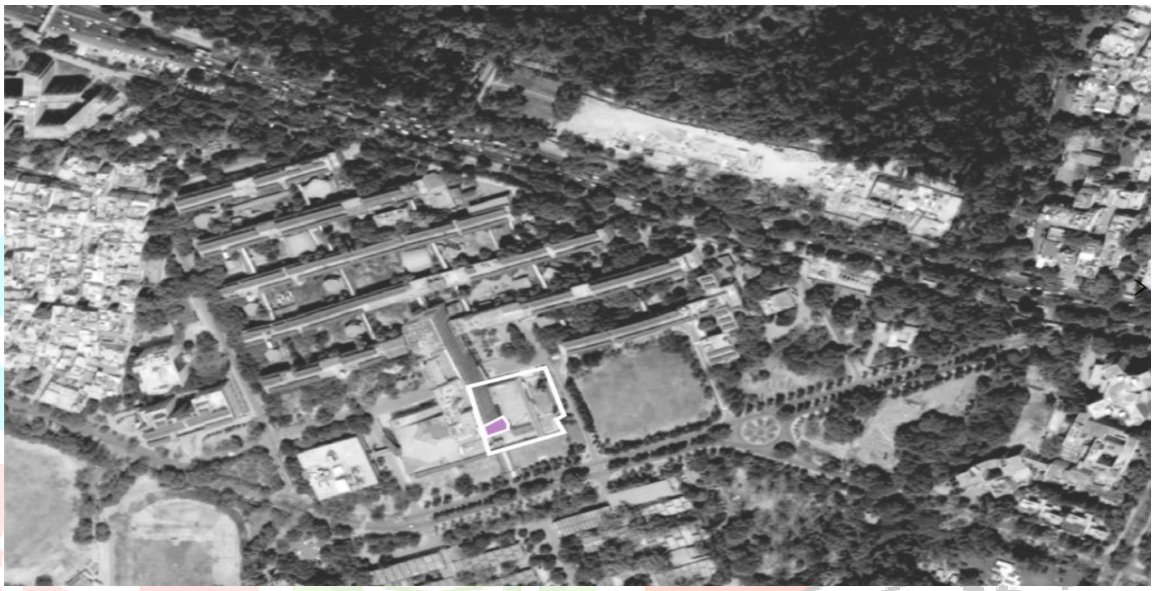
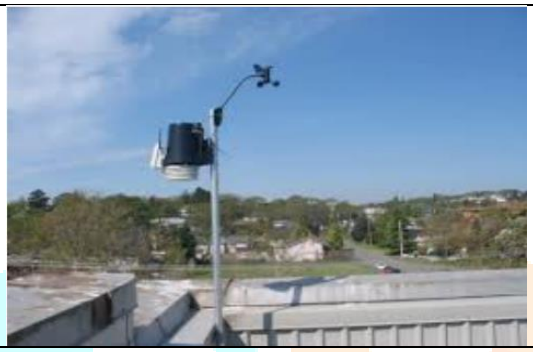


Fig. 5.2 Suitable location in New Delhi at the top of CoE for renewable energy

All chosen location have some advantages and disadvantages which is enlisted here

Table 5.2 Advantages and Disadvantages of selected locations

Sr No	Location View	Description
1		**At the top of CoE in South-East** Direction: Height: 25 m Advantage: (i)Very less distance to receiver (ii) direct sunlight Disadvantage: (i) **Interference due to** wind speed from north (ii) **Difficult to maintain** location
		**At the Wall of East side** Height: 30 m Advantage: (i) direct sunlight (ii) easier maintenance (iii) **Adequate** electricity supply Disadvantage: (i) **Wind disturbance**

3		**In the Lawn area** Height: 20m Advantage: (i) No **wind disturbance** (ii) easier maintenance (iii) **Adequate** electricity supply Disadvantage (i) Shadow of roof in the direct sunlight
4		**At The top most height of CoE Building** Height: 35m Advantage: (i) direct sunlight (ii)adequate accessibility (iii) No **wind disturbance** Disadvantage: (i) No lighting protection
5		**Terrace area of CoEbuiding** Height: 15m Advantage: (i) adequate accessibility (ii) adequate lighting (iii) Direct sunlight Disadvantage: (i) Wind Shadow from adjacent buiding (ii) Shadow to sunlight at the evening time

Finally the location 4 has been selected for the installation of own weather station due to its advantages which is more realistic and suitable for the investigation purpose. There was also a system for the solar energy has been installed which is having camera security which is also cover our setup.

