# An Energy Scheduling Eco-friendly Framework Solution in India.

**Thesis**
Submitted for the award of
Degree of Doctor of Philosophy
Discipline Civil Engineering
By

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# MAHARISHI UNIVERSITY OF INFORMATION TECHNOLOGY LUCKNOW, 226013, INDIA

## Candidate's Declaration

I hereby declare that the work presented in this thesis entitled **"An Energy Scheduling Eco-friendly Framework Solution in India"** in fulfilment of the requirements for the award of Degree of Doctor of Philosophy submitted in School of Engineering & Technology, Maharishi University of Information Technology, Lucknow is an authentic record of my own research work carried out under the supervision of **Dr. Gaurav Shukla**, Assistant Professor, School of Engineering & Technology in this University. I also declare that the work embodied in the present thesis-

i) is my original work and has not been copied from any journal/ thesis/ book; and

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Date -

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## Supervisor Certificate

This is to certify that **Mr. Manish Kumar Agarwal**, Enrollment No. **MUIT0116038071**, has completed the necessary academic turn and the swirl presented by his is a faithful record is a bonafide original work under my guidance and supervision. He has worked on the topic "**An Energy Scheduling Eco-friendly Framework Solution in India**" under the School of Engineering & Technology, Maharishi University of Information Technology, Lucknow – 226013, India. No part of this thesis has been submitted by the candidate for the award of any other degree or diploma in this or any other University around the globe.

**Dr. Gaurav Shukla**

Date:

Professor

School of Engineering & Technology

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Lucknow

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Manish Kumar Agarwal

# ABSTRACT


The Energy Scheduling Eco-friendly Framework Solution in India aims to revolutionize energy management by integrating renewable sources like solar and wind with advanced technologies such as smart grids and predictive analytics. This approach optimizes energy generation, distribution, and consumption to reduce carbon emissions, enhance energy security, and promote sustainable development. It emphasizes collaboration among stakeholders and regulatory support to achieve significant environmental and economic benefits for India's energy landscape.

In India, the increasing demand for energy coupled with environmental concerns necessitates innovative solutions for energy management. This abstract proposes an eco-friendly framework for energy scheduling to address these challenges effectively.

The framework integrates advanced technologies including renewable energy sources, smart grids, and predictive analytics to optimize energy generation, distribution, and consumption. Key components include:

Renewable Energy Integration: Leveraging solar, wind, and other renewable sources to diversify the energy mix and reduce dependency on fossil fuels.

Smart Grid Implementation: Utilizing smart meters, IoT devices, and real-time data analytics to monitor and manage energy flow efficiently across the grid.

Predictive Analytics: Applying machine learning algorithms to forecast energy demand patterns and optimize scheduling of energy production and distribution.

Demand Response Strategies: Encouraging consumers to shift their energy usage to off-peak hours through incentives and real-time pricing, thereby reducing peak demand.

Environmental Impact: Assessing and mitigating the environmental impact of energy generation through continuous monitoring and adaptation of sustainable practices.

Policy and Regulatory Support: Collaborating with policymakers and regulatory bodies to create a conducive environment for the adoption of eco-friendly energy solutions.

By implementing this framework, India can achieve significant reductions in carbon emissions, enhance energy security, and promote sustainable development. The abstract concludes by emphasizing the importance of interdisciplinary collaboration among stakeholders to realize the full potential of this eco-friendly energy scheduling framework in India.

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# CHAPTER 1
# INTRODUCTION

## 1.1 BACKGROUND:

Modern technology has made it possible for people to live longer in more comfort and with greater leisure. Technologies have brought intellectual and material privileges to ordinary people that kings could not have enjoyed only a few generations ago. Energy is the most important by-product of modern technology. As a result, energy has become the basic need of humans for the last hundred years. It is the major player for monetary and sociality growth of community. Currently, the electrical power is generated largely by oil, natural gas, and coal. However, these are the main cause of eco-friendly digression issue by GHG emissions, particulate matter (PM), mountain ash, layer ash, etc. these are greatly malignant for human being. Global climate change is a social problem which is caused by carbon dioxide ($CO_2$) and others harmful GHG liberated through combustion of fossil fuel that share to the –green-house‖ impact. 37% of total $CO_2$ concentration in the environment is caused by power plants. Therefore, some modifications and a unified perspective for present electricity generation in the country. It is also essential for an eco-friendly system approach.

In this research work, I have studied and analysed the present condition of power system in India and its total impact on environment such as emission of carbon dioxide and other harmful greenhouse gases (GHG).The power sector and its operation has been analysed and it is concluded that a clean energy project model through a modern efficient approach must be developed. In the present work, I have suggested the integration of solar energy generation with conventional power generation to reduce the emission of $CO_2$ and other GHG. We propose some modifications in the planning of power systems in such a way that minimizes the emission of $CO_2$ and other GHG.

The long-term goal of government is to make ―Environmentally Healthy and Clean India‖. The intent is to generate power keeping the environment healthy and contributing to Swachh Bharat. Government is also improving the energy efficiency programme with distribution of LED Bulbs. The Government has a commitment to provide 24x7 power supply to all and every household in country and provide electricity connection by December 2018.

In the subsequent paragraph, this chapter covers the energy scenario in Indian context. Problem statement is discussed in next section followed by the major findings in term of the proposed solutions. In remaining part of the chapter, the organization of the thesis is written followed by the conclusion.

## 1.2 INTRODUCTION TO ENERGY SCENARIO IN INDIA:

Energy scenario in India may be studied based on the different regions of all India installed capacity (MW) of power stations. There are total six energy regions in India: Northern Region, Western Region, Southern Region, Eastern Region, North Eastern Region and Islands. Total distribution is also divided based sectors into State sector, Private sector and Central Sector. It is further divided based on the several categories of fuels used in energy sector such as: total thermal (Coal, Gas, Oil), Hydro (Renewable), nuclear and RES (MNRE) based on the data received from

Central Electricity Authority (CEA) as on 31-03-2018. Total installed capacity is 24.6%, 30.2% and 45.2% for State Sector, Central Sector and Private Sector respectively based on CEA published dataset[2].

Based on Fig. 1.1, all India capacity for coal is 197171.5 MW which is the highest amount of fuel installed at power stations. It evident that diesel is the least installed fuel with value 837.63 MW. It means coal is the widely used fuel among all power stations in India. When we look at the same figure, RES has 69022.39 MW capacities. It signifies that the RES has one of the major contributing fuels among all fuels at different power stations in India for the reduction of $CO_2$ emission. These data values give confidence to the researchers to further explore the use of RES for the mitigation of the GHG.

Thermal energy is composed of coal, gas and diesel. To know the percentage of the different category of fuels installation in India, Fig 1.2 is presented. It is clear from Fig. 1.2 that major percentage belongs to thermal energy installation. There is still lot of efforts needed to be put to increase the percentage of nuclear and hydro energy. However, RES has 20.10% of contribution but more we install the RES, there are more chances of reduction of $CO_2$ emission. One of the major challenges is that if we increase or keep the same percentage of thermal energy installation in India, it is impossible to control the CHG emission. So, there is a strong demand to promote the RES and to reduce the use of thermal energy.

Sector wise percentage installation in India is shown in Fig 1.3. In Indian scenario, private sector is found to be main contributor to the energy generation with 45.20%. Here states govt. has the minimum percentage of energy generation with 24.60% in comparison of Central Govt. installation with 30.20%. It is suggested that the central government should promote the state govt. to increase their percentage of energy generation mainly using RES to meet the future demands till 2030.

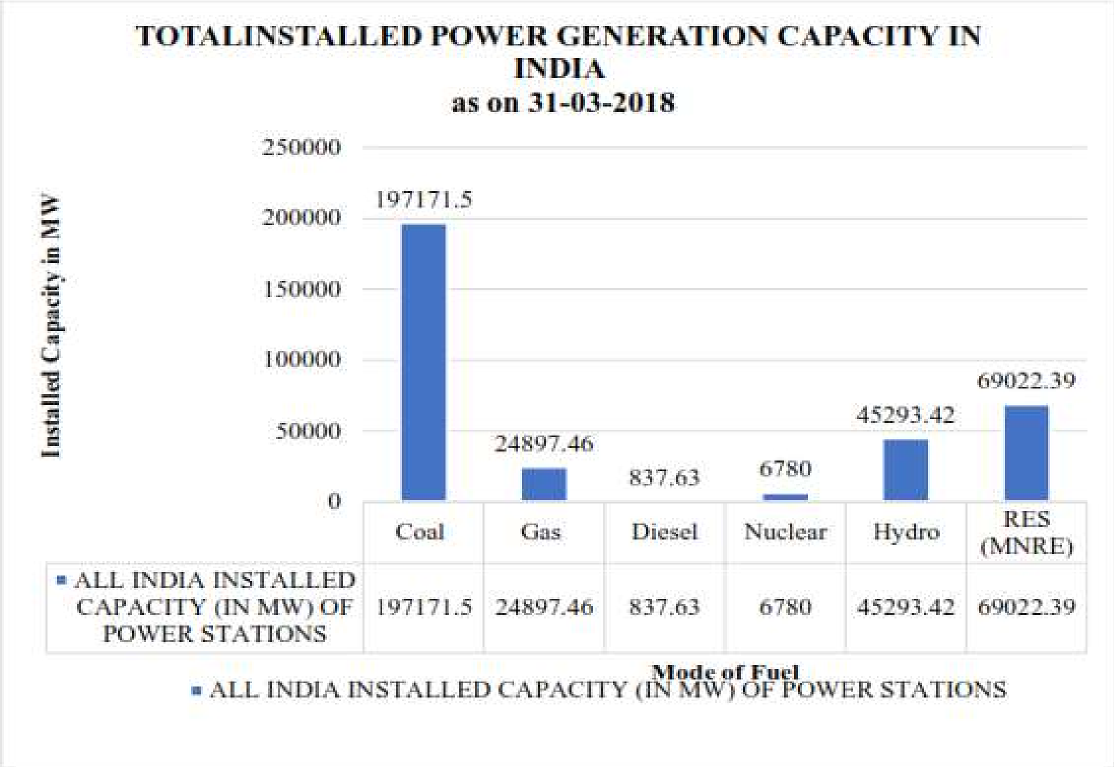


Figure 1.1 All India installed capacity (in MW) of power stations as on 31-052018 From CEA2

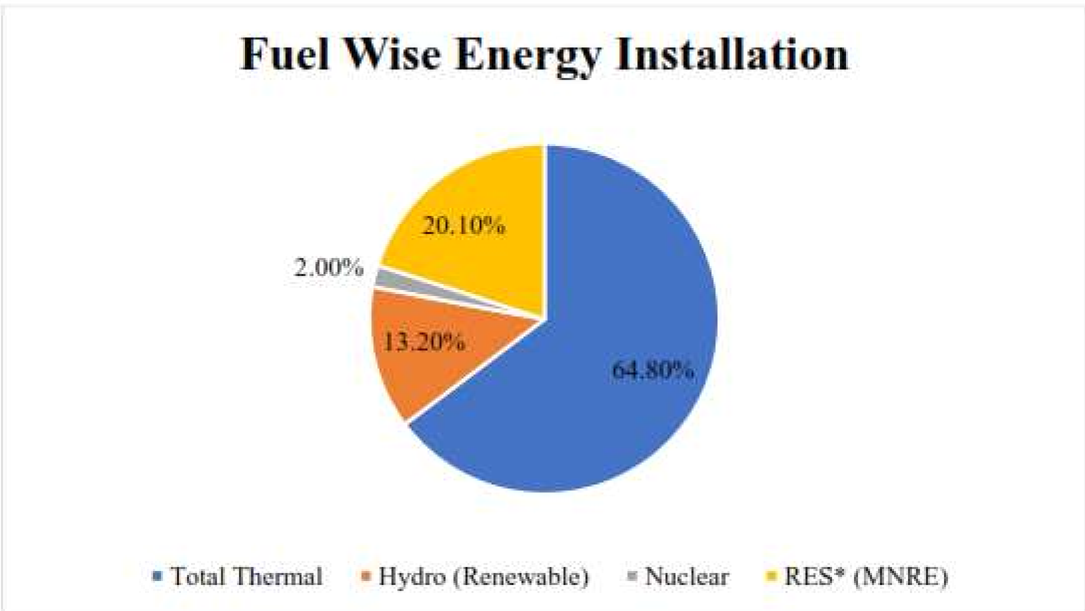


Figure 1.2 Percentage Fuel Wise Energy Installation in India[2]

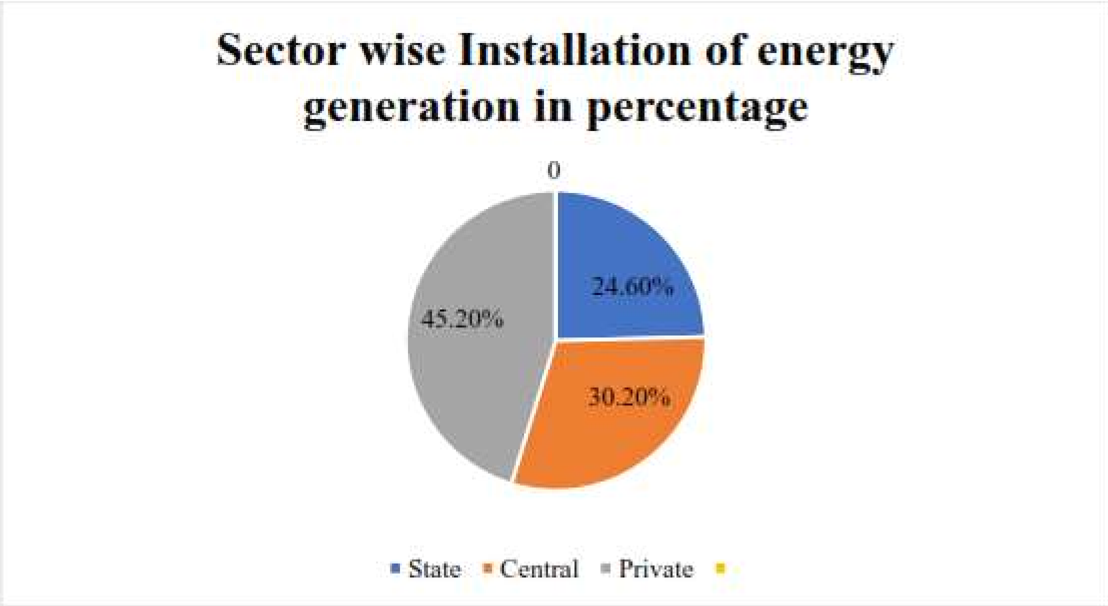


Figure 1.3 Sector Wise Percentage Installation of Power Sector in India[2]

Further yearly energy generation growth in MW for India is shown in Fig. 1.4. Continuous progress is seen during the last ten years from year 2009 to 2010 as reference point. CEA data is further analysed to understand the growth of conventional energy generation in India as shown in Fig. 1.5. In 2009 to 2010 it was reported to be at a level of 6.6 %, thereafter it reached its highest percentage in year 2014-2015 up to 8.43%. Then slight reduction in growth percentage of convention energy is observed due to the increased use of RES generation. Data shown in Fig 1.5 also gives us confidence and practical support that there are fare chances of improvement in use of RES energy due to high demand along the need of less emission of GHG and $CO_2$. Due to this we have explored the possibilities of research in the area of RES along with the integrated approaches in the proposed work to keep the emissions as less as possible for GHG and $CO_2$.

Based on the data analyzed from the Fig. 1.5, we know that there is clear cut demand of RES in Indian power scenario. However, to know the category of RES, which is most widely used in India, we have analyzed the RES power generation in Fig. 1.6.

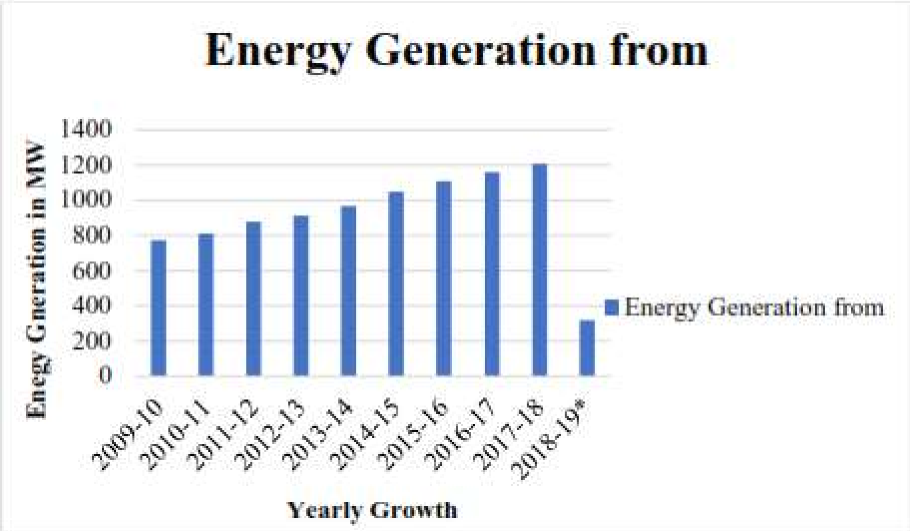


Figure 1.4 Energy Generation Growths in MW in India[2].

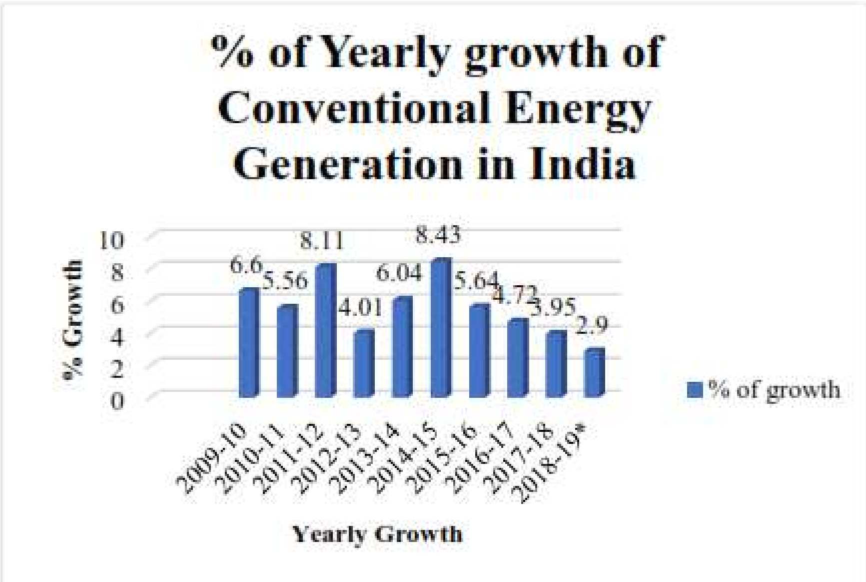


Figure 1.5 Indian thermal power generation during 2009-10 to 2018-19 from CEA[2]

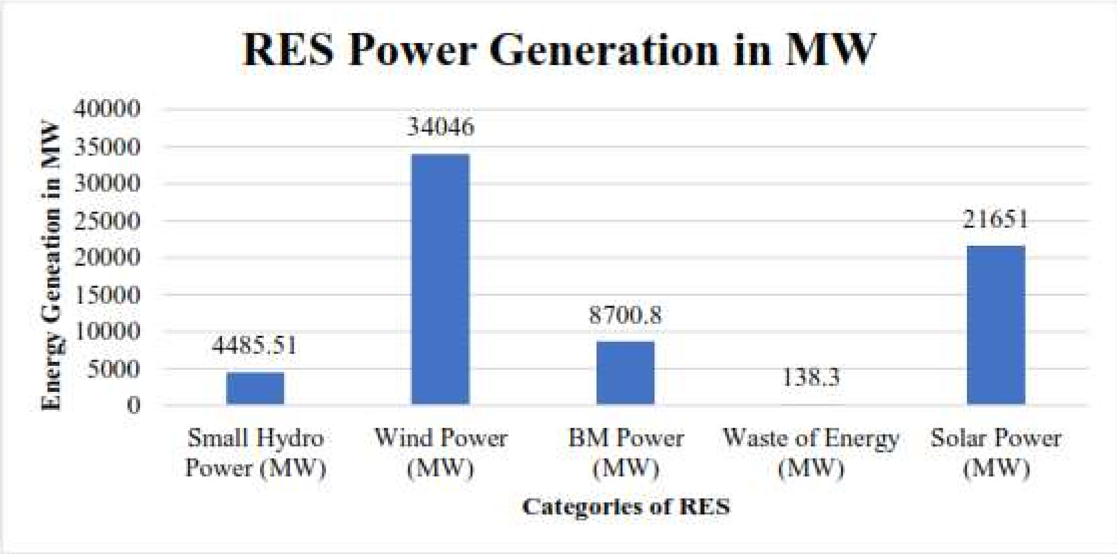


Figure 1.6 Renewable Energy Sources (RES) power generation in MW as 31-032018 (CEA[2])