Result

Table 5.3 provide an idea for all sensors for maintaining the standard

Table 5.3 Meteorological Specification

	Elevation above the floor	Specification	Fulfilled
Wind	2.25 m	AASC WMO EAP	NOK NOK NOK
Temperature and Relative humidity	1.75m	AASC WMO EAP	OK OK NOK
Rain	1.75m	AASC WMO EAP	NOK OK OK
Solar Radiation	• Planer setup • Without object $\geq 6^0$ • $\leq$ 4 m above the floor for maintenance		OK

Measurements

Temperature, Barometer Pressure and Relative humidity measurement

In this section, we found that changing various parameters in the configuration follows the trend of changing the same parameters at IGI Airport.

Fig. 5.4 depicts the temperature variation at both the places and provides an idea that how the own setup temperature trend is close to data of IGI airport

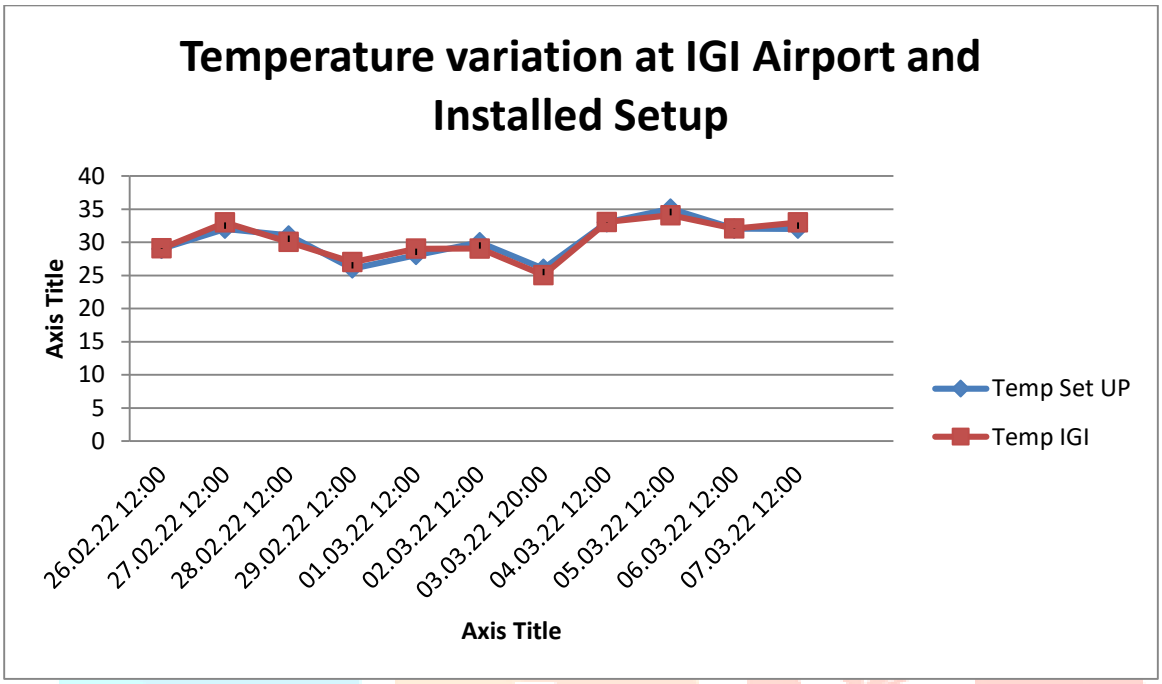


Fig 5.3 Temperature (^{0}C) variation at the CoE set up and IGI Airport

pressure variation is shown in Fig 5.4. it can be seen by the graph that setup installed at CoE has nearly 3 mbar more than the trend of IGI Airport

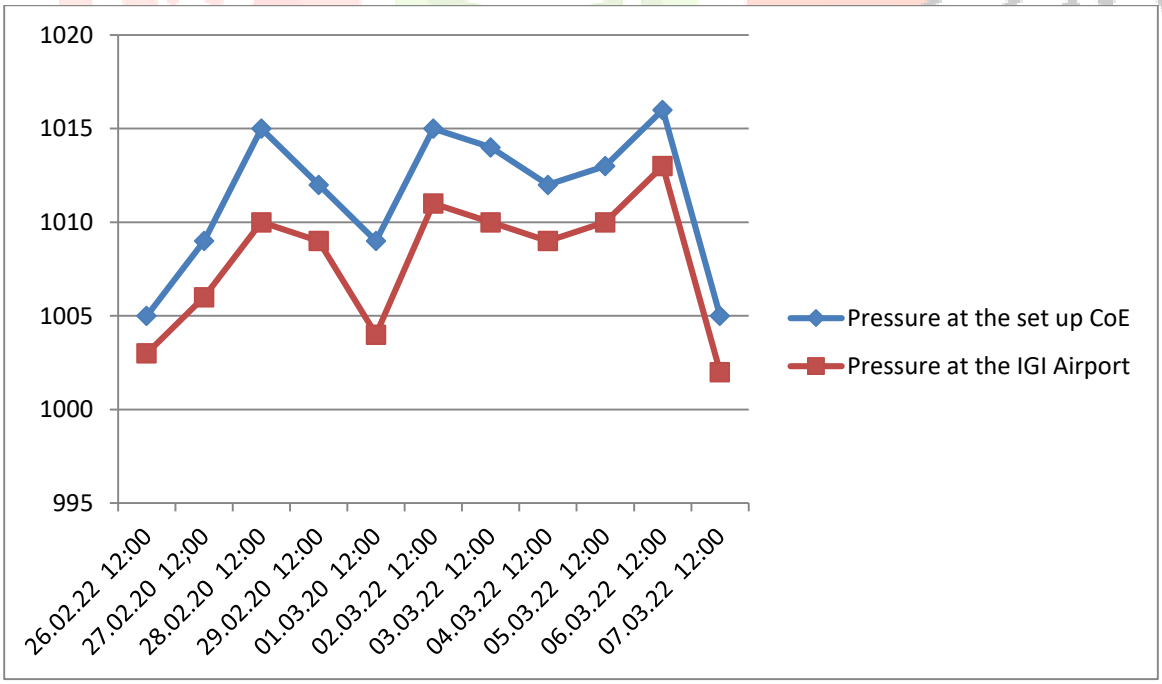


Fig 5.4 Pressure variation at the set up installed at CoE and at IGI Airport

Variation in Relative humidity is shown in Fig 5.5 to get a understanding the closeness of the this data at the installed set up and at IGI Airport

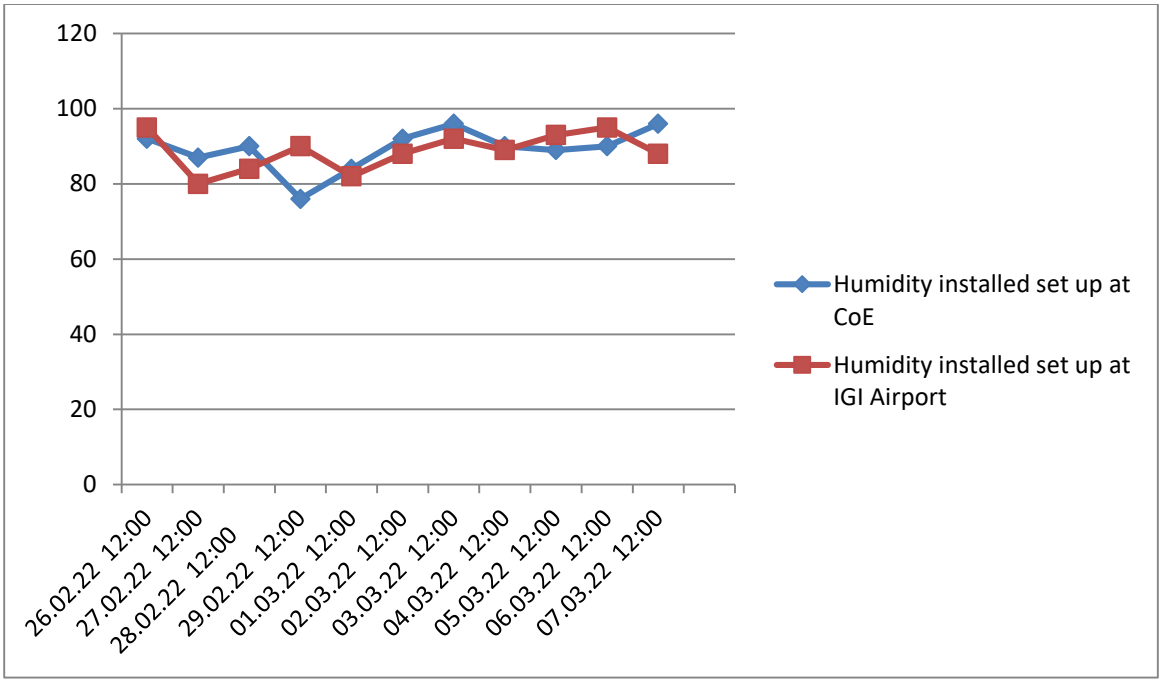


Fig 5.5 Variation in Relative humidity at the installed setup at CoE and at the IGI Airport

To get a clear understanding the average deviation has been calculated from the graphs which have shown above. Table 5.4 shows the deviation in various parameters at the installed setup.