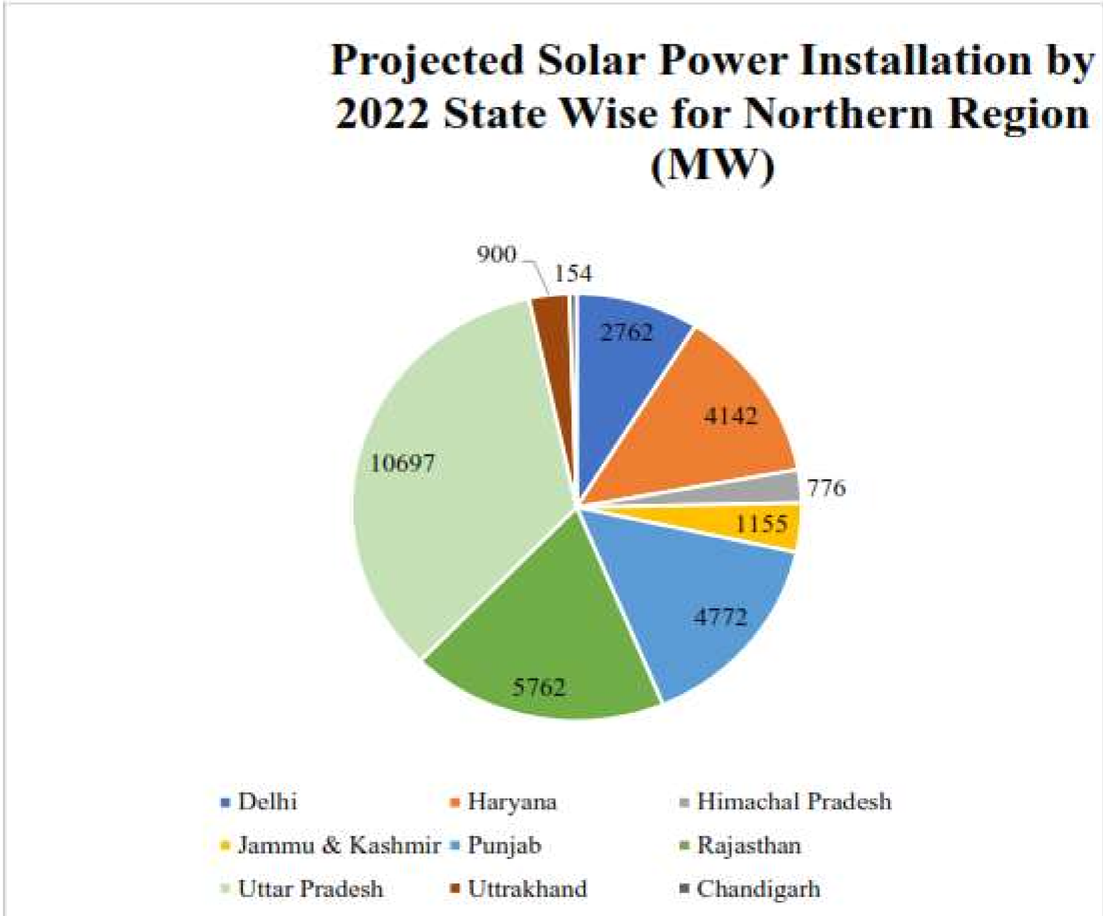


Figure 1.7 (a) Renewable Power target to be achieved by 2022 for Northern Region[1]

It is clear from the Fig 1.6 that wind power has generated the highest amount of energy followed by the solar power. On the other side small hydro power and biomass-based energy generation found less power in Indian power generation scenario. Fig 1.7 (a) to Fig. 1.7 (f) demonstrate the tentative solar power generation by 2022 with region wise distribution throughout the country.

Based on the Figs from 1.7 (a) to 1.7 (f), it is clear that UTs need more improvements in term of power installation by 2022. Another Fig. 1.8 is drawn to know the RES generation target region wise for RES only in MW for India. To know the total absolute carbon dioxide emissions from the power sectors between years 2010-11 to 2015-16 in Mt.in India as on March 2016 is shown in Fig. 1.9.

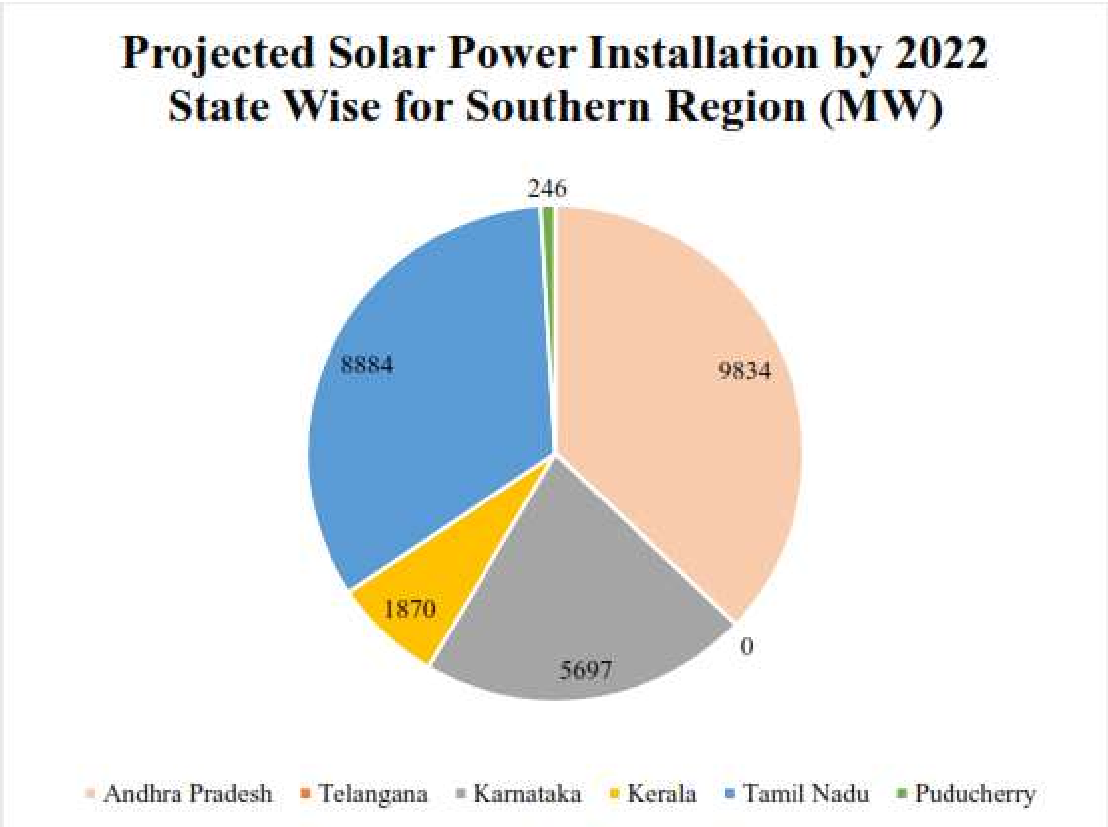


Figure 1.7(b) Renewable Power target to be achieved by 2022 for Southern Region[1]

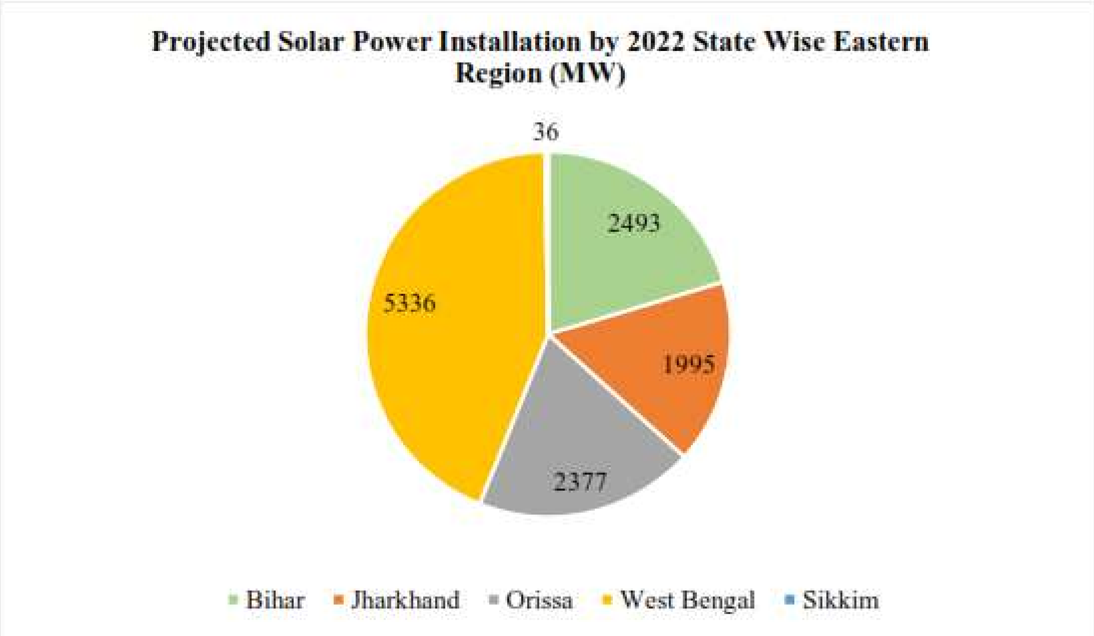


Fig. 1.7 (c) Renewable Power target to be achieved by 2022 for Eastern Region[1]

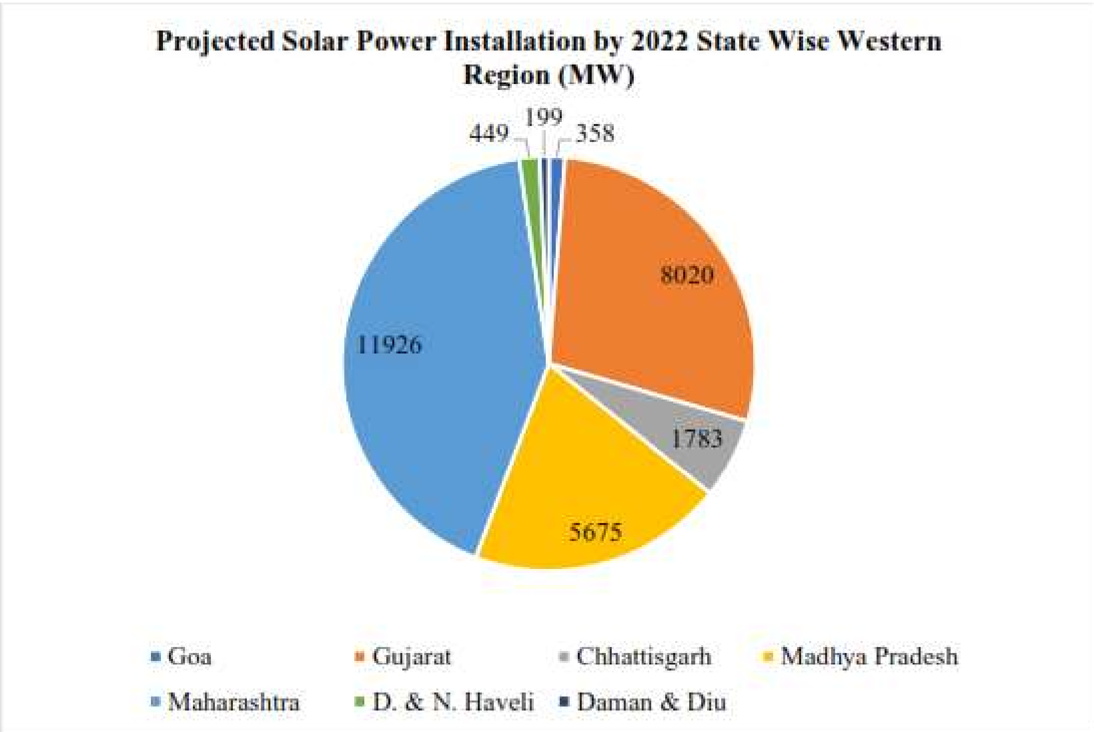


Fig. 1.7 (d) Renewable Power target to be achieved by 2022 for Western Region[1]

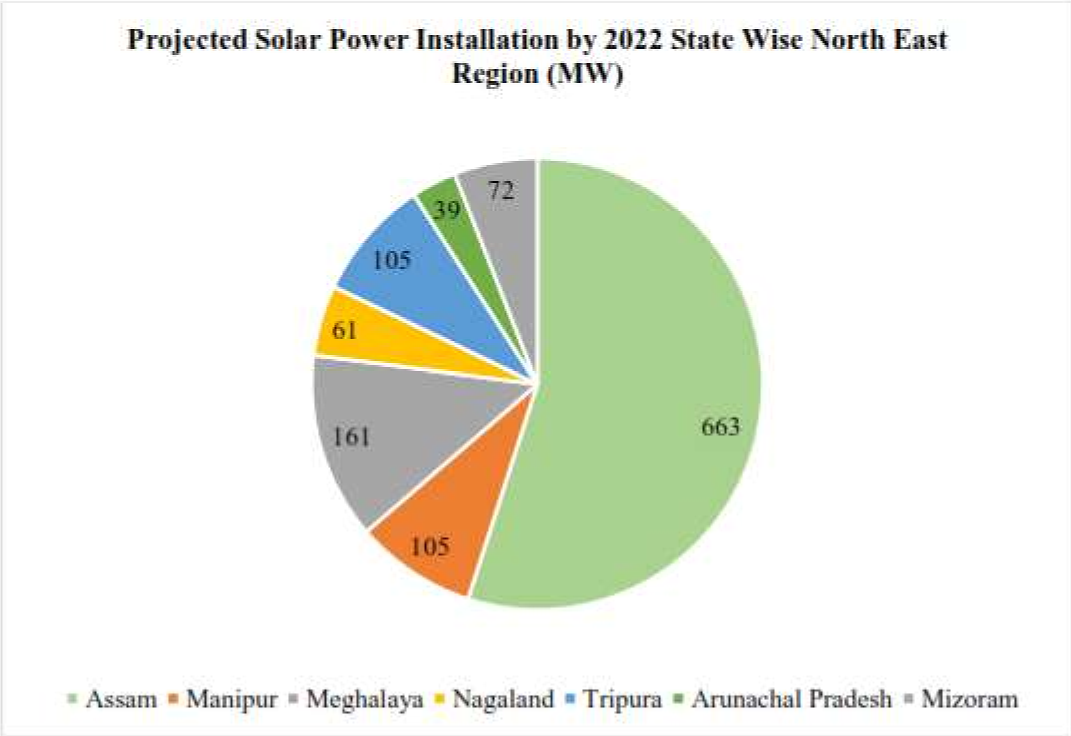


Fig. 1.7 (e) Renewable Power target to be achieved by 2022 for North East Region[1]

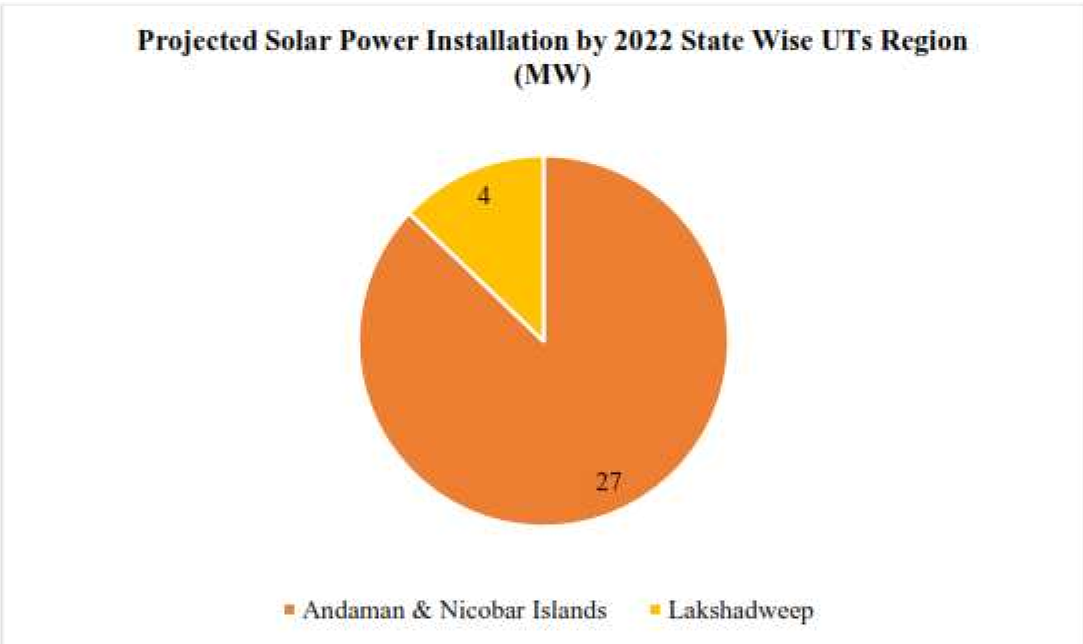


Fig. 1.7 (f) Renewable Power Target to be achieved by 2022 for UTs[1]

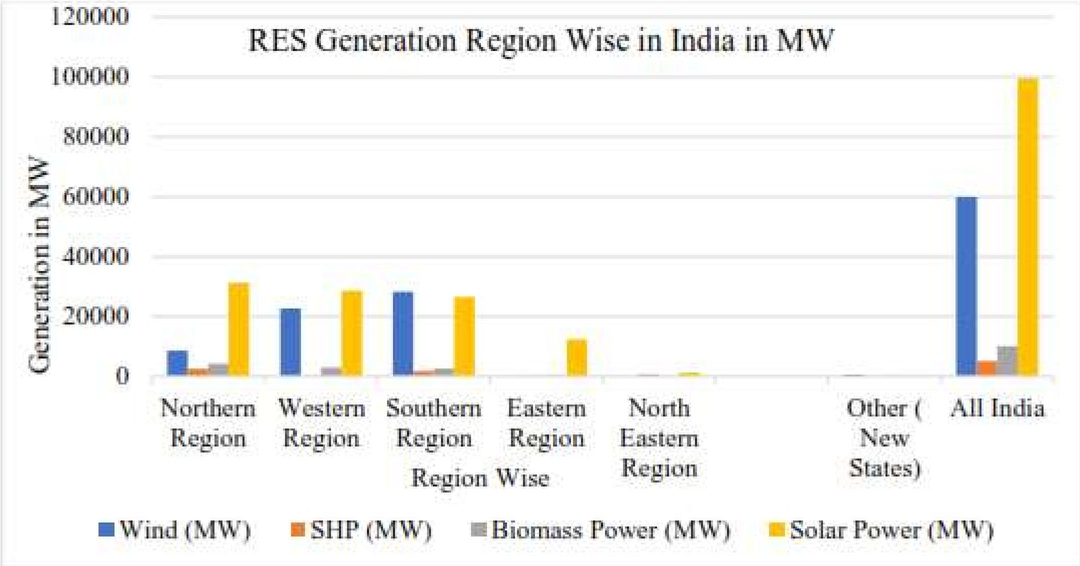


Fig 1.8 Renewable Power Target to be achieved by 2022 for RES[1]