Table 5.4 Deviation in Temperature, Pressure and Relative humidity at CoE

	Deviation
Temperature	0.4 ^{0}C
Pressure	1.9 mbar
Humidity	3.8%

From this it can be say that the installed weather station shows correct values, which indicates that the investigation can be start from this weather station. There is slight difference in data of both locations on same time that may be due to resolution of instruments and due to different environmental conditions.

Solar Radiation Investigation

The measurement was taken from February 27, 2022 to March 7, 2022. Data was taken from 11:55 am to 12:05 pm. and take the average, which is considered a perfect way to investigate.

Fig 5.7 depicts the variation in solar insulation for 1 minute, 10 minute and 1 hour for two different days, the days are chosen according to sun light availability first graph shows sunny day and second one is shows cloudy.

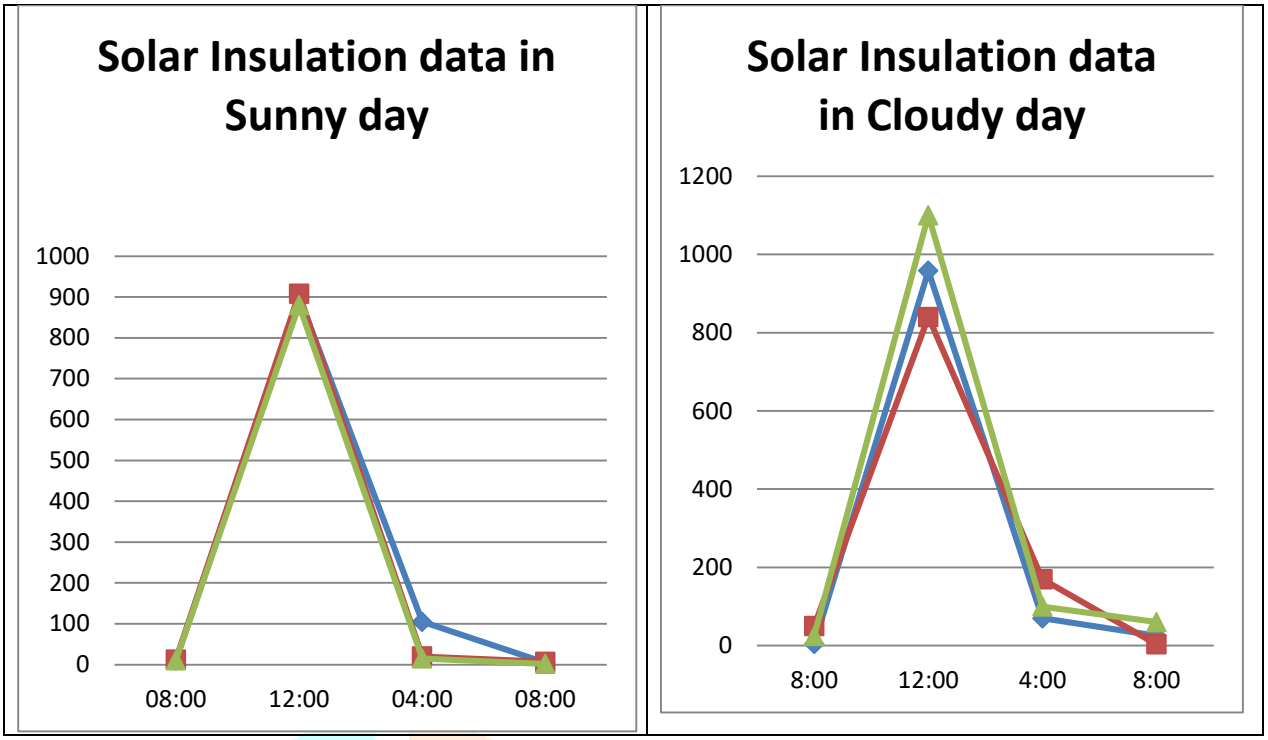


Fig 5.6 Sampling for 1 minute(Blue color), 10 minute(Red color) and for 1 hr (Graycolor) in sunny day and in cloudy day

Evaluation of wind data

For sampling, a total of 50,685 values were received over 2 minutes from February 2022 to March 2022. In the next section, we looked at changes in wind direction and wind speed for estimation purposes. This study is conducted to discuss the consequences of the measured values.