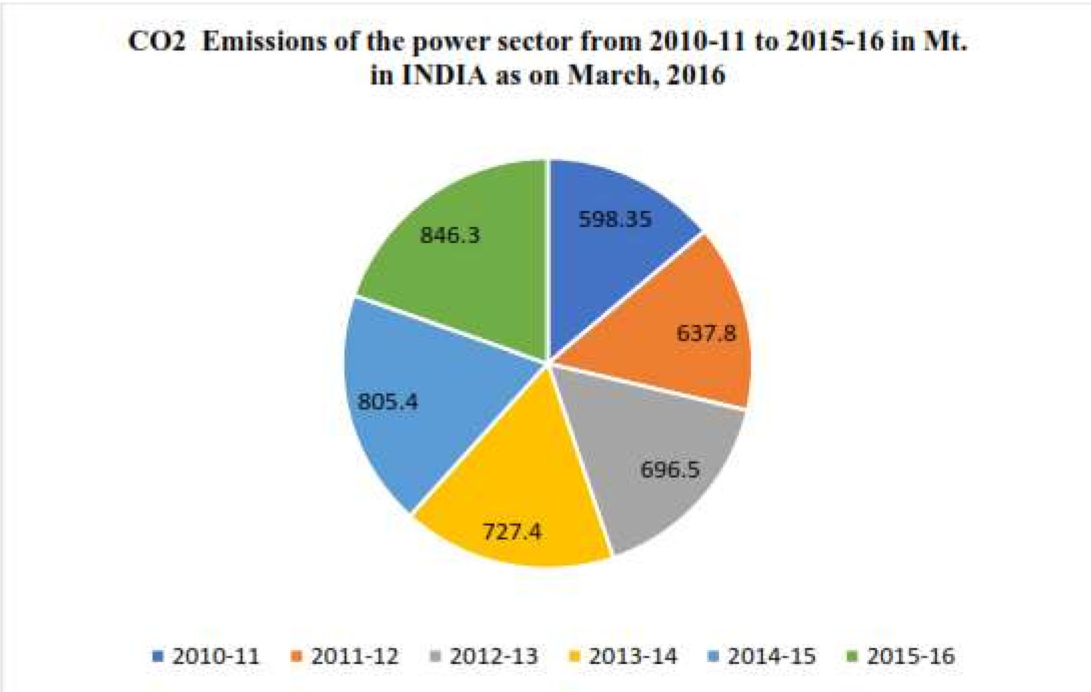


Fig 1.9 Total Absolute $CO_2$ emissions of the power sector from 2010-11 to 2015-16 in Mt.[4]

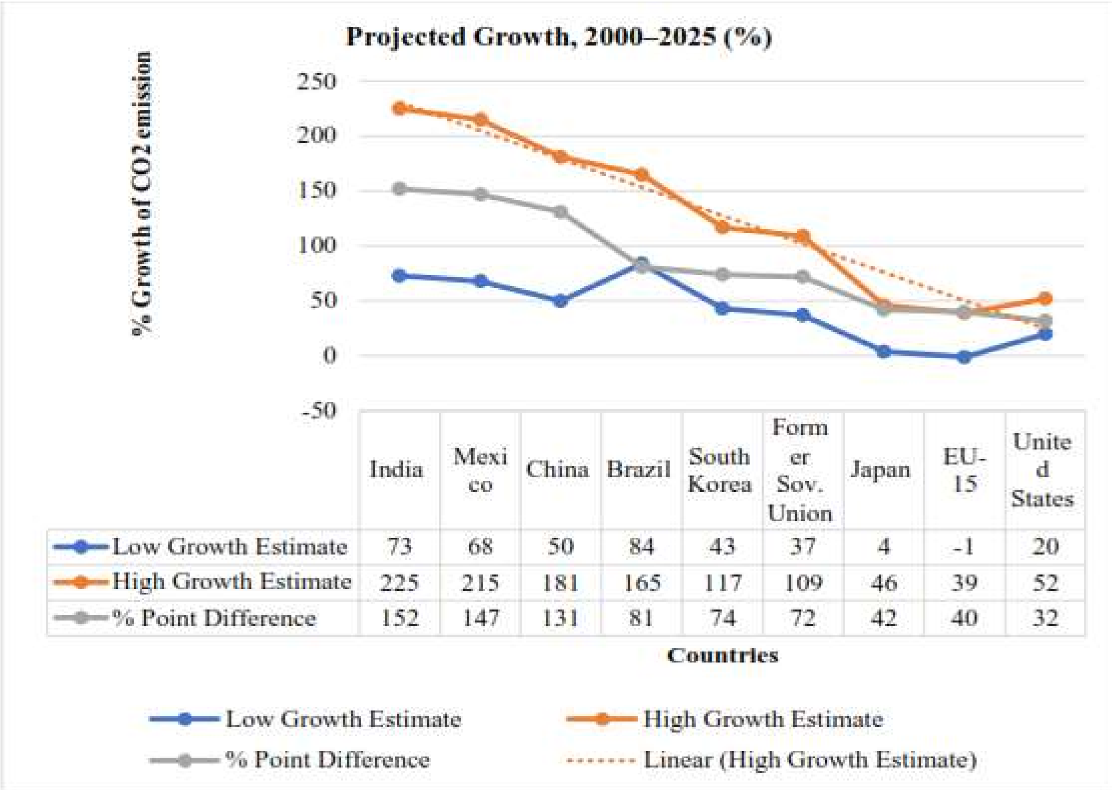


Fig 1.10 Predictions about the Future CO2 Emissions[5]

After analyzing the growth of energy in term of RES and various categories of fuels sector wise, region wise and state wise, it was exciting to know the future predictions of $CO_2$ emission by 2025 and is shown in Fig. 10. India, China and Mexico are found to be leading countries in future $CO_2$ emission generation. As we found that India is one of the leading countries in generation of $CO_2$ emission, we took this a challenge to propose a scheme which can help in reducing the GHG and $CO_2$ emissions. From the present scenario, we expect 73% growth in $CO_2$ emission at the minimum level. However, if we consider the case of high growth than this percentage, enhancement may lead to 225%.

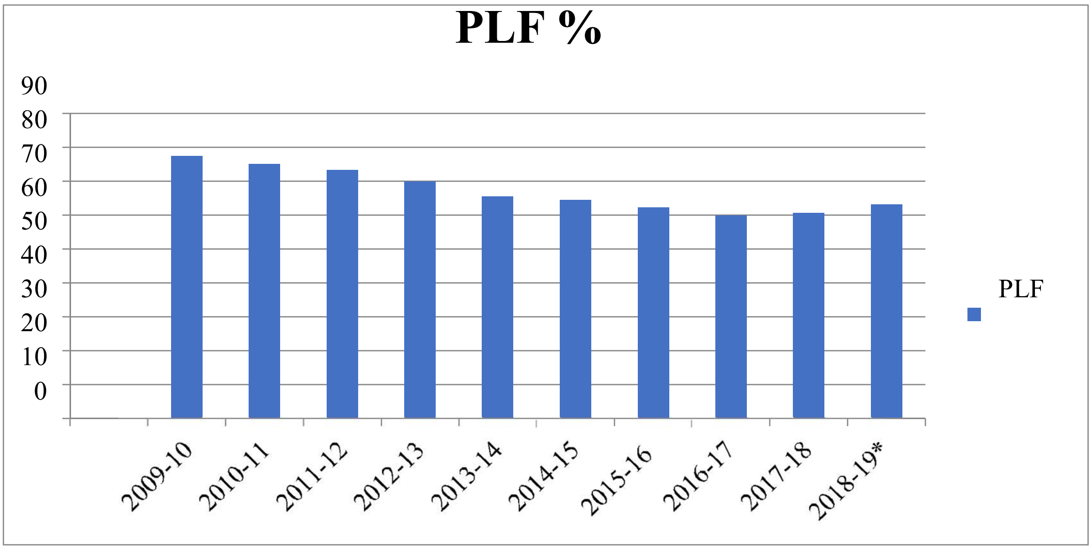


Fig 1.11 PLF Percentage in India from the year 2009 to 2018

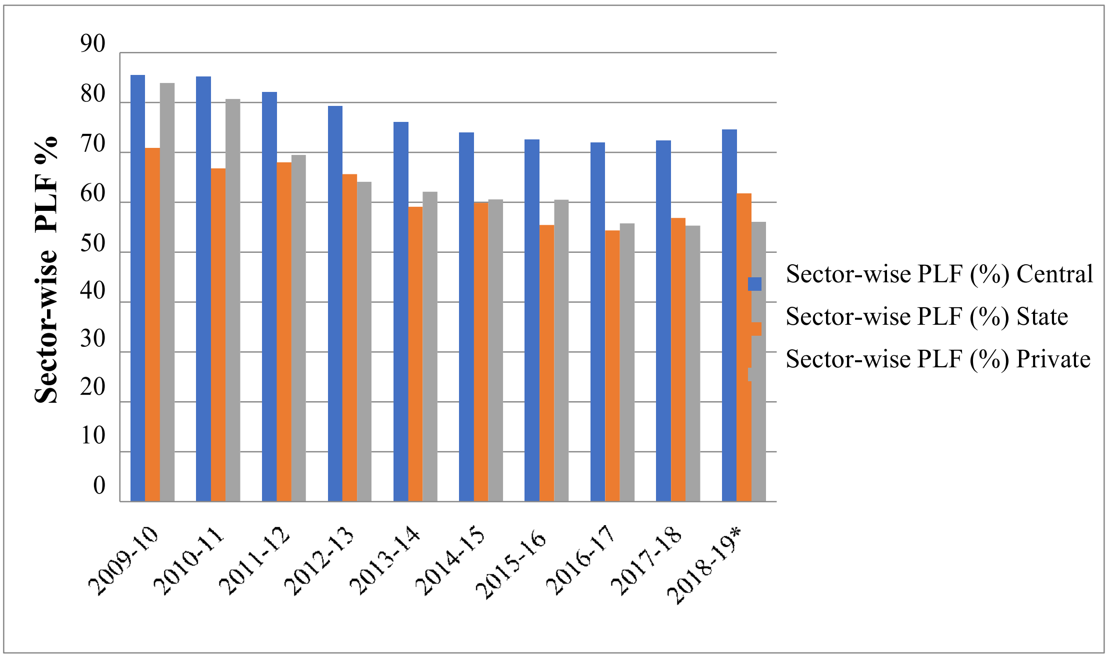


Fig 1.12 Sector-wise PLF Percentage in India from the year 2009 to 2018-19*

The Plant Load Factor (PLF) in India for fossil fuels-based power plant by 2009-10 to 2018-19 is presented in Fig. 1.11. It shows that the plant load factor has also decreased in term of coal and lignite from the year 2009 to year 2018-19. Fig. 1.12 shows the sector wise PLF percentage in India in last ten years from the year 2018. I is clear from the figure that Central government is leading in term of sector-wise PLF followed by private sector except year 2017-18.

It can be concluded that to control the $CO_2$ and GHG emissions, we need to move toward the eco-friendly frameworks-based approaches for energy generation in India for power sector. Eco-accommodating or eco-friendly frameworks approach is the need of present world. The eco-accommodating items are advance green living e.g., forest, air, water that assist to secure clamour contamination and land contamination. They endorse to be picked up for nature and furthermore keep human wellbeing from weakening. Eco-accommodating innovation are clean innovation (clean tech), green innovation (green tech) and ecological innovation (natural tech). Eco-friendly innovation can help moderate the earth through diminishment of unsafe waste and Greenhouse Gases (GHG) emanation. Green tech trend-setters utilize the most recent natural science and green science to decrease the hurtful effect of human movement on the earth. Eco-friendly resources in the form of natural resources are available in abundance. Through these natural resources, we can create sustainable power source (RE) diminishing the limitation of non-renewable energy sources. Advancements ofthese non-renewable sources are being utilized as a part of requirement of Earth's sustainable power sourceswhich have no negative effect on nature.

Green power is a term used to depict wellsprings that are inexhaustible and eco- accommodating.For example, geothermal, wind, biomass and sun are green power resources. Sustainable power source assets mean they are normally renewed. Conversely, petroleum derivatives are limited assets that take many years to create and will keep on diminishing with utilization.

India is one of the quickest developing economies in the world. The improvement targets centre for financial development, value and human prosperity. Non-renewable energy sources will keep on playing predominant role in the economic development of the country. Notwithstanding, traditional or non-renewable energy source assets are restricted, non-inexhaustible and contaminating. In this manner, an exhaustive study needs to be carried out to understand the demand of energy planning in India. Furthermore, sustainable power source assets are indigenous, non-contaminating and practically endless. India is supplied with inexhaustibly sustainable power source assets. Subsequently, their utilization ought to be empowered in each conceivable way.

Although India has gained noteworthy ground in RES, but larger part of the society is still not benefitted. Integration of few RESs, for example, wind, hydro, sunlight based, biomass, geothermal, bio-powers and so forth have high potential in India and in addition in world [1], [2]. Petro-based oil meets around 95% of the prerequisite for transportation energy and the request has been consistently rising. Temporary evaluations have demonstrated raw petroleum utilization in 2007-08 at around 156 million tons. The local unrefined petroleum can meet just around 23% of the request while the rest is met from imported raw petroleum. Such unanticipated heightening of unrefined petroleum costs is seriously stressing different economies the world over, especially those of the oil producing nations.In RES, the nation has a beam of expectation in giving social and economic security. For example, hydro control, sun- oriented power, wind control, biomass control, geothermal power, tidal power and bio-powers and so forth are eco-friendly and their usage would address worldwide worries about regulation of carbon outflows. The transportation segment has been recognized as a noteworthy contaminating area. Utilization of bio-powers has in this way ended up convincing in perspective of the fixing car vehicle emanation norms to control air contamination. Bio-powers from inexhaustible bio-mass assets give a key favourable position to elevate feasible improvement and to supplement regular power sources in meeting the quickly expanding necessities for transportation. In addition, it helps in financial development and in meeting the needs of India's tremendous country populace while diminishing reliance on import of petroleum derivatives. In this manner, RES gives a higher level of National Energy Security (NES).

The Indian way to deal with Renewable Energy Sources (RES) is extraordinary to the present global scenario. With regards to the International points of view and National goals, it is the undertaking of Indian central and state governments' policies to encourage and realize ideal advancement and use of indigenous RES. The arrangements set out the vision, medium term objectives, methodology and way to deal with RES advancement.

The expandable idea of the regular sources and different impediments related with it will have negative ecological impacts and declining wellbeing and social conditions. Hence,more manageable and earth agreeable sustainable power source is the only viable option in the present power situation in India [3]. India has demonstrated a relatively settled normal development with at a rate 4.72 % in the ongoing past. Health care is one of the pointers of the development of a nation's economy. Also, ongoing development rate of the nation demonstrates a significant increment in the use of RES [4].

India has seen a development rate increment in its introduced limit from 1.7 GW in 1950 to more than 326.833 GW on 31 March 2017 [5], [6]. By this sensational development in the power age, India still neglects to conquer any hindrance existing amongst age and aggregate request. This compels to facilitate expansion in the current age limit both by the administration of India and private segments with a bigger emphasis on sustainable power sources.

The utility electrical life segment in India has one nation expansive Grid with a set up ability of 343.899 GW as on 31 March 2018 [6]. RE cycle vegetation constituted 32.2% of whole electrical power built up capacity. Toward the monetary of 2016-17 year, the overall electrical force produced in the country is 1,236.39 TWh and the entire electrical power side the India, which was once when 1,433.4 TWh [5], [7]. During year 2016-17 the gross electrical force utilization was 1,122.40 kWh per capita [5]. India is the 1/3 biggest maker and fourth best customer of electrical force in the world with the associated power limit challenge 334.4 GW as of January 2018. The country moreover has the fifth best set up potential in the world [8]. The administration objective‘s range of elaboration is about 100 gigawatts (GW) during the thirteenth Five-Year Plan (2017– 22) [9]. The central government released a manual to the road ahead for power generation through RES and eco-friendly systems approaches by 2022. The manual target is to be achieved in RES power generation of 175 GW with sharing of 100 GW solar energy, 60 GW wind powers and 15 GW from others RES by 2022. Electrical power utilization in farming was recorded supreme remarkable (17.89%) in 2015-16among all nations [5]. The per capita electrical power utilization is low in assessment with numerous worldwide zones despite less electrical power duty in India [10].

India has surplus electrical power that needs enough foundation for offering electrical force to every patron. So, to keep up the shortage of enough electrical force to the entire country, it was decided to provide the energy to all by March 2019. Later on, due to the shortage of resources and other factors, the national administration of India has further extended the plan to as "Power for All" by 2022 [9]. Our Indian Honourable PM Sh. Narendra Modi had announced the 175GW of Renewable Energy (RE) Capacity till 2022. The activity expects to catch India's development direction post-fulfilment of the objectives by 2022 [9]. This plan will influence exceptional unfaltering and continuous electrical force to give to all family units, ventures and trade organizations with the help of creating and bettering most vital framework. It's a cooperation of the governments such as government of India with offer of states subsidizing and thus making monetary improvement [11]. The government has resolved to inspire 5.98 crore uncharged family units by means of December 2018 and has offered back to states from Power Finance Corporation (PFC) and Rural Electrification Corporation (REC) on no benefit, no misfortune premise. This is a move from the present country charge program where a town is proclaimed jolted if 10% of families and every open place have power [12].

The government has announced that now there is no requirement for extra unsustainable force in the country. The government by 2027 has targeted 50,035 MW fossil fuels-based power generations. The generation from inexhaustible power is expected to be 275,000 MW in new discharge limit [13], [14].

There are different innovations accessible for diminishment of the carbon dioxide from Renewable Energy Sources. The most recent innovation embraced in India and around the globe to meet the essential power necessities of the country regions and urban regions having no entrance to the network was the SPV innovation. The gigantic sum scale SPV development will help in the making positive monetary impact by decelerating the arrangement of ordinary electrical power age stations. Different properties related with SPV Systems are their effectiveness to build the dependability of the framework to which it is associated, lessen carbon dioxide outflow from electrical power age with decrease of transmission and appropriation misfortunes. In India 1 kg coal consumes for electrical power at warm power to outflows 2.90 kg$CO_2$. 1 kWh/unit power supply is equivalent to 1.6 kWh/units plant.

The greater part of the land zone gets sun-oriented at around 5kWh/$m^2$ consistently for at least 300 sunny mornings of the year in India. If 1% of such land zone is used for power producing through the utilizing of SPV at the general limit of 10 %, 429x109 kWh of electrical power can be created each year.

So, we can conclude that based on current scenario in Indian context it is identified that due to high amount of $CO_2$ emission, there is a strong demand to identify the solutions to control the GHG. However, on the other side, one of the biggest challenges is to meet the demand of increased population along with identification of alternative sources of energies. It is to be noted that basic fossils fuels are limited in capacity and these natural resources may not meet the demand of increased population in coming time.

## 1.3 PROBLEM STATEMENT:

Based on the above-mentioned challenges, following objectives are taken into account for detailed analysis.

**(1)** Study and analyze the present condition of power system and its total impact on environment such as emission of Carbon Dioxide and other harmful greenhouse gases.

- Develop a clean energy project model through a modern efficient methodological approach.
- Integration of solar generation with conventional power generation to reduce the emission of Carbon Dioxide and other harmful greenhouse gases.
- Proposed modifications in the planning of power system in such a way that emission of Carbon Dioxide and other harmful greenhouse gases are minimized.

## 1.4 PROPOSED SOLUTIONS:

Based on the literature review number of energy models have been identified. Number of energy utilization factors are being explored such as gross income, gross output, profit, energy quantity, GNP/energy ratio, energy performance, energy production. Work done in literature based on energy models is primarily based on the behavioural or econometric models. However, there is a lack of models forecasting the overall energy consumption and energy supply. There are various linear programming-based energy models existing in the literature. It is observed that the econometric models are best suited for the short and medium-term forecasting. In most of the studies, the efficiency, $CO_2$ emission and cost factors are the critical parameters during the analysis. It is concluded that the energy–economy models help in understanding the way in which energy–economy and eco-friendly interplay with each other. In addition, these factors are the main enablers to the planners to predict and plan the future guidelines. These analysis and studies may be served as a benchmark for the promotion, discussion and formulation of policies, which are most appropriate to the situation. As far as the utilization of renewable energy is concerned, it is based on the major factors like life span of the system, reliability, intermittent supply, site selection and investment. Number of studies has suggested that the neural networks can be used in the energy forecasting and the fuzzy logic for energy allocation during various situations. Number of studies also suggested the use of the –RETScreen Software‖ for Clean Energy Projects. This software is most suitable for the development of new models for $CO_2$ emission studies in India. It can be utilized for the optimization of cost effective, eco-friendly, $CO_2$ emission mitigation techniques. The focus during our work is on the mitigation of $CO_2$.

The analysis of the status of renewable energy in India along with the emission of $CO_2$ emission is reported in Chapter 3. Chapter 3 also identifies the impacts of $CO_2$ emission on the environment. In addition to this, a study is being made on the promotion of green energy generation and energy efficiency in Chapter 4. Legal rules, incentives and policies for renewable energy for eco-friendly system is also reported in Chapter 4. Energy Planning and management in power sector of India is mentioned in Chapter 5. Traditional fossil fuels are being utilized such as coal, diesel and other petroleum products. Chapter 5 covers the energy planning policies, generation and distribution of energy. This chapter provides the present status of energy management in India.

RETScreen software is used for calculating the technical potential of grid-connected solar PV which is in our case a Thermal Plant situated in Kanpur, India. RETScreen software is adopted world-wide to analyse the various projects like the clean energy generation project analysis, energy efficiency, project analysis, heating &refrigeration projection analysis.

Assorted heating can also be evaluated, evaluate power generation and savingof using the RETScreen plus clean energy project.

Chapter 6 reports a clean energy project model through a modern efficient methodological approach using the RETScreen software. GHG emission is calculated first, thereafter GHG reduction calculation is carried out based on standard formulas. Then calculation of emission factor for $CO_2$ is done. $CO_2$ emission percentage is calculated for PANKI THERMAL POWER PLANT at Kanpur, India as a case study. Results are compared for the coal, diesel and the proposed solution based on the integration of solar and conventional energy. So, the integration of solar generation with conventional power generation to reduce the emission of Carbon Dioxide and other harmful greenhouse gases is achieved.The aim of the proposed model is cost effective, eco-friendly system with $CO_2$ emission mitigation. Finally, $CO_2$ emission is calculated for the period of 2012 to 2032. Reduction in $CO_2$emission with the help of proposed model is achieved up to 23.30%.

Proposed modifications in the planning of power system are carried out in such a way that emission of Carbon Dioxide and other harmful greenhouse gases (GHG) are minimized. Proposed model methodology is based on the reduction of conventional energy sources like fossil fuels and to increase the share of renewable energy for eco- friendly power generation.

## 1.5 ORGANIZATION OF THESIS:

This thesis is organised in seven chapters. Introduction is followed by related work in Chapter 2. This chapter examined the advancement of sustainable power source in India, for example, financing and motivating forces, natural enactments. RES arrangement activity in India with power acts, revision, productivity and R&D of administrative framework to eco-accommodating framework in India is also identified.

To analyse the status of renewable energy in Indian context along with the emission of $CO_2$ is reported in Chapter 3. This chapter also identified the impacts of $CO_2$ emission on the environment. This chapter also investigates and examines the current state of Indian power frameworks and status of RES in India. Effects on condition with emanations of $CO_2$ and other unsafe GHG from power are also discussed here. To further explore the present status and to identify the policies and schemes in context to the renewable energy, efforts have been put in Chapter 4. Legal rules, incentives and policies for renewable energy for eco-friendly system is also examined based on various government orders, schemes and documents. We have identified the needs to study the energy planning and management in power sector for India. This is mentioned in Chapter 5. It is observed that in last ten years central and state governments have made various policies to meet the demand of energy with better planning and management. The planning and management is found essential to meet the demand of increased population. There is always a great need to meet the demand due to increasing population and reduction in GHG emission. As our main focus was to look into the $CO_2$ emission because main constituent of GHG is $CO_2$.This chapter provides the present status of energy management in India.

Finally, in Chapter 6, techniques for diminishment of $CO_2$ by incorporation of sun- oriented power are taken into consideration. Better results are achieved using the RETScreen software on the data of one power plant using the integrated approach to lessen the emission of $CO_2$ and other unsafe GHG. So, the Chapter 6 discussed a clean energy project model through a modern efficient methodological approach using the RETScreen software. Here we have calculated the GHG emission, GHG reduction, using standard formulas on the RETScreen software. Thereafter calculation of emission factor for $CO_2$ is carried out. Here a case study for the $CO_2$ emission percentage is calculated for PANKI THERMAL POWER PLANT at Kanpur, India. In this chapter, results are compared for the coal, diesel and the proposed solution based on the integration of solar and conventional energy. We have observed that the aim of the proposed model is cost effective, eco-friendly system with $CO_2$ emission mitigation. In this chapter, we have also calculated the $CO_2$ emission for the period of 2012 to 2032. Finally, the reduction in $CO_2$emission with the help of proposed model is achieved up to 23.30%. As per the objectives, we have achieved the proposed modifications in the planning of power system to reduce the emission of Carbon Dioxide and other harmful greenhouse gases (GHG). A point by point conclusion along with the future work and recommendations are written in Chapter 7.

## 1.6 CONCLUSION:

In 2016, Honourable Prime Minister Sh. Narendra Modi participated in Paris Climate Agreement. India is found to be one the largest emitter country in the world for GHG emission after top emitter of GHG like China (26%) and U.S. (13%). Recently the GHG emissions again rise as compared with last year emission data. Each country is trying to control the CHG emission and few of them has already decreases the GHG emissions such as China (-0.3%), U.S. (-2.0%), Russian Federation (-2.1%) using eco- friendly approaches. These eco-friendly systems are the main motivation factor during our proposed work to minimize the $CO_2$ emission. To achieve the better results in term of CHG reduction, we have also tried the integrated approaches and achieved the reduction up to 23.30%. Our proposed study may be used as a benchmark to further explore the possibilities to reduce the CHG emission to the next level. As the Indian government also want to reduce the emission, the National Electricity plan 2016 released an attractive incentives and subsidies for the promotion and installation of RES power generation in almost every state of India. Proposed work done in the thesis is inclined toward the aim of Indian government as the Ministry of New and Renewable Energy (MNRE) also want to do 40% power generation in the country by Renewable Energy Sources (RES) capacity. It is expected by the MNRE. Govt. of India that 35% emissions intensity of GHG need to be reduced by 2030. So, we want to state that the result achieved in Chapter 6 to reduce the emission of $CO_2$ up to 23.30% is one of the significant contributions toward the need of energy in India.

# CHAPTER 2
# REVIEW OF LITERATURE

## 2.1 INTRODUCTION

This chapter summarizes previous research applicable to this study. The literature review is divided into the following parts to facilitate comprehension of the various topics discussed here:

- The study and review of the current state of the power system and its overall effect on the atmosphere, including carbon dioxide and other hazardous greenhouse gases emissions.
- Development of a clean energy project model through a modern efficient mathematical approach.
- Integration of solar and conventional energy production to reduce carbon dioxide and other hazardous carbon emissions.

- Modifications to the power system's preparation to minimize the carbon dioxide Emissions and other hazardous greenhouse gases.

## 2.2 REVIEW OF LITERATURE:

### 2.2.1 Study and Analysis of the Present Condition of Power System:

The uninterrupted increase in the demand for electrical power forces the energy sector towards renewable energy generation with the competitive market. Over the years, the solar energy sector strives to find a prominent space in the restructured energy sector in India. The Electricity Act 2003, National Electricity Policy 2005, National Solar Mission and other renewable energy generation policies and regulations project the future perspective of renewable energy sources (RES) to move towards deregulation of the electricity sector and proponents the feed-in tariff as an advance renewable energy tariff policy. The need for grid-interactive renewable energy motivates several policies and camp up with policies for biomass by National Commission of Science and Environment, –Jawaharlal Nehru Solar Mission by Ministry of New and Renewable Energy‖ These policies and regulations facilitates the research & development and analysis for eco-friendly energy generation in India [1]-[21]

An increase in the share of RES in electricity generation in the total power scenarios invites further complexities to the already complicated power sector. A very Stable communication network is required for power management in RES based generation, micro-grid and distributed power generation for optimization and control of resources with and without storage using standalone or hybrid technologies. DFIG based wind power generation along with FACTS controllers provides a roadmap for large scale integration of RES power generation in the existing grid. The method for reduction of $CO_2$ emissions, GHG and fluctuation in the power generated from large scale wind and SPV system connected to the grid has been matured in the last decades with a focus on reduction in THD and improving exhaustive power quality. Custom power devices and mutable frequency in wind power generation control the power quality for optimal power flow management as well as in grid-connected SPV systems with batteries. Several modelling of large scale grid integration is available which presents power electronics equipment and provides a control structure for hybrid AC/DC smart microgrid with distributed voltage support. Advance power electronic converters for comparisons of the power losses in single and two-stage SPV systems considering equilibration between active and reactive powers empower optimum location based on reduction in loss, nodal pricing and voltage improvement. Management and control of small smart grids with optimum sizing and encouraging policy result in hybrid science of architecture with DG and eco-friendly system approach[22]-[56]. The survey report of IEA demonstrates the need for evaluating the role of distributed generation and integration of eco-friendly system approach and analyzing effects of moving clouds and fluctuations. Thereafter radial distribution-based systems on SPV power generation and optimum averaging of short term radiation data produce high levels of variable power generation. The countries like UK and Germany is successfully using the concept of distributed generation for reducing the $CO_2$ and GHG emissions with improving grid power management having high penetration of solar power generation [57]-[73].

### 2.2.2 ENERGY PLANNING MODELS:

Many energy models use models. Work is also being done in developed countries to create and implement energy strategies. Scientists are using industrial and alternative sources to meet the rising electricity demand. He came up with a simple approach to finding out if the economic benefits of solar thermal and PV technologies are present. He invented a whole industry out of scratch, first having shown how to produce primary oil. his theory explained that oil was in a condition of quasi-equilibrium A monopolist approach was established for the American natural gas industry in the U.S.A.A. in the sixties [4] and later that year [5] These authors have already extensively examined this thermal management approach: Ambrosius and others have already attempted to model this. Steven suggested a soft energy management framework Many energy manager's checklists were constructed on the new model. He studied various energy-value (EV) models to understand how much energy buildings use was, as well as various parametric studies to assess building characteristics Leief supplemented the classical input-output model with an energy planning model, giving it a name based on a character from Sesame Street.

An econometric model of developing countries' energy-use and economic systems was produced by Sultan The dollar and investment were also used as key factors in the economic model. Earlier in the series, Nayan had told about problems in countries with low economic development. In her discussion of both theoretical and empirical problems in the synthesis of the Hermes-Mid method, Capel et al. spoke about theoretical and real aspects. there was discussion of the use and in business about the economic models established by Arnold and Anthony Yoichi performed a study on the model's Japan-based reputation. These authors spoke about the numerous engineering economic models of energy demand, including those that take a more alternative approach to consumption, such as David et al. These models posed a major problem in formulating short/medium-term energy-based models, namely Hermes-Midas' method, as stated by Capotosto and his colleagues Xia and Yinghong combined a conventional and multi-sectoral economic theory to explain China. He began to explore the various data processing and modelling processes that were employed in the preliminary research [in the 18th century] Using a mathematical equation, Walter and Weyant tackled the integrated modelling. As demonstrated by Gale and his associates [a reference from Gale and his colleagues A computer model had been developed, derived from the dynamics of the system, to aid in policy development. Most econometric models are alternative methods, but some methods, in his view, are better. Both Walter and Hiroshi took a more pragmatic approach in regards to process models by discussing their applicability in the industry. a way to enhance system expansion models, they utilized a type of dynamic programming.

The study concluded that multi-objective approaches could be successfully integrated into a large-scale energy-resource model. Let Walter review the various programming models: Walter explained several specialized programming strategies, including elementary spatial programming, quadratic programming, and complementary programming. possible interdependence Lev suggested a solution to the issue of indecision. the challenge of parameters that went berserk to the pair of them Previously, Thomas and his colleagues had employed Markov models to prepare and develop engineering-economic structures. The term "stochastic" means to make random decisions, and also refers to making statistical optimization decisions. He attempted to define the challenge of engineering-based economic modelling in terms of arbitrary and difficult decision-making. For that matter, they [pregnant women] used a multi-criteria approach to the new energy system in Taiwan. Waggoner and associates [33] suggested a cogeneration system using steam and hot water for power generation. To try to minimize the cost function for a typical Indian village, the authors developed a linear model for decentralized energy supply Ideals and the physical property was able to develop a linear programming (LP) model for industrial estates using a personal computer the Mackay and Probert Corporation had analyzed the oil industry's toughest problems Arranging the facts and the truths so that they form the best picture is difficult, as they oppose one another, but seeing that they're all one string of the same truths and transforming them into the story gives us perspective, as they agree on a point. Soderstrom and Nilsson established a formula for optimized energy consumption in the design process design of [37].

A hybrid wind/hydro/diesel system by Ashok Sinha Several groups have developed an integer mixed-integer linear programming (MILP) solution for planning an integrated power system. in comparison to energy technology, Blake [40] conducted a critical analysis of the associated assumptions and conclusions. A forward model of energy control (FEC) was developed by Zaha-din and Zheng [see reference]. As they discussed, Andy, along with other researchers, discussed recent developments in the field of long-term energy forecasting Precise identification of cause and effect is Ramathan and Ganesh's specialty The work of Huang et al. was published in a recent book entitled "Decision Analysis: From Theory to Practice" A regular trend analysis [45] was performed on Mika et al. Victor and his colleagues comprehensively analyzed the results of Mexico's energy reform from 1988 to 1994.

Before this, Peter and Campbell explored applying Monte-Carlo modelling techniques to utility planning, the utilities used integrated resource planning (IRP). The Kumar et al. study demonstrated that the financial performance of box-type solar cookers was adequate and feasible when they looked at costs (for the first time) at cost functions He spoke about the various opportunities and requirements that clean, renewable technologies can serve in countries that are less developed. The proposals are based on the models of Abdelhak and Mohamed, and their use in energy audits will greatly help businesses reduce their energy bills. A MOP method was used for a variety of smaller, mid-sized, and larger farms to figure out how much energy they would need to produce. Based on their computer-based mixed integer/data list techniques, Malik and Satsi programmed a hybrid integer/linear extrapolation-based energy system bottom-up model which monitored the energy consumption in SAVE households Use of a comprehensive integrated electric planning model to estimate projects that are pursued separately is defined by Franklin et al. as an integrated utility strategy.

Alam and associates [55] measured the physical quality of life (PQL) as a function of energy consumption using statistical analysis. Before their current study, Gomes and his colleagues (2009) suggested a methodology for district energy planning in historic districts [55]. the two alternative energy-saving devices proposed by Akisawa et al. Additionally, the researchers put together an estimation model to quantify the energy savings that Michael et al. [58] are estimating and to better assess sources of uncertainty and importance. Carbon taxes are applied on both the supply and demand sides of the market for long-term resources. Bent and Peter [62] have utilized GIS tools to show how to create renewable energy. Harry, et al. used a database to model the use of non-residential buildings in England and Wales The different planning approaches to life-energy development have been discussed [62] following mixed-integer linear programming by Rozakis et al. [63] developed a model focused on mixed integer programming for the integration of microeconomic theory and algorithms (MILP). "Gross national product (GNP) makes no sense" On several political and planning questions, Rahul has established top-down and bottom-up energy models. It had previously been suggested that Jayram and Ashok proposed a hybrid model that combines photovoltaic, diesel, and nuclear energy. a top-down and bottom-up integrating energy model was created by Christopher, et al. Beccali, in collaboration with researchers from all over the world, demonstrated the value of multi-criteria decision-making for the spatial diffusion of sustainable technologies Huber et al. identified the features and significant findings of the EU Green computer model, which is employed for the promotion of a variety of EU technologies.

### 2.2.3 MODELS OF ENERGY SUPPLY–DEMAND:

A generic approach assisted any of the company's energy analysts in understanding the modelling process for Noel and Saad. Fatma and Cliff created a model for price and supply forecasts to estimate energy prices and the utility companies' needs As a result, the integrated supply and demand planning model proposed by Charles and Mark [72] was put into place for the state of Illinois. Although they didn't have access to internal records, John and his colleagues built an energy model to estimate petroleum reserves. To estimate energy demands, Kamal and associates constructed a linear multiple regression model [75]." Walter applied econometrically approached the supply models with econometrics. Walter and Thomas investigated econometric models for supply chains and found delays and lags to be critical factors in determining overall flow and production development. Be called and Yu-Chun home. The energy output results had been run for a limited period in a static input-output (or simple in-and-out) analysis. In response to their complaints, he set up a cost model for magma development and submitted a proposal to the town council [78].

Halvorson's model for evaluating residential, commercial, and industrial consumption The two-stage model was suggested by Antonio and Alfredo, who said energy demand would drop in stages. that was created by Vishwanath et al. (1981) to serve as an energy supply model for developing countries a linear model of energy supply and demand that was designed for forecasting and tracking the longer-term changes in the system To gain insight into the significance of the effect of energy consumption on the manufacturing sector, Blomer et al. [83] used an econometric model in a disaggregated approach. Dubai et al. developed the Asia-Pacific energy model Norbert had previously spoken about the approach taken by the IEA in energy demand modelling Michik et al. have developed a structural model to forecast the total energy consumption needed by different types of residences The output of the dynamic model was applied to the LeapFrog model, and a bottom-up approach was used to produce total energy balances demand is calculated using the representation of the electrical load curves (RLCs) To discover a way to predict coal demand over the next four years, Mudit and Jyoti produced a long-based time series of data. applied the autoregressive distributed (ARDL) and error-correction models (my paraph) Biogas plants, solar cookers, and improved cookstoves were all utilized in the effort to calculate the capacity for India's domestic electricity. They modelled the market for commercial resources, namely gas, petroleum products, and electricity with econometrics. They worked out an energy model to evaluate supply and demand for global warming.

### 2.2.4 MODELS OF COMMERCIAL ENERGY:

Noel developed a hybrid economic and time series forecasting model based on the Box–Jen framework [95–97] to predict monthly peak unit loads. He used an equation to calculate the cost of energy conservation. Although operating costs were to be kept at a minimum, Ornek [14] developed a forecasting model for predicting minimum fuel requirements in a multi-stage inventory system. Badi and James constructed a fuel consumption forecasting model that predicts the car, the automobile, and the entire fleet. The straight-line correlation was used by both Deeble and Probert to calculate annual energy consumption Bhattacharya et al. studied non-commercial energy usage in rural areas with an emphasis on energy resources such as biomass and solar photovoltaics. In previous conversations, Newborough and Probert (1985) have previously addressed the intake of energy and the costs of dietary decisions Logistic and energy models were employed to estimate the amount of energy that would be needed to implement the switchover from fossil fuels to renewable sources. The implementation of energy use and cost analysis (PEC) is previously suggested by Manfred and Sabine (FCA) We found that John showed how adaptive assumptions and single variable trend extrapolation can be used to better understand energy demand [generate future estimates] over time. He created a dynamic econometric forecasting formula that utilizes non-linear data points to estimate electricity consumption. They created the international petroleum exchange (IPE) as well as innovative demand forecasts for utility managers. The utility sector benefited from new econometric and end-use forecasting methods Industrial energy usage was used to trackers have been applied to various industries including cement, garment, and food processing It was empirically discovered that the energy conversion efficiency to GDP is provided by Harel and Bant's [i.e., they're] electricity-to-to-GDP ratio Various energy-intensive technologies' dense diffusion models have been constructed to investigate the use of energy Dating from utility bills, Radu [177] came up with a novel idea for measuring the normalized energy usage in office buildings. Lutzer investigated the cultural shift from conservation behaviour change to physical, economic, emotional, and social needs and functional patterns of energy use as the study began to address the demand side. district heating can be modelled mathematically by Professor Stig that year. They produced a forecast for oil and gas supply and demand that showed great promise Deering and his colleagues [118] investigated energy use at home. Kodah and Tamimi predicted that Jordan's energy demand will grow exponentially US crude output was predicted to follow growth and decline curves as set out by Heffington and Brasovan The modelling system that Ahmed had created accounted for both global solar radiation, weather, and population made it possible to predict his electrical demand as a function of resources Mackay and Probert previously developed an updated the logit-function demand model, using a saturation curve to project ideal energy intensity, to use national data on crude and natural gas production saturation and utilization to determine the optimal values of oil and natural gas saturation curve for future projections. Many methodological and practical issues went into determining how to decompose industrial energy consumption by levels of production, structure, and its strength within the various sectors. As they neared the end of their lives, Luis and Barry created energy models for pulp, paper, and paperboard mills. He applied an energy-lad model to domestic fuel shifts; it's based on the cooking and water heating habit theory Their research with Raghu and Jyoti investigated the need for petroleum products in India He modelled demand for electrical energy in a regional grid by working out in advance with very conservative estimates of how much electricity will be used in the future. Gonzales et al. created a single-series A model to predict energy output and consumption by the univariate Box–Jen method [128] Florides, along with his collaborators used the TRNS program to model and simulate the energy flows in Cypriot homes, and after that, an analysis of consumption Taking into account population growth and economic growth, the trend over the present and near future, Shiro et al. [130] conclude that we will use as much energy as we did during the middle of the 20th century before the end of the 21st century. Samer and colleagues experimented with various techniques in the field of univariate analysis to discover energy consumption trends for each month Bottom-up methodology by Mackay and Probert enabled them to foresee the future of liquid fuels supply and demand. Efforts were made to identify an oil and gas supply model (OGSM) by Jai and Uma He is a writer in the field of industrial energy, particularly concerning the residential sector Using semistandetical methods, Volkan and Husein created a mathematical model of primary energy demand They used the heating degree-day approach to estimate natural gas consumption. The study team assessed a variety of possibilities, including the use of kerosene and liquefied petroleum (LPG) as a fuel in transportation, replacement of charcoal stoves, conversion of coal to gas, and biomass technologies for generating electricity, to provide electricity. According to an expansion of the Hubbert model, Jakub et al. [138] projected Poland's natural gas use in the future to be approximately the same as in the present. Jesus and his colleagues studied a battery of univariate models on electricity spot prices using data from the Leipzig, Germany, electric power exchange, to see if they could provide accurate forecasts of future price movements.