Analysis of wind direction

The value of wind speed is calculated according to relative frequencies, depicts in fig 5.7 in a radar form.

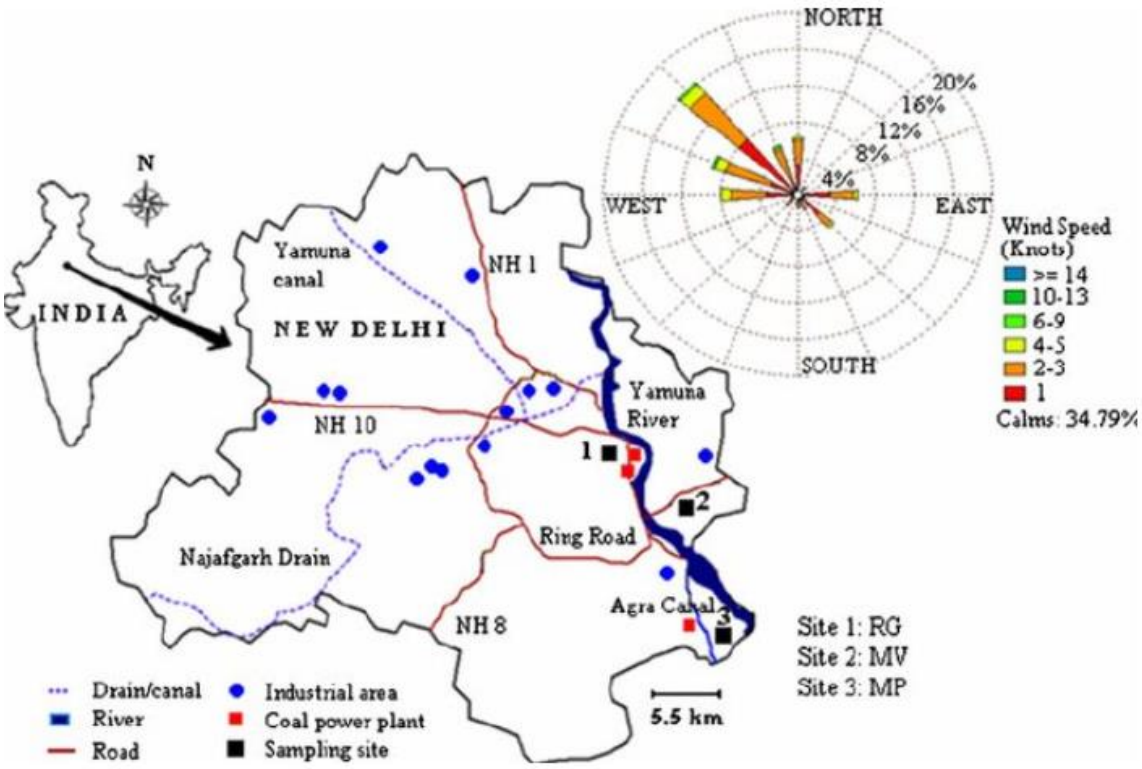


Fig 5.7 wind direction analysis in February 2022 to March 2022 in %

In North-West direction the participation of wind was highest in the month of February 2022 and March 2022. It was nearly 16%, when moving toward slightly west direction from North-West we found it was second most potential area for wind flow. From the radar diagram it was concluded that the during 40% time it is air is still or it can be say that there is no flow of air in any direction.

Analysis of wind speed

Weibull curve is used for analysis which is earlier discussed. Calculations for Weibull factors done with the help of equations which has earlier mentioned in the section 5.1.4.2. The findings are shown in table 5.5

Table 5.5 Avarage wind speed, standard deviation, shape factor and scale parameter in March 2022

	Average Wind speed $\bar{v}$	**Standard Deviation σ**	**Shape Factor K**	**Scale Factor c**
At Installed Weather station at CoE	1.58 m/s	1.22m/s	1.32	1.72 m/s

For the investigation of wind speed the process will be same as the done in the wind direction calculation. Fig. 5.8 represent the magnitudes with a bar diagram, it is found from this chart the maximum time the speed is 1-1.2 m/s. As per earlier discussion it was found that 40% time the wind in still condition or below 0.1 m/s. maximum value of wind speed takes place 10.5 m/s in March 2022.