## 2.2.5 MODELS OF RENEWABLE ENERGY:

Habana et al. revised the solar radiation model to determine solar irradiance from sunlight hours at a variety of stations in hot, dry, and arid climates [140]. Akinoslu and Ecevit established five solar correlations to estimate global solar radiation [141]. Additionally, Ragab and Som [142] identified an hourly and regular connection between estimated and measured solar fluxes over Bahrain. Paul developed global forecasting capabilities for photovoltaic markets and technologies [143]. Gopinathan and Alfonso developed diffuse radiation models for forecasting monthly average and daily diffuse radiation over a wide latitude range [144]. Azmi [145] studied the over-sizing process for estimating the mismatch in photovoltaic systems, as well as theoretical approximations to the mismatch. Parishwad et al. developed a direct, diffuse, and global method for estimating the hourly solar radiation on a horizontal surface [146]. Abdeen [147] spent several years collecting, analyzing, and presenting data on solar radiation on a horizontal surface, sunshine length, and wind speed in Sudan. Viorel established a link between monthly mean daily global solar irradiation and the number of sunny hours [148]. Shafiqur Rehman pioneered the use of empirical correlations to estimate global solar radiation [149]. Meyer and Van Dyk developed the energy model, which is based on total irradiance and ambient temperature averages [150]. Additionally, Iqbal's suggested parametric model was used to estimate direct irradiance in cloudy sky conditions [151]. Zekai and Elcin created a three-parameter parabolic model for estimating global or diffuse radiation on an hourly, monthly, or annual basis [152]. Additionally, two parametric models have been validated and used to forecast Hong Kong's hourly irradiance [153]. Amauri developed a correlation model for measuring diffuse solar radiation on the horizontal on an hourly, regular, and monthly basis [154]. Global solar radiation was measured by Safi et al. using two distinct techniques based on higher-order statistics [155]. Tsangrassoulis et al. [156] assess time-varying diffuse irradiance by calculating angular shading variables using a Monte-Carlo backward ray-tracing technique (ASF). Jain developed stochastic models for the sunshine cycle and solar irradiation using the Box and Jenkins technique [157]. Additionally, Surapong et al. [158] present mathematical models for predicting daytime luminance and solar irradiance at the global and horizontal scales. Raja et al. [159] created a conceptual model for the marketing of solar-based technologies in developing countries. Kablan [160] developed a forecasting model for estimating demand for solar water heating systems and the energy savings associated with them in households. Cardinale et al. investigated a solar water heating plant using a dynamic simulation code (TRNSYS) [161]. Jain et al. developed bivariate models to link solar irradiation to day length and solar irradiation extremes [162].

### 2.2.6 WIND ENERGY MODELS:

Barry measured the amount of energy produced by a wind energy conversion system using a computer-based simulation model that takes wind speeds, residential electricity demands, and generator, inverter, and storage system parameters into account [163]. Panda and colleagues created a probabilistic wind model [164]. Using the Weibull probability distribution function and statistical evidence, Jamil et al. calculated the wind energy density and other wind characteristics [165]. Saleh [166] discussed the different types of wind measurement equipment, instruments, site specifications, and other technical requirements. To forecast regional wind energy potential trends, Zekai and Ahmet developed a cumulative model [167]. Ramachandra et al. examined the availability and characteristics of wind energy in these locations using primary data gathered over 24 months [168]. Sfetsos compared many forecasting techniques for mean hourly wind speed, including time series analysis, standard linear (ARMA) models, feed-forward and recurrent neural networks, adaptive neuro-fuzzy interference systems (ANFIS), and neural logic networks [169]-[170]. Gomez- Munoz and PortaGandara employ cluster analysis to characterize local wind patterns to simulate wind-dependent renewable energy systems [171]. The current state of wind energy consumption was explored by Bartholy et al. [172]. Youcef et al. bivariate modelled wind using wind speed and direction measurements by using first-order Markov chains and Weibull distribution methods [173]. Additionally, Weisser determined the wind energy potential by combining the Weibull density function with historical data on mean hourly wind velocity [174]. Poggi et al. examined the feasibility of forecasting and simulating wind speed in Corsica using an autoregressive time series model [175].

### 2.2.7 MODELS OF BIOMASS AND BIOENERGY:

Rajeswaran et al. [176] created a statistical model to examine the effect of biogas plants on the energy consumption habits of rural households in India. Tara et al. [177] proposed a generalized approach for assessing the economics of biogas plants that takes capacity into account when calculating the benefits of biogas use. Gardner and Probert [178] examined forecasting models for describing the process of landfill gas output. Tani and David developed equations for estimating short-rotation black locust yields using the stepwise ordinary least-squares regression technique [180]. Kimmins evaluated the sustainability of bioenergy plantations using second-and third-generation hybrid simulation models [181]. Alam et al. developed a quantitative dynamic simulation model for rural household–biomass fuel consumption as part of a system analysis [182]. Yasuko et al. proposed a novel approach for estimating forest cover in the vicinity of deserts [183]. Hiromi et al. [184] developed the global land use and energy model (GLUE) to assess the global potential for bioenergy development, land-use changes, and CO2 emissions. Haripriya addressed the estimate of biomass and carbon content in biomass for all forest strata in different states using species-level volume inventories [185]. Robert et al. [186] used a GIS-based modelling method to investigate a system for predicting future biomass supplies from energy crops. Roos and Rakos [187] discussed the intricacies of designing bioenergy models. Harje et al. developed a long-term forecasting model for evaluating forest fuels on a local scale using satellite images [188]. Specht and West developed a statistical model to estimate the biomass and carbon sequestered by agricultural forest plantations [189].

### 2.2.8 OPTIMIZATION MODELS:

A more sophisticated energy budgeting technique The purpose of this formulation was to employ linear programming with the functions of system and demand and total cost as constraints. For the acid rain control strategies by Ellis et al., a deterministic linear programming model was developed. The aim was to get the maximum amount of resources for each new unit while respecting the environment. He constructed a mathematical model that allowed optimization to use multiple objectives and called it dynamic multi-objective linear programming. It had been argued that Satsang and Sarma had deliberated on how to meet the country's energy requirements Andy presented the two Brookhaven system flow models (BESOM): the Brookhaven System Optimization and Evolutionary Operating Model (BESOM) and the Brookhaven Optimized Continuum Operating Model (BOCOM) (TESOM). The writers, Pasternak, Marjorie, et al., created an energy conservation project evaluation model that focuses on the primary duration [purchase] The use of the mathematical programming energy (MPE) model has resulted in excellent software developments such as Sugi and Jagdish's. An overview of energy research that employs optimization models with a forecasting model on the LEAP plan was performed by Luhanga, et al. Mustafa and his associates used a multi-attribute model to measure the long-term economic and environmental impact Growth has established a model in which the municipal and regional data-flow networks are described as data flows In this approach, which Messner et al. [314] presented, a stochastic variant of the dynamic linear programming model was presented. Using Lai and Chen, created a model for cost minimization of import strategy Lehtila and Pirila created a sustainable energy policy based on a bottom-up system optimization model to assist in the design of a policy in Finland To complete the model, a small, energy-intensive pulp and paper industry sub-specific model is included. To see if different energy problems, including self-sufficiency, conservation, and sustainability, could be used in various ways, they used multi-level optimization (MLO) Michael and Zhijun had developed a network-level investment strategy and the optimization model for electricity delivery for a multinational In MODEST, Dag referred to it as an energy model. Planning for sustainable agricultural development using the simple linear programming model suggested by Raj and his colleagues was an innovative suggestion. Koppen and Ramachran created an optimization model for maximum biomass that eliminates biomass for cattle, oilseeds, and grains while satisfying population food requirements for cereals, pulses, vegetables, and oils. Iniiniyan and Jagesson created the optimal renewable energy usage model they built an integrated renewable energy model (OREM) to balance social acceptance, capacity, cost, and reliability while aiming to maintain efficiency and reach potential A modified econometric model was created which connects economic growth, technological advancement, and resource conservation to the environment by combining them with time-series models. by studying real-world measurements, such as long-term wind speed and wind conditions, to figure out the physical device requirements and operational requirements. The bottom-up energy optimization model was focused on the EFOM model to facilitate renewable energy use policies (168) It combines the physical, social, and climatic elements as well. Proposed a performance model for a theoretical well drilled for geothermal energy. MeiSOL created the MIND (Method for Multi-period analysis of Industrial Energy Systems) to analyze industrial energy systems that include cost optimization using a feedback loop for both materials and energy. A linear programming methodology was proposed by Professor Ashok Kumar Sinha and Surekha Dudhani for allocating various resource shares of varying technical and cost coefficients.

### 2.2.9 MODELS OF ENERGY BASED ON NEURAL NETWORKS:

Sanders et al. [220] employed fuzzy logic in supply and demand-side determination to provide a guide for comparative worth and demand. The model was examined with a visual technique and the chi-square test to assess its adequacy The authors of this paper built a mathematical model based on linguistics and fuzzy logic to predict residential energy consumption Abdel-Al and his colleagues suggested a new form of neural network for modelling and forecasting domestic sector energy consumption called abduction instead of conventional multiple regression. Mean and fluctuating wind speed were taken into consideration, along with the results of a statistical model developed by Mohamed et al., and artificial neural networks were developed for wind speed prediction. Cid [225] suggested a fuzzy multiobjective energy allocation algorithm. Computers with artificial neural networks have been used to simulate building loads and predict the amount of energy a passive solar structure can use. With an artificial neural network, Sis developed a model for predicting the building's energy consumption. The multi-layered neural network architecture was used, along with a traditional back-propagation algorithm. Yao et al. [228] used wavelet and neural network techniques to forecast short-term electrical load. They performed a complex study on how to maximize the use of energy during cooking By calculating a radial basis (RBF) and multi-layered perceptron (MLP) functions, Atsu et al. predicted solar radiation levels (Figure 3.5). The Merih et al. energy model was constructed using neural networks for the Canadian market. By using real-world data to determine and experiment with an artificial neural network model, Che-yang and Chiaoq developed a method for forecasting the island's peak load Artificial intelligence was discussed by Metis et al. about short-term electric load forecasting [233].

### 2.2.10 MODELS FOR EMISSION REDUCTION:

In combination, Mr Edmonds and Mr Reilly developed a long-term model of CO2 emissions associated with fossil fuel usage over the long term Called "A simple model can be paired with a more complicated model" following that, John and Jae suggested three possible emission scenarios, including current practices as well as more radical proposals. To aid in the projections of future changes in the carbon cycle, we need a coupled climate/carbon cycle model. Carbon dioxide and hydrocarbon emissions that do not contribute to movement can be reduced using an end-use assessment model Kuto developed a simple model of the global carbon cycle by using a previous theoretical model which took CO2 storage capacity into account to account. We can use the model to monitor changes in CO2 emissions over the last two centuries as well as track how much CO2 was recently released from deforestation and the Earth's landmass. at the suggestion of Kamo and Karina, I composed carbon cycle models, as well as a global population model, along with the carbon dioxide levels. Tiris et al. used the EPA-approved ISLRT model to forecast pollutant concentrations using meteorological and topographical data loaded data. G has a working model for controlling overall $CO_2$ concentrations in Denmark Mark ran through some of a series of basic greenhouse gas mitigation strategies. The methodology created by Kris and William allowed them to determine the pollution liability of each application on their building's power bill to evaluate different possibilities, George and Feng-Y constructed an intertemporal $CO_2$ reduction model that consists of two mathematical models, each with an objective equation and 1340 constraint equations The Matthews developed a systematic methodology for biofuel production systems that is particularly beneficial for evaluating the carbon and energy costs. Ki and Ang performed a time series of carbon emissions and related variables in Korea, such as energy use and GNP, to research time series of them together. Ricardo compared various $CO_2$ emission and energy scenarios to test the sensitivity of model findings to them. Marian Leimbach conducted an empirical analysis using the CLIPS framework.

# CHAPTER 3
# STUDY AND ANALYSIS OF THE PRESENT CONDITION OF INDIAN POWER SYSTEMS

This chapter will cover the topics related to the present condition of Indian power systems. The overall chapter is divided into five sections. Introduction to the demand for power and various solutions is discussed in section 3.1. The structure of Indian power sectors is discussed in section 3.2, followed by the current status of renewable energy sources in India in section 3.3. After that, the impacts on the environment with co2 emissions and other hazardous greenhouse gas emissions (GHG) is stated in section 3.4, concluding remarks in section 3.5.

## 3.1 INTRODUCTION

RER energy generation sharply growth in India meets the aim of eco-friendly system approach energy planning in the country. The Indian economy meeting considerable challenges regarding eco-friendly energy generation and meet demand.

According to rapidly increase the domestic fuel such as bio-fuels and potential of other RES power generation resources. It has met to the eco-friendly power generation and imports the energy generation in the country. In the world, India is the $5^{th}$ largest county for emissions of GHG.

The population of India is 1.25 billion, with 70 % sharing of the rural population of the total population of the country according to the 2011 census. Out of the total Indian population, 44.7 % of the rural population than 7.3 %

urban population, such as 396 million among 1250 billion, does not approach electricity. 592 million as 62.5% rural and 20.1% urban people still use firewood for cooking. Most population in India, rural residential people depend on non-utility electricity sources like biomass, Waste, animal relics, wood fuel etc., for the requirement of electricity use. Even approximately 80% population, including 28% of urban areas resident, depends on the combustion of biomass and wood fuels for cooking activities. In India during 2004 were deaths 488.200 due to cause of indoor pollution by the use of biomass and wood for cooking. The quantity of power consumption in India increasing depends on commercial fuels, about 40% of total power needs particularly in villages household areas. For which there are use biomass, wood fuel, the residue of crops, etc.The power consumption being in villages areas regarding energy efficiency and higher quality of commercial power rapidly exchange with conventional power resources.

Energy is a critical component of infrastructure that is essential for the country's monetary and emotional growth. Sufficient infrastructure is needed for environmentally sustainable energy evolution and the continued existence of the financial sector. India's energy sector is unique in the world. Energy generation from fossil fuels such as coal, natural gas, lignite, oil, hydropower, and nuclear power must be replaced with possible renewable energy sources such as solar energy, wind energy, biomass, agriculture, and household waste. India's power demand has increased significantly as a result of population growth. However, the increasing demand for electricity in the region necessitates a massive increase in installed power generation. The Indian government has placed a premium on "Power for All" in the region.

India's total installed capacity of power generation is 343.789 Gigawatts (GW) as of April 2018. [6] The Indian government has issued its roadmap for achieving 175 GW of renewable energy potential by 2022, including 100 GW of solar and 60 GW of wind. The Indian Union Government is developing an a'rent a roof' strategy to help it meet its 40 installed capacity (GW) of solar rooftop power generation by 2022.India's coal-fired power generation capacity, currently 192 GW, is expected to increase to 330-441 GW by 2040. India's non-hydro renewable power capacity forecast for 2026 has been expanded to 155 GW from 130 GW, owing to higher solar installation rates and competitive wind energy auctions. India may become the first country in the world to use LEDs for all general lighting by 2019, saving Rs 40,000 crore annually [21]. By 2019, the government's immediate target is to produce two trillion units of energy (kilowatt-hours). This entails doubling current production capacity to provide electricity 24 hours a day, seven days a week for residential, industrial, commercial, and agricultural use. The Indian government is taking a range of steps and initiatives, such as a 10-year tax holiday on solar energy projects, to help India meet its ambitious renewable energy goals of adding 175 GW of sustainable power by 2022, including 100 GW of solar energy. Additionally, the government has sought to restart dormant hydroelectric projects and raise the goal for wind energy output to 60 GW by 2022 from the current 20 GW.

In India's electricity sector, fossil fuels, especially coal, account for roughly three-quarters of total generation. The government, on the other hand, is promoting greater investment in renewables. According to India's 2018 National Electricity Plan, the country will not need an increase in non-power stations in the upstream segment until 2027, following the commissioning of 50,025 MW of coal-fired power plants under construction and the achievement of 275,000 MW of total installed renewable energy capacity. The next segment of this chapter discusses the Indian power sector's structure[6].

## 3.2 STRUCTURE OF INDIAN POWER SECTORS

From the year 1947 to March 2018, India has changed from 854MW to 222,906 MW. Year-wise description of the change in installation capacity is discussed in more detail in chapter 4 and has all the data in Table 4.1. On the other side, if we look at the total renewable energy generation from the year 1947 to 2018, it comes from 508 MW to 114,315 MW. As there is a tremendous improvement in RES power installation, it is considered an area of research during this thesis.

As illustrated in Table 3.1, hydroelectricity has produced a negligible amount of power. Thus, when considering renewable energy sources, solar energy and other renewable energy sources can be considered viable options. According to the data, as of May 31, 2018, the private sector leads in cumulative installed capacity of power in India. The data in Table 3.3 pertains to the installed capacity (in MW) of electricity stations in India as a whole, as derived from the CEA dataset[3].