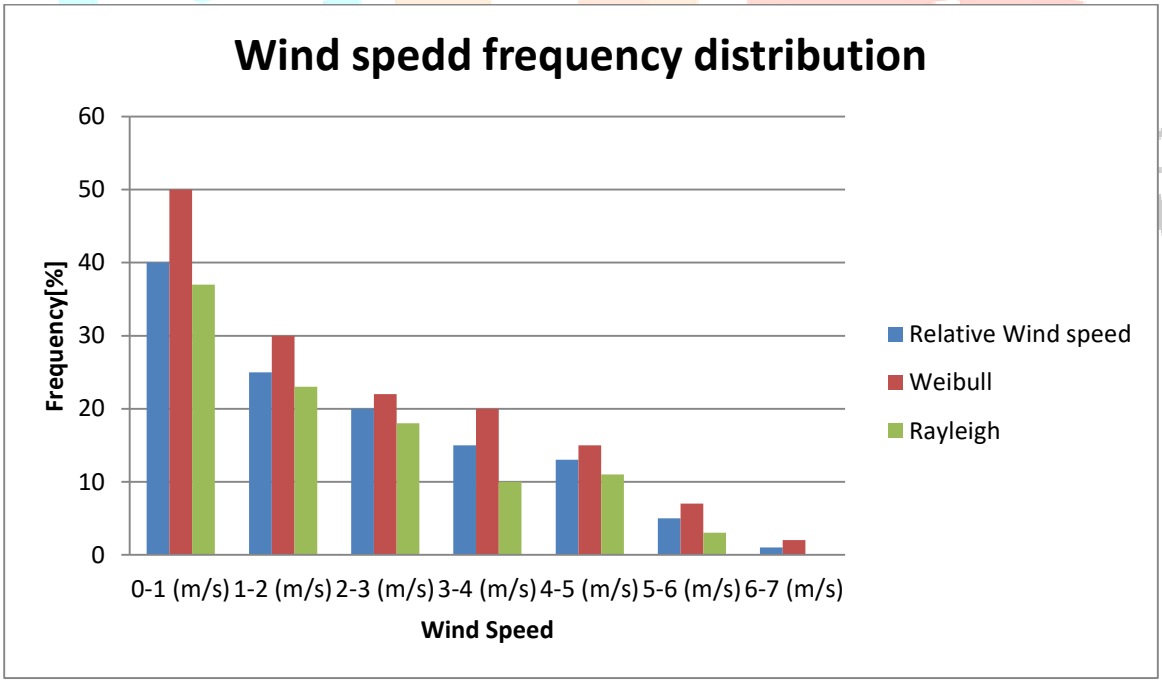


Fig. 5.8 Wind speed frequency, Weibull and Rayleigh observation for February 2022 and March 2022

Discussion in the aspect of wind speed and wind direction

There is a meteorological system at IGI Airport which maintains the wind data monthly with considering wind speed and wind direction. The available data shows that the record has been maintained from 1990 to till the date March 2022. The investigation of data has been revealed that wind flow mainly North-West direction. The distance between IGI airport and the location where own weather station is installed is 9.7KM.

The wind direction at the installed weather station and the IGI Airport shows almost same pattern. There is slight difference in wind speed which may be due to technique used at the airport and the installed weather station.

Another reason may be the height of pole at the airport which is more than that of own set up weather station. At the installed set up of weather station at CoE the effect of ground obstacle is considered.

Having an average wind speed 2.01 m/s the CoE where own set up has been installed in not a windy location. Below mentioned table 5.6 depicts magnitude for the evaluation of wind energy potential.

Table 5.6 Average wind speed, standard deviation, shape factor and scale parameter in February 2022 and March 2022

	Average Wind speed$\bar{v}$	**Standard deviation σ**	**Shape factor k**	**Scale factor c**
IGI Airport	2.67 m/s	0.75 m/s	3.67	2.87 m/s
CoE location of installed set up	2.01 m/s	1.85 m/s	1.97	1.86m/s

It can be seen that the average wind speed as well shape factor and scale factor at IGI Airport having large value than that of location of own installed weather station, it may be due to the outer space of airport from the city as well the open area are available at airport where a large area are restricted for any construction.