Table 3.1 Capita power capacity in India

| **Capita power capacity** | | |
|---|---|---|
| Source | Capita power capacity(MW) | % of share |
| Coal | 29,888 | 59.43% |
| Hydroelectricity | 54 | 0.11 |
| **RES includes in 'Oil'** | | |
| Natural Gas | 6,061 | 12.05% |
| Oil | 14,285 | 28.41% |
| Total | 50,289 | 100.00% |

Table 3.2 Total power sectors Installed Capacity (As of 31.05.2018)

| **Sector** | **MW** | **% of Total** |
|---|---|---|
| State Sector | 84,627 | 24.6 % |
| Central Sector | 103,761 | 30.2% |
| Private Sector | 155,511 | 45.2% |
| **Total** | **343,899** | **100%** |

Table 3.3 All India installed capacity (in MW) of power stations (As of 30.06.2018)[3]

**ALL INDIA INSTALLED CAPACITY (IN MW) OF POWER STATIONS**
**(As of 30.06.2018)**

**Modes breakup**

| Region | Ownership/ Sector | Thermal | | | | Nuclear | Hydro | RES * (MNRE) | Grand Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Coal | Gas | Diesel | Total | | | | |
| Northern Region | State sector | 16887.00 | 2879.20 | 0.00 | 19768.20 | 0.00 | 8643.55 | 689.56 | 29100.31 |
| | Private sector | 22790.83 | 557.00 | 0.00 | 23319.83 | 0.00 | 2514.00 | 11854.66 | 37687.49 |
| | Central sector | 13291.37 | 2345.06 | 0.00 | 15633.43 | 1621.00 | 8596.22 | 329.00 | 26179.65 |
| | **Total of NR** | **52938.20** | **5781.26** | **0.00** | **58720.46** | **1620.00** | **19753.77** | **12873.22** | **92967.45** |
| Western Region | State sector | 21280.00 | 2849.82 | 0.00 | 24130.82 | 0.00 | 5446.50 | 311.19 | 29887.51 |
| | Private sector | 34285.67 | 4676.00 | 0.00 | 38961.67 | 0.00 | 481.00 | 19473.89 | 58916.56 |
| | Central sector | 15042.95 | 3280.67 | 0.00 | 18323.62 | 1840.00 | 1520.00 | 661.30 | 22344.92 |
| | **Total of WR** | **70608.62** | **10806.49** | **0.00** | **81415.11** | **1840.00** | **7447.50** | **20446.38** | **111148.99** |
| Southern Region | State Sector | 19432.50 | 791.98 | 287.88 | 20512.36 | 0.00 | 11808.03 | 518.02 | 32838.41 |
| | Private Sector | 12124.50 | 5322.10 | 473.70 | 17920.30 | 0.00 | 0.00 | 33359.36 | 51279.66 |
| | Central Sector | 14225.02 | 359.58 | 0.00 | 14584.60 | 3320.00 | 0.00 | 491.90 | 18396.50 |
| | **Total of SR** | **45782.02** | **6473.66** | **761.58** | **53017.26** | **3320.00** | **11808.03** | **34369.28** | **102514.57** |
| Eastern Region | State Sector | 7070.00 | 100.00 | 0.00 | 7170.00 | 0.00 | 3538.92 | 225.12 | 10934.04 |
| | Private Sector | 6376.00 | 0.00 | 0.00 | 6375.00 | 0.00 | 398.00 | 803.39 | 7576.29 |
| | Central Sector | 13875.64 | 0.00 | 0.00 | 13876.64 | 0.00 | 1005.20 | 10.00 | 14891.83 |
| | **Total of ER** | **27321.64** | **100.00** | **0.00** | **27421.64** | **0.00** | **4942.12** | **1038.41** | **33402.16** |
| North Eastern Region | State Sector | 0.00 | 457.95 | 36.00 | 493.95 | 0.00 | 422.00 | 254.25 | 1170.20 |
| | Private Sector | 0.00 | 24.50 | 0.00 | 24.50 | 0.00 | 0.00 | 23.31 | 47.81 |
| | Central Sector | 520.02 | 1253.60 | 0.00 | 1773.62 | 0.00 | 920.00 | 5.00 | 2698.62 |
| | **Total oF NER** | **520.02** | **1736.05** | **36.00** | **2292.07** | **0.00** | **1342.00** | **282.56** | **3916.63** |
| Islands | State Sector | 0.00 | 0.00 | 40.05 | 40.05 | 0.00 | 0.00 | 5.25 | 45.30 |
| | Private Sector | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.21 | 2.21 |
| | Central Sector | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.10 | 5.10 |
| | **Total of Islands** | **0.00** | **0.00** | **40.05** | **40.05** | **0.00** | **0.00** | **12.56** | **52.61** |
| ALL INDIA | State Sector | 64670.50 | 7078.95 | 363.93 | 72113.38 | 0.00 | 29858.00 | 2003.37 | 103974.75 |
| | Private Sector | 75546.00 | 10580.60 | 473.70 | 86600.30 | 0.00 | 3394.00 | 65516.72 | 155511.02 |
| | Central Sector | 56955.00 | 7237.91 | 0.00 | 64192.91 | 6780.00 | 12041.42 | 1502.30 | 84516.63 |
| | **Total** | **197171.50** | **24897.46** | **837.63** | **222906.59** | **6780.00** | **45293.42** | **69022.39** | **344002.39** |

Table 3.4 Power consumption growth in India (as of 31.03.2017) [294]

| Growth of power consumption in India | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fiscal year-end | Consumption (MW) | Percentage of total consumption by used | | | | | | Per capita consumption (kWh) |
| | | Domestic | Commercial | Industrial | Traction | Agriculture | Misc. | |
| 31.12.1947 | 4,182 | 10.11% | 4.26% | 70.78% | 6.62% | 2.99% | 5.24% | 16.30 |
| 31.12.1950 | 5,610 | 9.36% | 5.51% | 72.32% | 5.49% | 2.89% | 4.44% | 18.20 |
| 31.03.1956 | 10,150 | 9.20% | 5.38% | 74.03% | 3.99% | 3.11% | 4.29% | 30.90 |
| 31.03.1961 | 16,804 | 8.88% | 5.05% | 74.67% | 2.70% | 4.96% | 3.75% | 45.90 |
| 31.03.1966 | 30,455 | 7.73% | 5.42% | 74.19% | 3.47% | 6.21% | 2.97% | 73.90 |
| 31.03.1974 | 55,557 | 8.36% | 5.38% | 68.02% | 2.76% | 11.36% | 4.13% | 126.20 |
| 31.03.1979 | 84,004 | 9.02% | 5.15% | 64.81% | 2.60% | 14.32% | 4.10% | 171.60 |
| 31.03.1985 | 124,569 | 12.45% | 5.57% | 59.02% | 2.31% | 16.83% | 3.83% | 228.70 |
| 31.03.1990 | 195,098 | 15.16% | 4.89% | 51.45% | 2.09% | 22.58% | 3.83% | 329.20 |
| 31.03.1997 | 315,294 | 17.53% | 5.56% | 44.17% | 2.09% | 26.65% | 4.01% | 464.60 |
| 31.03.2002 | 374,670 | 21.27% | 6.44% | 42.57% | 2.16% | 21.80% | 5.75% | 671.90 |
| 31.03.2007 | 525,627 | 21.12% | 7.65% | 45.89% | 2.05% | 18.84% | 4.45% | 559.20 |
| 31.03.2012 | 785,194 | 22.00% | 8.00% | 45.00% | 2.00% | 18.00% | 5.00% | 883.60 |
| 31.03.2013 | 824,301 | 22.29% | 8.83% | 44.40% | 1.71% | 17.89% | 4.88% | 914.40 |
| 31.03.2014 | 881,562 | 22.95% | 8.80% | 43.17% | 1.75% | 18.19% | 5.14% | 957.00 |
| 31.03.2015 | 938,823 | 23.53% | 8.77% | 42.10% | 1.79% | 18.45% | 5.37% | 1010.00 |
| 31.03.2016 | 1,001,191 | 23.86% | 8.59% | 42.30% | 1.66% | 17.30% | 6.29% | 1075.00 |
| 31.03.2017 | 1,066,268 | 24.32% | 9.22% | 40.01% | 1.61% | 18.33% | 6.50% | 1122.00 |

Table 3.3 we have achieved 344002 MW in India among all power stations by considering the RES, conventional energy and thermal energy. The total power consumption growth rate of India is shown in Table 3.4. It can be seen from Table 3.4 that in 1947 Per capita consumption was 16.30 (kWh), which is reached 1122 (kWh) in the year 2017. In the next section, we will discuss the current status of RES in India to understand the possibilities for future research and development in the Indian scenario.

## 3.3 INDIA'S CURRENT STATUS OF RESOURCES:

The current state of RES in India is considered in this section to explore the possibilities for future research and development in the Indian context. According to Table 3.5, thermal power accounted for 64.8 percent of India's total installed capacity of power generation in 2018. RES also has a sizable market share of 20.01 percent. One might argue that the more renewable energy sources we use, the greater the likelihood that CO2 emissions will decrease. This is one of the primary points we considered when writing our thesis. — The conventional energy generation goal for 2018-19 has been set at 1265 billion units (BU). The increase of approximately 4.87 percent over the current traditional generation of 1206.306.

BU for the preceding fiscal year (2017-18). In 2017-18, conventional generation totalled 1206.306 BU, up from 1160.141 BU in 2016-17, a gain of approximately 3.98 percent. Table 3.6 summarises the generation and development of traditional energy production in the world from 2009-10 to 2018-19 [14].

Table 3.5 Total Installed capacity of power generation in respect of RES (MNRE) (As of 31.03.2018) [14]

| Fuel | MW | % of Total |
|---|---|---|
| Total thermal | 2,22,693 | 64.8% |
| Coal | 196,958 | 57.2% |
| Gas | 24,897 | 7.2% |
| Oil | 838 | 0.2% |
| Hydro (Renewable) | 45,403 | 13.2% |
| Nuclear | 6,780 | 2.0% |
| RES * (MNRE) | 69,022 | 20.01 |
| Total | 343,899 | |

*RES (Renewable Energy Sources) include Small Hydro Project, Biomass Gasifier, Biomass Power, Urban & Industrial Waste Power, Solar and Wind Energy.

Table 3.6 Conventional generation and development in the country from 2009-10 to 2018-19 (as of 31.05.2018) [14].

| Year | Energy generation from Conventional sources (BU) | % of growth |
|---|---|---|
| 2009-10 | 771.551 | 6.6 |
| 2010-11 | 811.143 | 5.56 |
| 2011-12 | 876.887 | 8.11 |
| 2012-13 | 912.056 | 4.01 |
| 2013-14 | 967.150 | 6.04 |
| 2014-15 | 1048.673 | 8.43 |
| 2015-16 | 1107.822 | 5.64 |
| 2016-17 | 1160.141 | 4.72 |
| 2017-18 | 1205.921 | 3.95 |
| 2018-19* (Till March) | 316.901 | 2.90 |

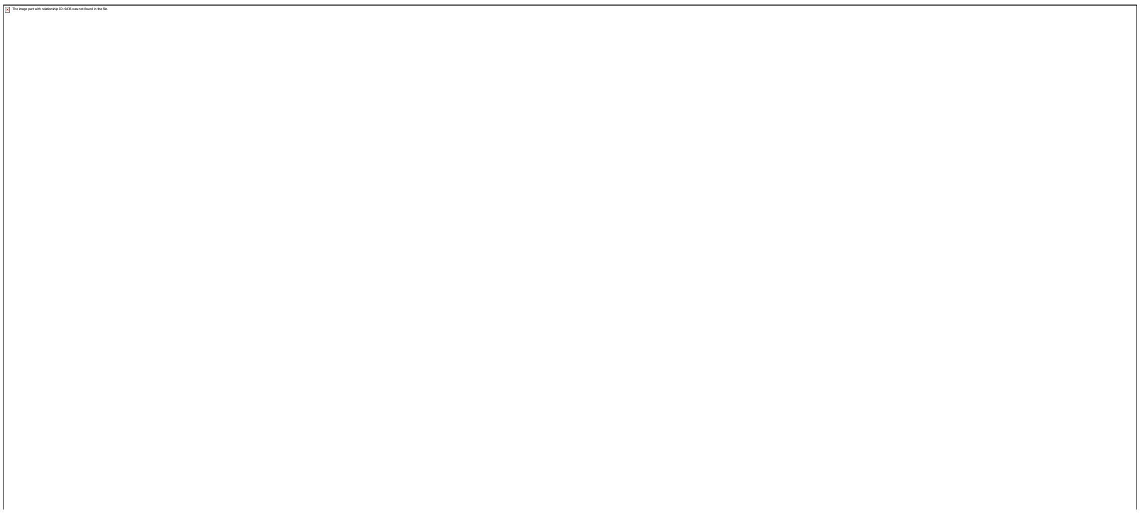

Fig. 3.1 Generation and growth of power in India (Billion Units)

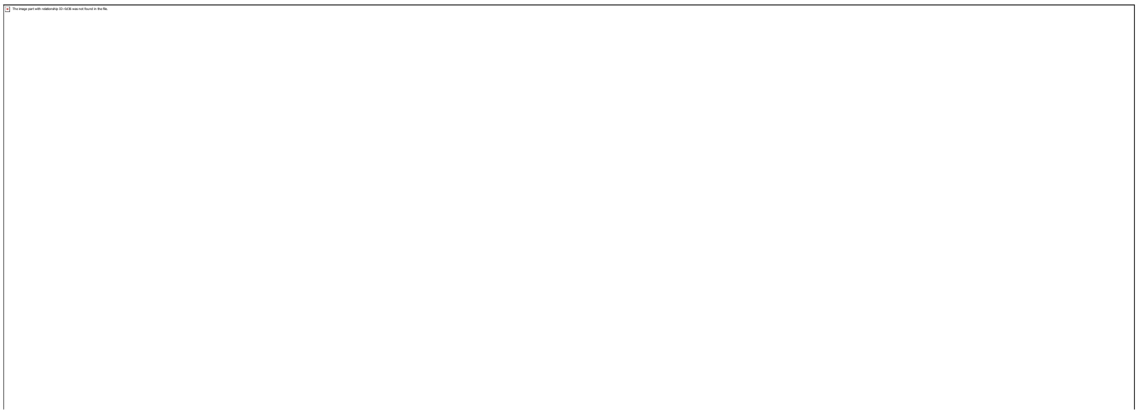

Fig. 3.2 Generation and Growth of power in India in (%).

Figures 3.1 and 3.2 illustrate the generation and development of power in India (Billion Units) in percentage terms. For additional research, we considered Plant Load Factor (PLF) and collected data on PLF in the country (based on coal and lignite) from 2009-10 to 2018-19. The same is true for Table 3.7. Table 3.8 illustrates the country's power supply situation from 2009-10 to 2018-19, illustrating the country's energy needs and availability over the last decade. Due to successful Indian national policies and increased use of renewable energy sources, we have reduced the shortage to a marginal level of -0.7, down from -12.7 in 2009-10, as can be seen in Table 3.8.

Table 3.7 Indian power load factor (as of 30.06.2018) [294]

| Year | PLF | Sector-wise PLF (%) | | |
|---|---|---|---|---|
| | % | Central | State | Private |
| 2009-10 | 77.5 | 85.5 | 70.9 | 83.9 |
| 2010-11 | 75.1 | 85.1 | 66.7 | 80.7 |
| 2011-12 | 73.3 | 82.1 | 68.0 | 69.5 |
| 2012-13 | 69.9 | 79.2 | 65.6 | 64.1 |
| 2013-14 | 65.60 | 76.10 | 59.10 | 62.10 |
| 2014-15 | 64.46 | 73.96 | 59.83 | 60.58 |
| 2015-16 | 62.29 | 72.52 | 55.41 | 60.49 |
| 2016-17 | 59.88 | 71.98 | 54.35 | 55.73 |
| 2017-18 | 60.67 | 72.35 | 56.83 | 55.32 |
| 2018-19* | 63.24 | 74.51 | 61.72 | 56.02 |

*Up to June 2018 (provisionally)

Table 3.8 The power supply position in the country during 2009-10 to 2018-19

| Finance Year | Energy | | | | Peak | | | |
|---|---|---|---|---|---|---|---|---|
| | Requirement | Availability | Surplus (+)/ Deficit (-) | | Peak demand | Peak met | Surplus (+)/ Deficit (-) | |
| | (MU) | (MU) | (MU) | (%) | (MW) | (MW) | (MW) | (%) |
| 2009-10 | 8,30,594 | 7,46,644 | -83,950 | -10.1 | 1,19,166 | 1,04,009 | -15,157 | -12.7 |
| 2010-11 | 8,61,591 | 7,88,355 | -73,236 | -8.5 | 1,22,287 | 1,10,256 | -12,031 | -9.8 |
| 2011-12 | 9,37,199 | 8,57,886 | -79,313 | -8.5 | 130,006 | 1,16,191 | -13,815 | -10.6 |
| 2012-13 | 9,95,557 | 9,08,652 | -86,905 | -8.7 | 1,35,453 | 1,23,294 | -12,159 | -9.0 |
| 2013-14 | 10,02,257 | 9,59,829 | -42,428 | -4.2 | 1,35,918 | 1,29,815 | -6,103 | -4.5 |
| 2014-15 | 10,68,923 | 10,30,785 | -38,138 | -3.6 | 1,48,166 | 1,41,160 | -7,006 | -4.7 |
| 2015-16 | 11,14,408 | 10,90,850 | -23,558 | -2.1 | 1,53,366 | 1,48,463 | -4,903 | -3.2 |
| 2016-17 | 11,42,929 | 11,35,334 | -7,595 | -0.7 | 1,59,542 | 1,56,934 | -2,608 | -1.6 |
| 2017-18 | 12,12,134 | 12,03,567 | -8,567 | -0.7 | 1,64,066 | 1,56,752 | -3,314 | -2.0 |
| 2018-19* | 3,25,428 | 3,23,418 | -2,009 | -0.6 | 1,71,973 | 1,70,765 | -1,208 | -0.7 |

* Upto June 2018 (Provisional) [294]

### 3.3.1 ON-GRID INTERACTIVE RENEWABLE POWER:

In 2006, the Indian government established and formed an MNRE, which was renamed the Ministry of Non-Conventional Energy Sources (MNES), established in 1992. The Ministry of New and Renewable Energy (MNRE) of the Indian government is the nodal agency for all issues relating to RES energy. The Ministry was formed through the consolidation of several departments and ministries within the Indian government, including (1) the Commission for Additional Sources of Energy (CASE),1981, (2) the Department of Non-Conventional Energy Sources (DNES),1982, and (3) the Ministry of Non-Conventional Energy Sources (MNES),1992. The Ministry's wide objective is to develop and deploy new and renewable energy to meet India's energy requirements. The MNRE promotes renewable energy generation in India and provides incentives and subsidies to users to encourage eco-friendly energy systems in the region. Table 3.10 summarises India's on-grid interactive renewable energy generation capacity (as of 31.03.2018).

As we have seen a lot of potential in RES power generation, we have collected the data for the Sector-wise RES grid-interactive power capacities (MW) as given in Table 3.10. Now, it is very much clear that solar energy is the leading sources of RES in India in terms of installed capacity and target capacity compared to the other RES type. The total installed capacity of power generation in respect of RES is given in Table 3.11.

Table 3.9 On-grid interactive RES power generation capacity in India (as of 31.03.2018)

| Sector wise RES grid-interactive power capacities (MW) | | | |
|---|---|---|---|
| **Sectors** | **Financial Year 2017-18** | | **Cumulative** |
| | **Targets (MW)** | **Achievements (MW) (April 2017-March 2018)** | **Achievements(MW) (as on 31.03.2018)** |
| Wind Power | 4,000.00 | 1,766.25 | 34,046.00 |
| Solar Power-Ground Mounted | 9,000.00 | 9,009.81 | 20,587.83 |
| Solar Power-Roof Top | 1,000.00 | 552.83 | 1063.63 |
| Small Hydro Power | 100.00 | 105.00 | 4485.80 |
| Biomass (Bagasse) Cogeneration | 340.00 | 519.10 | 8700.80 |
| Biomass (Non-bagasse) Cogeneration/ Captive Power | 60.00 | 9.50 | 662.81 |
| Waste-to-Power | 10.00 | 24.22 | 138.30 |
| **Total** | **14510.00** | **11787.66** | **69685.17** |

Table 3.10 Total Installed capacity of power generation in respect of RES (MNRE) (As of 31.05.2018)

| Fuel | MW | % of Total |
|---|---|---|
| Total thermal | 2,22,693 | 64.8% |
| Coal | 196,958 | 57.2% |
| Gas | 24,897 | 7.2% |
| Oil | 838 | 0.2% |
| Hydro (Renewable) | 45,403 | 13.2% |
| Nuclear | 6,780 | 2.0% |
| RES * (MNRE) | 69,022 | 20.01 |
| Total | 343,899 | |

## 3.3.2 OFF-GRID RENEWABLE POWER:

A systematic diagram for the Off-grid solar system in India is shown in Fig 3.3.

Fig. 3.3 Off-grid solar system in India

Off-grid/Captive power interactive RES power generation capacities in India (as of 31.03.2018) is given in Table 3.11. It is derived from Table 3.11 that the watermill is the area that is still untouched. In the case of SPV Systems, more than the target amount of energy is generated. Still, on the other side, the target is not achieved for the Waste to energy, Biomass gasifiers and Aero-generators/Hybrid systems.

Table 3.11 Off-grid/ Captive power interactive RES power generation capacities in India (as of 31.03.2018)

| Off-grid/ captive power capacities(MW) | | | |
|---|---|---|---|
| Sectors | Financial Year 2017-18 | | Cumulative Achievements(MW) (as on 31.03.2018) |
| | Targets (MW) | Achievements (MW) (April 2017-March 2018) | |
| Waste to energy | 15.00 | 5.50 | 172.15 |
| Biomass gasifiers | 7.50 | 0.92 | 163.37 |
| Aero-generators/Hybrid systems | 0.50 | 0.14 | 3.29 |
| iohSPV Systems | 150.00 | 216.63 | 671.41 |
| Total | 173.00 | 223.19 | 1010.22 |
| **OTHER RENEWABLE ENERGY SYSTEMS** | | | |
| Family Biogas Plants (numbers in lakh) | 1.10 | 0.40 | 50.05 |
| Water mills/micro hydel (Nos) | 150/25 | 0.00 | 2690/72 |

## 3.4 Impact on the Environment as a Result of the Carbon Dioxide Emissions AND OTHER DANGEROUS GREENHOUSE GASES:

Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated emissions are all examples of greenhouse gases. CO2 accounts for 81 percent of GHG, while methane accounts for 10%. The total emissions of the power sector from fiscal years 2010-11 to 2014-15 are summarized in Table 3.12 [295]. Additional negative consequences of increased CO2 and GHG emissions include greenhouse gases, acidification, smog and ozone pollution, and ozone layer depletion. Both of these factors contribute directly to the degradation of environmental quality due to high CO2 GHG emissions. As a result, there is an urgent need to develop eco-friendly, renewable energy-based sustainable solutions to meet India's energy demand.

Table 3.12 Total emissions of the power sector for the FY 2010-11 to 2014-15 (in a million tonnes CO2)

| FY | $CO_2$ Emission million tonnes from Power Sector |
|---|---|
| 2010-11 | 598.4 |
| 2011-12 | 637.8 |
| 2012-13 | 696.5 |
| 2013-14 | 727.4 |
| 2014-15 | 805.4 |

## 3.5 CONCLUSION

Two major concerns are listed as a result of the review above: I Major Issues and Challenges in the Indian Energy Sector and (ii) Current renewable energy generation and emphasis on developing to meet energy demand. The major issues affecting India's energy sector can be divided into three broad categories: (a) rising oil imports and oil prices, (ii) a scarcity of high-quality coal and coal cleaning technologies, and (c) inadequate electric and other power generation to meet India's energy demand [296].

In term of the key problems of the energy sector, one of the main issues is rising oil imports because the requirements for oil has raised six times in last twenty years to fulfil the demand of energy in India.

The quality of coal in India is quite poor, and we are the third biggest producer of coal in the world. However, India lacks the infrastructure to clean the coal and cause environmental pollution and has an income burden. In India's electric supply networks, the primary issue is power loss even during the distribution chain. Additionally, India's traditional system of supplying electricity is a major issue. A smart grid-based solution could be considered one of the more intelligent solutions for India's electric supply. Additionally, this energy supply problem can be addressed by producing renewable energy sources (RES) and producing more power in an environmentally friendly manner with lower GHG emissions.

Renewable energy sources are widely regarded as the most environmentally sustainable way to produce electricity. In the same vein, India is gradually implementing the policies and guidelines necessary for renewable energy production, reducing carbon emissions, cleaning the environment, and ensuring a more sustainable future. In India, over the last decade or so, the government has launched several initiatives to encourage the private sector to invest in renewable energy development. Numerous activities relating to research, growth, policy formulation, and guidelines preparation had already been borrowed from foreign countries to assess their suitability for energy generation. Additionally, India is demonstrating, manufacturing, and applying a range of renewable energy technologies for use in various sectors[297]. One may infer that in the future, renewable energy systems would be the only viable option for meeting India's energy requirements in an environmentally friendly manner.

# CHAPTER 4

# INDIA'S ENERGY PLANNING AND MANAGEMENT

The chapter's primary contribution is to identify power management and planning in India that promotes energy efficiency through eco-friendly system approaches to power generation. This chapter is divided into seven sections. The introduction is followed by energy planning in India in section 5.2. Power generation grid management is discussed in section 5.3. RES based power generation planning and management in India are described in section 5.4. In section5.5, grid management with integrated RES power generation, such as solar energy generation with conventional power generation for $CO_2$ emission reduction, is described. Off-grid RES power management is covered in section 5.6. In section 5.7, conclusions are discussed.

## 4.1 INTRODUCTION:

India is made many attempts to action toward a low $CO_2$ other GHG emissions passage as cumulatively endeavour to obtain total the progressive challenges. The Honorable Prime Minister of India eyesight is taking work onward with Intended Nationality Determined Contribution (INDC) for a sustainable lifestyle and climate justice to protect the terrible and porous from the aversive effect of climate change. Coal is the main and most dominant fossil fuel for energy generation in Indian thermal power plants (TPP). The major pollution emissions are NOx, $CO_2$, CO, $SO_2$ and HC by-product of coal combustion. But the $CO_2$ is a major pollutant emitted from TPPs in India. $CO_2$ is responsible for over 60% of the increased greenhouse impact. This research work has attempted to supply the reduction of $CO_2$ emission from coal-based TPPs in the country. RES is fully favourable, and energy integration in this reference of GHG impact with now-a-day research. The coal-based electricity generation has 56% of India‘s capacity and 66% of power generation during the $12^{th}$ five-year plan. The electricity generation in coal-based TPP is discouraged due to the reducing cost of renewable energy power generation, the pressure of reducing carbon emission and increased fossil fuel prices. The installed capacity of coal-based TPP grows slowly up to 270 GW in 2032 and will reduce up to 253 GW due to integrated energy policy.

According to the conference of parties (Paris COP 21), India set a voluntary goal of reducing environmental impact by 33-35% by the year 2030, in terms of Gross Domestic Product (GDP) from 2005 levels. It is a multilateral treaty, known as the United Nations Framework Convention on Climate Change (UNFCCC), signed by the 195 member states to address the matter of global-warming crisis and restore the climate. There are advantages in dealing with fossil fuels or electricity from traditional, non-renewable energy sources such as nuclear and coal. In 2015, India's non-fossil fuel share of total capacity was estimated to be 30% of the total but is projected to jump to 40% by 2030. Raising renewable energy output to an estimated annual level of 175 gigawatts and CO2 reduction at an equivalent rate of 32.2 million tonnes per year, or about 2.22 million tonnes per day, per year. Several industries deal with renewable fuels (PV, thermal, hydro, tidal, and wave) and biogas. Agriculture, environment, and climate change: Solid waste management, water management, and recycling: Perpetuating a healthy lifestyle by environmentally conscious design (greenhouses, mass transit, green vehicles, etc.). The constant and exhausting work to support renewable energy generation isn't helped by the price of electricity and by the weather in the winter and rain. Another method would be to switch away from less active/off-peak hours or offer utilities for peak use only when disconnecting from renewable energy sources.

Subsequent climate conferences acknowledged the importance of integrating emerging renewable energy sources into electricity production as one of the most cost-effective and rapid ways to minimize carbon dioxide emissions. Proper siting, installation, and operation of sustainable and non-traditional energy sources would aid in reducing, replacing, and avoiding negative environmental impacts [4]. — Each unit of solar energy produced prevents 800 grammes of carbon dioxide (CO2).

## 4.2 Energy Planning In India

Energy challenges in India and other developing countries include overcoming a heavy dependence on traditional energy sources, which account for more than 90% of total energy consumption, resulting in rapid deforestation and disforestation, reduced soil fertility, etc. As a consequence, a large amount of data is required to represent their interactions. Numerous instruments are used to analyze several issues and produce the mixed results necessary for the planning process. Apart from the unusual population growth, the marvels of digital technology have raised people's aspirations for a higher standard of living. One measure of improved quality of life is the steady increase in per capita energy consumption over the last few decades. As a result, energy demand has risen exponentially and can no longer be met by obsolete energy technologies reliant on a few local resources. Before the 1970s oil crisis, Third World planners and politicians fantasized about bringing rural areas up to par with developed countries' energy standards. They hoped to create energy models that would aid in energy planning, forecasting, and optimization. Over the last decade, research in India has shown that decentralized energy technologies based on locally available resources can be viable alternatives to various commercial energy sources for a variety of energy end-uses. The models include industry-standard energy planning tools. Recent years have seen significant progress in establishing and enforcing energy planning policies in developing countries. Appropriate energy survey methodologies are developed to estimate and project sector-specific useful energy requirements [325].

India's energy demand is constantly growing due to population growth, and conventional energy supply options could not keep up. Due to advancements in efficiency, carrier replacement, and renewable energy as alternative energy sources, it is implausible to adhere to only macro-level energy planning. Sustainable construction at the local scale (district/taluk) becomes conceivable in these circumstances to achieve sustainable development goals and maximize the use of locally available energy resources [326].

Global warming has intensified into a major global crisis, prompting all nations to make various attempts to reduce their greenhouse gas emissions, according to the United National Action Plan on Climate Change (UNFCCC). Additionally, the Indian government is attempting to minimize CO2 and other greenhouse gas emissions by spearheading the Green-School Project. This project aims to establish an energy-saving strategy for out-of-date school buildings by renovation. CO2 emission reduction scenarios are proposed in this study using energy-saving techniques (ESTs) in educational facilities. An optimal scenario is created by performing a life cycle cost (LCC) analysis on each scenario. To this end, we analyzed the reductions in energy consumption and CO2 emissions in two schools using Design Builder models focused on 15 scenarios involving combinations of four ESTs.

Furthermore, an LCC study was performed. The findings indicate that replacing existing lighting with light-emitting diode (LED) lighting is the most cost-effective choice in energy efficiency, CO2 emission reduction, and life-cycle cost analysis. Additionally, the results suggested that energy efficiency, carbon pollution reduction, and life cycle cost analysis differ according to the design and size of the school building. Suppose the results of this study are integrated into the policy-making efforts of the Indian Ministry of Electricity. In that case, New and Renewable Energy, Education, Science, and Technology, CO2 emissions from the maintenance process of Indian educational institutions should be minimized. A sophisticated processing mechanism with a limited budget should also be feasible [327].

Rural India's Low-Cost Bioenergy Options is achieved by implementing a distributed generation planning (DEP) approach to environmentally sustainable energy generation. This approach shows that biomass-based energy systems can meet rural areas' entire energy demand, from village to district. DEP was developed and implemented in an Indian district with a long history (Tumkur). This analysis's primary objective is to ascertain the economic viability of bioenergy for rural applications. According to model study, the cost of producing biomass at the household level is extremely low. Energy crop plantations may be established on available marginal lands or wastelands. Through the use of plantation gasification technology, it has been demonstrated that biomass feedstock produced from plantations is sufficient to meet all of the rural areas' electricity needs. Electricity needs can be met by using biomass-based energy generation systems on available wastelands [328].

India has been humiliated at the ongoing climate change talks in Copenhagen. Government data indicate that the frequency with which Indian nuclear power plants emit carbon dioxide (CO2) has improved after years of decline.

New CEA emissions figures show that the plants released 0.82 tonnes of $CO_2$ per thousand mega (MT-1,000) per year compared to the previous year, rising by approximately 4 per cent over the year before that accounts for nearly 60% of global warming's carbon dioxide.

Coal-fired power plants emitted more than 60% of India's total carbon dioxide emissions. The country's power plants emit more than 540 million tonnes of $CO_2$ each year. India has proposed a 20-25 significant decrease in emission intensity by 2025. The country's policy has already committed approximately Rs 74,000 crore over the next five years to reduce carbon emissions from the country's power sector.

This investment would support a range of initiatives to lower the domestic economy's energy intensity, including improving the efficiency of existing power plants and implementing clean coal technologies. The Bureau of Energy Consumption and the power ministry estimate that these steps would reduce 98.5 million tonnes of $CO_2$ emissions over the century.

India is thought to have one of the world's least energy-intensive economies. The Planning Commission reports that the country's energy-GDP (gross domestic product) elasticity index has decreased to 0.8 from more than one in the early 1990s. According to the CEA, the increased $CO_2$ emissions from power plants are mainly due to lower nuclear and hydropower output in the previous fiscal year. While India's per capita greenhouse gas emissions, at 1.02 tonnes, remain well below the global average of 4.25 tonnes, the country still relies heavily on coal-fired power plants to produce most of its electricity. Another obstacle to future emissions reduction is the inefficiency of older power plants. India's installed capacity of over 5,000 Mw is currently running at less than 5% capacity utilization. Although these systems are being phased out during the current Plan period, the government plans to phase out an additional 10,000 Mw of power during the Twelfth Plan period (2012-17) [329].

By 2022, India intended to put old thermal power plants' emission levels up to national standards and renovate them. According to a senior Environment Ministry official, which will begin next year. Union Environment Ministry Secretary CK Mishra also stated that some of the country's very old plants could be closed. When it comes to solving climate change problems, the first step is to recognize a problem. In light of the Paris agreement, India's NDCs (Nationally Determined Contributions) are already audacious. However, there are development imperatives, and India is one of the fastest-growing economies, which means that as growth occurs, emissions levels are constrained from increasing. By 2022, it is planned that all existing power plants will meet national emission requirements. Some will be closed due to their age, but the remainder will be completed "According to Mishra [9]-[10]. The state-run National Thermal Power Corporation (NTPC) is investing heavily in retrofitting older plants, the secretary said. "It's a lengthy process that takes about 18 months for one of these additions, he said. Mishra said that the pollution scenario would improve if emission standards for boilers and emission-reducing technologies were introduced. Thermoelectric and other fossil fuel-fired power plants are a significant source of air pollution.

According to the minister, Delhi's Badarpur Thermal Power Plant remains "closed" and will be used only in the event of a "highly critical power situation" in the national capital. The gas power plant in Bawana is operating at 20% capacity. It consists of two 750 MW units, Mishra explained. "By the end of next month, the first 750 MW unit will be completely operational on gas at maximum range. Gas is a much more environmentally friendly fuel source,"'He said. Although the Paris agreement has its own set of modalities, Mishra asked, "what about the pre-2020 commitments?" — The 2015 Paris accord is a United Nations Framework Convention on Climate Change (UNFCCC) agreement that addresses greenhouse gas emissions reduction, adaptation, and financing beginning in 2020. The agreement details a global action plan to put the planet on track to prevent serious climate change by keeping global warming far below two degrees Celsius. "There are two critical factors in the context of the Paris accord: technology transfer to developing countries must be unrestricted, and climate finance must be novel and distinguishing," Mishra said. Energy control has long been a focal point of India's development planning. In most cases, this has taken the form of increasing the generation and availability of energy through increased coal, gas, nuclear, and renewable energy sources, among others. Current energy plans emphasize this trend on coal (with a domestic output goal of 1.5 billion tonnes by 2020) and on renewable energy generation (to generate 175 gigatonnes of renewable energy by 2022) [331].

## (A) COMMONLY USED APPROACH:

The expanded method of emphasizing supply is consistent with the Indian energy planning tradition, as shown by the 11th and 12th Five-Year Plans and a slew of national modelling studies. However, there is a lesser-known background of an eco-friendly solution that focuses not just on energy supply but also on energy consumption, thus reducing CO2 and other environmental impacts.

Such a narrative break was first advocated in the mid-1980s by Amulya Reddy, who shifted the traditional focus away from energy sources and toward energy services. From this vantage point, the energy system - and the practises associated with its supply and use - exist to provide energy services such as illumination, pleasant interior temperatures, refrigeration, transportation, and pollution to achieve development goals. However, Reddy's interventions remained unimplemented in part due to the necessity of reimagining how energy policy is produced. Numerous government policies are now refocusing their efforts on energy demand, specifically through end-use renewable energy technologies.

These efforts are encouraging, even though they are not completely conceptualized. However, the transformational change would necessitate the rediscovery of a broader understanding of energy planning that considers the interconnections between energy supply.

**(B) IN THE DIRECTION OF IMPROVED PRODUCTIVITY:**

There are three main reasons why it would be more efficient for India's energy novelette to directly address the supply of energy and its use and distribution. First, the Indian economy is experiencing a series of transformations, which means that the implications for its future requirements are massive and unpredictable and potentially resilient. Demographically, India is expected to add approximately 10 million jobs per year for the next two decades, resulting in increased energy consumption, especially from manufacturers and generation. Simultaneously, urbanization would result in an additional 200 million people moving into cities, increasing demand for infrastructure to support towering lifestyles.

Infrastructure changes are imminent, with forecasts indicating that two-thirds of India's buildings in 2032 will remain unbuilt. In terms of energy, these transitions present a significant risk of unintentional lock-in to consummation trends since most growth has yet to occur.

Suppose the end-use of energy-inefficient technology (for example, inefficient structures and gadgets) or cities with high electricity needs (for example, private transport) becomes the norm in yet-to-exist infrastructures and improved lifestyles. In that case, it can result in a set of path-dependent outcomes that render consumption reduction extremely difficult for decades to come.

Second, integrating demand as a central component of energy planning simplifies energy supply management and, therefore, reduces the number of supplies required and, consequently, carbon emissions emitted. Indeed, the quondam Planning Commission estimates that sectors such as construction, transportation, and industry will contribute the majority of the reduction in the emissions intensity of up to 23-25 per cent from 2005 levels by 2020.

More importantly, demand understanding is needed for good supply-side planning. Consider India's international climate commitment to increase its non-fossil fuel electricity generation to 40% of total capacity by 2032. India must prepare for both fossil and non-fossil energy sources to meet this target. However, the magnitude of supply in any proposal is contingent on the grid's size or total capacity in 2030, which is eventually determined by potential demand. We do not yet have an exact estimate for India's potential grid size, and study forecasts vary between 650 and 1000 gigawatts, implying a range of supply requirements on either end. Inaccurate demand forecasts could jeopardize energy security or result in a series of stranded fortunes, both of which cause concern.

### (C) GOING AGAINST THE GENERAL TRADITION:

Finally, the conventional supply-dominated orientation has been insufficient to correct India's energy diagnosis. Despite increased electricity output and a maze of policy priorities, the sector is fashionable despite various systemic inefficiencies and economic losses.

Lack of access to energy continues to be a good characteristic. According to the 2011 Census, over 400 million people lack access to electricity, and even though there is availability, there are serious concerns about fuel quality. Power shortages continue to haunt the grid, with polluting diesel generators increasingly being used to compensate.

Coal-fired thermal power plants are often used to meet peak load demands, resulting in economic and resource waste and environmental implications. India's compelling case is to reconsider its current energy planning imagination, which is primarily motivated by an incomplete narrative of deficiency and its related solution of increased availability.

Alternatively, a different conceptualization would emphasize the importance of comprehending demand trajectories as an input to supply requirements. It should, preferably, also consider the energy strategy's broader ultimate goals, such as energy efficiency and socio-environmental benefits. This transition will not be effortless or automatic - all the more so because demand-side solutions are often embedded in a complex network of social structures and behaviours and can require explicit normative roles [332].

## 4.3 POWER GENERATION GRID MANAGEMENT

Electricity cannot be safely or reliably stored in large amounts. In an energy grid, power generation and consumption must always be closely balanced. Some fundamental principles are essential for our understanding of electricity. When energy generation and consumption become unmanageable, blackouts and other structural failures occur. Electricity must be produced on a demand basis. Demand, of course, fluctuates over the day, month, and year. Demands are met by a combination of continuous-operation power plants (baseload) and peak-load power plants. They must be able to meet available supply in real-time collectively.

This is expensive and uncertain. When the demand is low, expensive facilities are idle, which are planned to serve peak capacity. When the market is high, all available resources are placed under pressure, impairs the system's dependability. The power grid can be built and run more cost- and energy-efficiently when supply doesn't fluctuate widely.

### (A) REQUEST RESPONSE:

A concerted effort is being made to involve the customers in the planning process. If you prefer to demand a response, you are speaking of partnering with customers to get them to use less energy. Communication with the only method is important to notify the customer when a change in requirements is required (supply is low, useless or supply is high, a good time to use more). Many techniques and technologies exist under supply-side approaches known as the supply side (DSM).

"In this context, DSM refers to eliminating end-use facilities or processes. DSM minimizes the client demand during times of high availability and scarcity. On the one hand, the DSM has big, and immediate programmes, such as construction of equipment such as the power utility takes on average for large customers, which minimizes energy consumption. On the other, it, it has tailored and intensive programming projects for the industries such as power production, including temporary stops for the industry's most demanding processes."