Solar evaluation for February 2022 and March 2022

Observation

The February and March heatstroke survey was conducted. For comparison, Figure 5.9 shows the distribution of two months. It can be seen that March receives more sunshine than February.

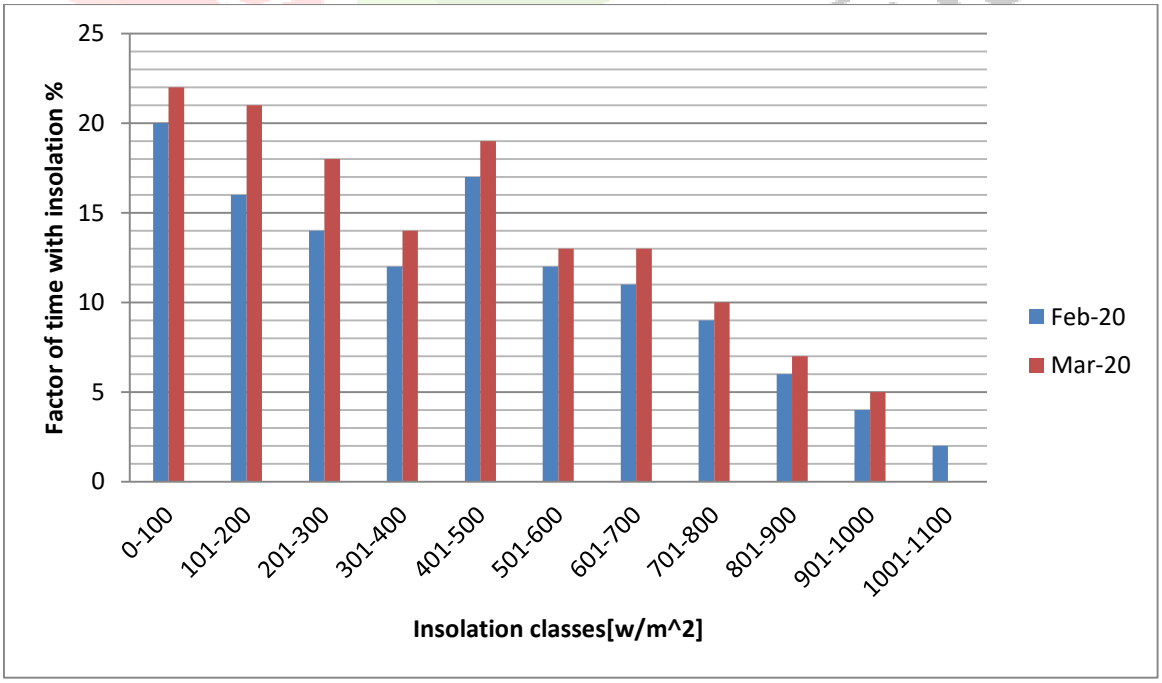


Fig.5.9 frequency of insolation in February 2022 March 2022

Collective energy for February and March month from the CoE weather station is 105.8 kWh/$m^{2.}$. A comparison is made in daily and monthly average values measured with the help of satellite as well as ground base measurement which is presented in table 5.7.

Table 5.7 Solar insolation data for IGI Airport in February 2022 month measured by different mechanism

	Monthly kWh/m^2	**Average Daily kWh/m^2**
CoE Weather station	**112.7**	**4.02**
METER Weather Station Data, February and March	105.6	3.85
NASA-SSE Satellite	145.8	4.32
SolarGIS satellite	159.7	5.85

The value of daily average PSH for CoE in February 2022 was 4.02 h/day, For February and March the value of solar insolation was 152kWh/m^2. The measurement is analyse with the same sources. This is depicted in the table 4.8

Table 5.8 Solar insolation data for IGI Airport in March 2022 month measured by different mechanism

	Monthly kWh/m^2	**Average Daily kWh/m^2**
CoE Weather station	**152.7**	**5.03**
METER Weather Station Data, February and March	135.6	4.35
NASA-SSE Satellite	167.8	5.82
SolarGIS satellite	185.7	6.85

The value of daily average PSH in March 2022 was 5.03 h/day, for and March.

The value of solar insolation is represents for February and March month in above mentioned tables. It can be observed that a deviation of 26%, 32% and 9% is seen METER, NASA-SSE, Solar GIS respectively for February month. This deviation is 16%, 20% and 8% is seen METER, NASA-SSE, Solar GIS respectively for March month.

Discussion in the aspect of solar insolation

Fig 5.9 shows the frequency variation for February and March month, it can be finding that the amount of isolation is higher in the March month. The reason may be due to start of sunny days, which causes increase of incidence. From observation it can be found that the maximum value of insolation occur till 1000 to 1100 in the March month, a prime reason behind this that some time rain takes place in this season which clear the surrounding and provide a hurdle free surrounding.

From the various literatures survey it was concluded that there in less deviation in the values of satellite based measurement and ground base measurement in the time when there is clear sky and fully overcast

days. In the ground based data we can find a record for only a particular place but in the same time satellite gives a record of a region. We have mentioned about the error which occur due to the cloud or fog. The mechanism followed by NASA-SSE uses PV simulation operator PVSyst. A small deviation from the own installed weather setup can be seen due to its large area resolution which reduces accuracy in the planer area. Reason behind the larger deviation may be due to its location in New Delhi, large number of industries and a dense population who uses various appliances affects the aerosols of the air.

Conclusion and Future scope

When the suitable location was finalized then the set up for weather station has been installed for measurement. It was found that the trend of pressure, relative humidity and temperature follow the same trend like a professional weather station. We get sampling in the sample timing. The investigation of February and March month was done in this study. Measurement of rainfall in not considered due to inappropriate location for continuous rain it may be considered in future study. Short time sampling required for clear understanding of weather stations especially for solar insolation. This short timing observation is mainly required when the change of sunny day to a rainy day quickly.

Solar evaluation is not very accurate because of it is found by derivations of satellite and ground base data. For a precise measurement the reading should be taken for a long duration nearly one year.

At the time of installation all the restriction by meteorological standard can't be avoided, due to limitation of cost and available of less time. To follow a standard we should do some steps like heating above roof should be avoided, to be avoiding the superheated air. The tendency of warm air to stick at the roof surface when there is no wind is flow. To decrease the temperature derivations forced ventilation is required, or a grassland roof is also reduces the temperature derivations.

The biggest challenge was finding the right place to install the weather station.

Another problem is that the wireless system and the sensor are limited by being close to each other. A pyranometer was used to determine the exact location. For this reason, we have chosen the highest location of the Council of Europe building. Many auxiliary sensors were also used. To measure wind speed, the sensor should not be installed at too high a height to avoid turbulence. It is not recommended to measure the temperature above concrete. Due to the location, the CPU is always in warm conditions, but the IGI conditions are slightly different. Wind and sun assessments are made after proper measurements within 14 days.

• The wind direction at IGI Airport was found to be mainly north-westerly. There are slight differences in wind direction, speed, standard deviation, and shape factor.

• He pointed out that the measurements of the weather station he installed were unprofessional when needed. Taking this measurement over a long period of time can make a big difference in your location data.

• Maintenance and modification are required when installing the wind vane.

• It can be seen that there is a large difference between the data obtained from the ground-based survey and the satellite-based survey.

• A study of CoE position anomalies with configuration and satellite data established was larger in February than in March, but the difference was larger in March.

• Documentation showing the relationship between clear skies and measured data discrepancies for confirmed terrestrial and satellite data and justification for changes.

Modeling of photovoltaic systems could be a future work in this field of research. The main disadvantage is that there is a significant investment during installation. To overcome this, thin-film technology can be used at a reasonable cost. The accessibility area above the CPU building has an 8.5 kW peak power plant that can be installed at 8.95 MWh per year. Changes in the observable base in crystalline descriptions for hot climates are often affected by the temperature coefficient. This system used the base surface of the top of the building. To maximize the efficiency of available space, crystalline technology that takes up very little working space should be used. Our main concern is the analysis of a scientific approach, as our motive is not the concern for best performance.

If PV installations are to be made in the future, some guidelines in this study should be followed. Meteorological stations can make weather forecasts to calculate energy yields. The data recorded by the meteorological station and PV system can be used for future research work. Apart from the statistical data used in this study, IGI airport data should also be used for future work comparison purposes. The previously proposed improvements should also apply to future work. Davis guarantees a 2% variation in solar rating for one year and provides guidance for further calibration.

The on-going efforts of the Renewable Energy Excellence Center (CoE) to study in the field of renewable energy by providing the best possible services to researchers in the field of renewable energy will make India the energy sector. Has made a significant contribution to making it an emerging market. We gather real-world experience when planning future PV systems at meteorological stations. The measurements at my meteorological station are still functioning and there are no problems with the operation of the meteorological station. You can get some data for future observations. This environment is intriguing to various researchers working in this field.

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