**(B) STORAGE OF ENERGY ON THE GRID:**

The Electric Energy Association claims that storage plays a vital role in the grid. "Energy storage can fundamentally alter how electricity is produced, distributed, and consumed. Energy storage is advantageous in emergencies, such as blackouts triggered by earthquakes, system failures, personal injury, or even terrorist attacks. However, the game-changing potential of energy storage is its ability to rapidly balance energy supply and demand – within milliseconds – making power networks more resilient, secure, and safer than ever before. [333].

Additionally, we know that a vast quantity of energy is not easily or effectively processed. The Electricity Storage Organization classifies energy storage technologies into six groups.

Solid-State Batteries: Solid-state batteries are electromechanical energy storage devices that include lithium-ion batteries and capacitors.

**Flow Batteries:** Flow batteries store energy directly in the electrolyte solution, resulting in longer cycle life and faster reaction time.

**Flywheels:** mechanical devices that convert rotational energy into instantaneous electricity.

**Compressed Air Energy Storage:** Thermochemical energy storage is a method of storing energy by compressing air.

**Thermal**: Thermal energy is produced by capturing heat and coal and converting it to electricity on demand.

**Pumped Hydropower**: Electricity generated using dams Water reservoirs, constructed on a wide scale, can be used for energy production. The most primitive but extremely simple way to store energy involves building water elevators and pumping them to a higher location to be put under pressure. Then, sitting it in the clouds, which is considered an energy technology of last resort, has the greatest potential for increasing energy yields. Pumped water is used to convert to kinetic energy when pumped back up to a higher elevation to produce hydroelectricity. Due to the enormous storage size, this is currently the most common type of grid-level energy storage. When the water-pumping capacity of a power plant is increased, it allows the plant to power itself uphill. When the plant is at its most effective, pumping storage provides the greatest economic advantage and power costs are the lowest.

**(C) NATIONAL GRID EVALUATION:**

There are five regional grids for grid control in India, namely the Northern, Eastern, Western, North Eastern, and Southern regions, which are all synchronously linked to the country's transmission system. In October 1991, the

NER and ER grids were linked, and in March 2003, the WR and ER-NER grids were connected. In 2006, the ER and NR grids were linked. Operating at a single frequency enables establishing a central grid in which the NR, ER, WR, and NER grids are synchronously linked, thus achieving the Central government's goal of ONE NATION'-'ONE GRID'-'ONE FREQUENCY. SR was connected to the CR grid in synchronous mode on 31 December 2013, completing and commissioning the 765 kV Solapur-Raichur transmission line [334].

## 4.4 RES BASED GENERATION PLANNING AND MANAGEMENT

India is rapidly expanding its investments in renewable energy sources such as wind and solar. With such volatile energy sources feeding the grid, it is critical to have a highly adaptive grid (supply and demand). A reliable electricity supply is a critical component of the infrastructure required to sustain overall growth. As a result, the prospects for developing smart grids in India are enormous. Apurva Jain and Navneet Gupta [335].

Infrastructure is greatly influenced a nation's economic growth and well-being. Infrastructure is needed to support economic growth in India and vice versa. One of the world's most powerful and interesting power markets is India's. Although conventional energy sources such as coal, natural gas, and nuclear have been used to provide electricity in the past, newer methods include renewable energy, such as wind, solar, and domestic resources. The electricity demand has increased over the last few years, and it is anticipated to do so in the future. A massive increase in generating capacity is needed to meet the country's energy needs, particularly to power new buildings and vehicles. According to creative capital, the global ranking of countries was determined in May 2018 and placed India at No. 4 in the country. 4, out of 25.

India's power market is experiencing drastic change, altering the industry's outlook. India's electricity demand has been sustained by economic development. The Indian government's focus on achieving 'Power for all' has resulted in a major increase in regional capability addition. Simultaneously, both the supply and demand sides of the equation are becoming more dynamic (fuel, logistics, finances, and workforce). India's gross installed capacity of power plants stood at 343.79 Gigawatts in April 2018. (GW). Between April 2000 and December 2017, the industry attracted US$ 12.97 billion in Foreign Direct Investment (FDI), or 3.52 percent of total FDI inflows into India.

Several major investments and developments in India's power sector include the following:

Energy Efficiency Services Ltd (EESL) has received US$ 454 million in funding from the Global Environment Facility (GEF) to support energy efficiency initiatives in India, accelerating the country's transition to a low-carbon economy.

IL&FS Financial Services Ltd has partnered with Jammu and Kashmir (J&K) Bank Ltd to finance nine hydropower projects in J&K with a combined capacity of 2,000 megawatts (MW) and a funding requirement of approximately Rs 20,000 crore (US$ 3.12 billion).

Sterlite Power has been granted one of Brazil's largest 1,800-kilometer transmission projects, worth US$ 800 million. This is the Company'sCompany's third project in the country and the largest that an Indian company has ever won in Latin America.

In April 2018, ReNew Power concluded the largest M&A deal to date, acquiring Ostrow Energy for US$ 1,668.21 million.

The Indian government has identified the power sector as a priority sector for long-term industrial growth. The Indian government has taken several measures to bolster the Indian power market, including the following:

Energy Efficiency Services (EESL) programmes have resulted in energy savings of 37 billion kilowatt-hours (kWh) and greenhouse gas (GHG) emissions reduction of 30 million tonnes.

The Union and state governments have agreed to implement a Direct Benefit Transfer (DBT) scheme in the electricity sector to boost subsidy targeting, according to Mr Raj Kumar Singh, Minister of State for Power (Independent Charge).

The Indian government has approved the 2018 National Biofuels Policy, which is expected to benefit health, the environment, job development, reduced dependence on imports, increased rural infrastructure investment, and increased farmer income.

The Indian government has set a target of 175 gigawatts of renewable energy capacity by 2022, including 100 gigawatts of solar and 60 gigawatts of wind. The Indian Union Government is designing a'rent a roof' strategy to assist it in meeting its goal of 40 gigawatts (GW) of rooftop solar energy production by 2022."[336].

## 4.5 GRID MANAGEMENT WITH INTEGRATED RES:

Initially, environmental effects were viewed as constraints on the operation of the power grid, with tolerance limits set for the maximum allowable emission rates. Another conventional solution included external costs associated with the system's multiple power plants' environmental impacts [337].

The smart grid allows an integrated and reliable end-to-end intelligent two-way delivery system from source to sink by incorporating renewable energy sources, smart transmission, and distribution. Thus, Smart Grid technology will contribute to efficiency and sustainability by ensuring the reliability and highest possible quality of energy supply in response to increasing energy demand. Additionally, a smart grid enables real-time monitoring and control of the power system and aids in the reduction of AT&C losses, demand response and demand-side management, power quality management, and failure management, among other benefits. Apart from providing more resilient and stable energy grids and tariff regimes, the Smart Grid will act as the foundation for evolving business models such as smart cities, electric vehicles, and smart societies. Recognizing the importance, Power Grid pioneered the implementation of Smart Grid technology through the entire value chain of electricity supply, including establishing a smart grid pilot project in Puducherry through open collaboration on all aspects of smart grid distribution [338].

According to the Power Grid Corporation of India Limited (POWERGRID), approximately 43GW of capacity has been installed, primarily via wind and solar, under the 12th plan with integration for renewable energy-rich states such as Himachal Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh, Tamil Nadu, Jammu& Kashmir, and Karnataka as part of Green Energy Corridors. Recognizing the critical need for large-scale production of alternative energy sources such as solar and wind, POWERGRID prepared a report on the development of desert power in India's desert regions of Rajasthan (The Thar), Gujarat (Rann of Kutch), Himachal Pradesh (Lahul & Spiti valley), and Jammu & Kashmir (Ladakh), for a time horizon of 2050. The report forecasts approximately 300 GW of renewable energy potential in Indian deserts, mainly through solar and wind energy and its development over the medium and long term. It discusses, among other items, transmission infrastructure requirements for renewable energy integration in desert regions, grid balancing and spinning reserve infrastructure requirements, desert power production challenges and impacts, indigenous renewable energy manufacturing research and development, and investment in desert power development capability [339].

India's electricity market is expanding at a rapid rate. Peak demand is approximately 164.1 GW in the current fiscal year 2017-2018 (through 30.11.2017), while installed capacity is 330.8 GW, with a mix of thermal (66.2%), hydro (13.6%), renewable (18.2%), and nuclear generation (2.0 percent ). Natural resources used to produce electricity in India are inequitably distributed and concentrated in a few pockets. Hydropower capacity exists in the North Eastern Region's Himalayan foothills (NER). The highest concentrations of coal reserves are in Jharkhand, Odisha, West Bengal, Chhattisgarh, and parts of Madhya Pradesh. The highest concentrations of lignite reserves are in Tamil Nadu and Gujarat. Additionally, the country has seen various natural gas-fired power plants and renewable energy sources such as solar, wind, and geothermal.

POWERGRID, a Central Transmission Utility (CTU), is responsible for interstate transmission system planning (ISTS). Similarly, State Transmission Utilities (STUs) are responsible for developing the Intra State Transmission System (more precisely, State Transco/SEBs).

Over the years, many transmission lines have been established to evaluate and transmit energy generated by various electricity generating stations. Acceptable voltage lines are laid in proportion to the amount of power and the distance involved. 800 kV HVDC and 765 kV, 400 kV, 230/220 kV, 110 kV, and 66 kV AC lines are the most frequently used nominal Extra High Voltage lines. All SEBs and utilities engaged in generation, transmission, and distribution, including those in the Central Sector, have installed these. In 2017-18, 13,820 circuit kilometres (Ckm) of transmission lines were commissioned (April- November 2017). This is 59.9% of the annual goal of 23,086 Ckm set for 2017–18. Similarly, during 2017-18 (April-November 2017), substations added 50,805 MVA of transformation capacity, accounting for 94.1 percent of the annual goal of 53,978 MVA set for 2017-18. As of 30 November 2017, the country's transmission grid included 3,81,671 kilometres of transmission lines and 7,91,570 megawatts of transformer power at substations. As of 30 November 2017, the total transmission power of the interregional links is 78,050 MW.
Transmission lines are governed by the regulations and standards of the Central Electricity Authority (CEA), the Central Electricity Regulatory Commission (CERC), and the State Electricity Regulatory Commission (SERC) (SERC). However, under some circumstances, transmission line loading can be regulated to preserve voltage stability, angular stability, loop flows, load flow pattern, and grid security. Except for some congestion in the southern region's power supply, power surplus states have been able to supply surplus power to utilities in power deficient states worldwide. Power System

Operation Corporation Limited (POSOCO) operates the National and Regional grids through its National Load Despatch Centre (NLDC) and five Regional Load Despatch Centres (RLDC).

Under the Ministry of Power, a Navratna company is tasked with the responsibility of engaging the power transmission industry in India for the planning, execution, operation, and maintenance of Inter-state transmission systems (ISTS), dubbed POWERGRID (power grid corporation of India limited) as the Central Transmission Utility (CTU). POWERGRID owns and operates approximately 1,42,989 kilometres of Extra High Voltage (EHV) transmission lines spanning the length and breadth of the country and 226 EHV AC & HVDC Substations with a combined transformation capacity of over 3,11,185 MVA. Its comprehensive transmission network accounts for more than 45% of the country's electricity production. Owing to the use of cutting-edge operation and maintenance methods that conform to international standards, the availability of this vast transmission network is consistently greater than 99 percent. During the fiscal year 2016-17, POWERGRID earned approximately Rs. 26,581.46 crore in revenue and Rs. 7,520.15 crore in benefit.

Additionally, as of 31.03.2017, the Company'sCompany's Gross Fixed Assets increased to Rs.1,49,730 crore. HCPTCs have been developed to meet the bulk power evacuation requirements of various Independent Power Producers (IPPs) in resource-rich and coastal states such as Chhattisgarh, Odisha, Madhya, Sikkim, Jharkhand, Tamil Nadu, and Andhra Pradesh. Construction of the corridor has been phased to conform to generation schedules.

The country's total inter-regional transmission capacity (220kV and above) was increased from 27,150 MW to 75,050 MW between the XIth and XIIth plans. POWERGRID's efforts, backed by the Ministry of Power, have decreased electricity prices and a more reliable supply of electricity in the Northern Region. During the XII Plan, POWERGRID invested approximately Rs.1,12,600 crore in the inter-State transmission system, compared to the goal of Rs.1,10,000 crore. During the XII programme, it added approximately 45,900 kilometres of transmission line and approximately 1,64,000 megawatts of transformation capacity, compared to the goal of 40,000 kilometres and 100,000 megawatts, respectively. The company has an excellent credit rating with financial institutions, which positions it well for resource mobilization.

Additionally, POWERGRID assists in the grid interconnection of renewable energy across the country by introducing a section of the Green Energy Corridors' ISTS part. Conserving right-of-way (RoW), minimizing effects on natural resources, co-developing cost-effective transmission corridors, and allowing for flexibility in upgrading lines' transfer capability to meet power transfer requirements are critical considerations country's transmission network expansion. In this direction, the CompanyCompany has been operating on higher transmission voltages of 800 kV HVDC and 1200 kV HVAC. The 800 kV, 3000 MW HVDC bi-pole line (CK-I) was commissioned between Champa, Chhattisgarh, and Kurukshetra, Haryana. Additionally, this transmission system is being upgraded to 6000 MW capacity by constructing a second HVDC Bipole (CK-2) with a 3000MW capacity and 800kV HVDC Terminals, which is scheduled to be completed by December 2018.

Similarly, the transmission of electricity has begun through the 1200 kV National Test Station (NTS) in Bina, Madhya Pradesh. POWERGRID entered the telecom sector to diversify its revenue sources and create value for its stakeholders, leveraging its vast transmission infrastructure in the country. The CompanyCompany connects all metros, major cities, towns, and remote areas of Jammu and Kashmir and the North-Eastern States through its backbone network. Overall, the network coverage is more than 41,000 kilometres, and there are 662 Points of Presence (stations) on the network. The Telecom Backbone Network covered throughout 2016-17 had a capacity of about 99.9 percent. POWERGRID has completed the prestigious project on the NKN (National Knowledge Network), which links all scientific and technical universities and research institutes across India, including the IITs (Indian Institutes of Technology) and the Sciences (IISs). Creative expression: Bharat Sanchar Bharti Public Limited (BSNL) has signed a pact with the North-eastern States, including Sikkim, to increase internet connectivity. Optical fibres would provide broadband over existing high-tension electric transmission lines. Once the network is built, service reliability in the north-eastern area will improve significantly.

The Indian government has made the difficult task of connecting the 250,000 Gram Panchayats (GP) a part of their state initiatives by assigning one of the implementing agencies to build and maintain the state optical fibres and deploy it to Punjab Haryana, Jharkhand, and Orissa, POWERGRID. By developing Deendayalaya Gram Jyoti Yojana (DDUGY) and Integrated Power Development Scheme (IPDS) projects, the POWERGRID also helps with distribution reforms in India.

POWERGRID has a strong presence in South Asia and is actively engaged in creating a strong SAARC grid for the efficient use of shared resources. Various electrical connections exist between India and Bhutan, India and Nepal, and India and Bangladesh. Additionally, India's interconnections with Bhutan, Nepal, and Bangladesh are being improved to facilitate significant cross-border power exchange. POWERGRID offers advisory services to a diverse range of domestic and foreign clients, including various countries in South Asia, Africa, and the Middle East. The "India Smart Grid Task Force" is the name given to the government's efforts in the field of smart grid [20]. The transmission system for the entire Indian power sector is divided into five regions: northern, southern, north-eastern, western, and eastern. A regional grid is used to refer to each distinct area within an interconnected system.

## 4.6 OFF-GRID RES POWER MANAGEMENT:

In the rural areas, off-grid power management systems are offered and developed by the union and state governments to provide incentives and subsidies to the users through the local nodal agencies and state DISCOM or mini-grid which rich and poor consumers would pay the costs. This type of grid management is called mini-grid and surplus energy generation storage in batteries banks. Solar power generation costs are decreasing by the latest projects bids with a price of Rs.2.42 / kWh. The costs of gas, oil and coal will go up, and the cost of solar power generation will come down. The decentralized power supply due to decentralize the demand in India.

RES power generation capacity 175 GW targets to be achieved by India by 2022, under the roadmap of eco-friendly energy generation planning and strategy to the whole system. However, implementation and formulation for the aspired leap quantity with policy in institutional mechanisms with exploring issues and challenges in India by the Indian government for RES power generations. The financial support for eco-friendly power generation development in India for users to be available by the state and central governments. The off-grid management in India for green energy generation and significantly on requirements for the population of the rural areas to be avoided the gripping of cuts and brownouts of electricity. The electricity supply and demands to be not connected with the grid management where governments ideas should be aggressive to promote the off-grid RES power generation management such as remote areas and rural areas.

India aspires to achieve RES power generation capacity to be installed 175 GW by 2022 to establish the largest RES power generation programs aim. After the US and China, India is the biggest emitter of $CO_2$ and GHG emissions. Therefore, the RES power generation has significantly progressed and commitments by India. India has installed terrible with dramatical growth over the last recent years. In 2002, RES power generation installation was 3.40 GW in India with the contribution of 3.2% in the total installed capacity of power generation, which is constituted with a very small form. So, the Indian power sector has been seen exponential growth from 2002 to 2016, resulting in the installed generation of RE in 45.90 GW as an end on December 2016 in 15% sharing of the total power generation installed capacity. During the period 2002 to 2016, the RES power generation installed capacity growth rate in the compound was 20% compared to fossil fuel base capacity such as nuclear and thermal evolve at 5.6 % and 7.7%, respectively (PRAYAS,2015).

In the power sector-top research fundamentality areas to electricity access of off-grid. Electricity modernity challenge is to development of eco-friendly power systems in the objective towards to the off-grid access. And the cheaper comparison to fossil fuels electricity for affordable access. By off-grid. The government objective and support in the valuable reduction of price and $CO_2$ emissions for individual premises and increase energy efficiency and performance of RES power generation systems by 2020 for remote areas communities. Funding opportunity announcement (FOA) has been accelerating the electricity of off-grid access in its ongoing efforts.

The high cost up to compound 100 kW RES power generation systems operation, reliable, the robust, climate condition and diverse geographically to demonstrate by 2020 in India is lower than the present condition.

Off-Grid FOA objective to promote accessible and affordable access to eco-friendly energy derived for off-grid electricity generation as outlined in the challenge document of MI-Innovation. Especially, the objectives are overarching for individual domestic users, is to be financial support valuable reduction in price and enlargement performance of RES power generation systems by 2020 and for remote areas community's objective is to demonstrate For remote areas communities, to demonstrate the objective in robust and climate conditions, reliable, autonomous operation, diverse geographically of RES power generation systems less than valuable lower cost than today by 2020.

## 4.7 CONCLUSION

At present, the coal-based TPPs energy generation in India is defined with 197 GW approximately, and it is to be needed to reach almost 500 GW by 2050. India has a current total RES power generation installed capacity of 130 GW by sharing of non-hydro RES power generation capacity of 70 GW. It will be increased more expected 155 GW by sharing solar power generation and successful wind power sellout. India could be got the first position in the world's countries to be used LEDs for all lighting requirements by 2019. The government of India instant target to achieve a generation of 2 trillion kWh (units) by 2019. Present power generation capacity to supply 24x7 hours for agriculture, residential, commercial and industrial etc., in the meaning of twofold power generation.

The various footsteps are holding by the Indian government, such as subsidies, incentives and initiatives of a tax rebate or exemption for promotion of RES power generation projects and $CO_2$ emission reduction under the IT Act.115 BBG. The country's ambition is to be targeted with an additional 175 GW installation of RES power generation, including sharing 100 GW solar energy generation by 2022. The Indian governments have also restarted the impeded hydro energy generation projects. The wind power generation to be enhanced goals 60 GW from present generation 20 GW by 2022.

In the energy structure scenario in India, concerning intense progress momentum in demand, short dispersion in generation corresponding transmission and distribution to be situated for economical and eco-friendly growth. The demand for a large amount of power investment and to contest in the comprehensive system. The power generation system opened to the private businessman for sharing of partnership I generation. At this moment, certain the pathway for investment utilizing market occasion.

# CHAPTER 5
# REDUCTION OF CARBON DIOXIDE EMISSIONS

In this chapter, an eco-friendly approach to power generation for carbon dioxide reduction is discussed. This chapter is divided into six sections. The introduction is followed by methods of removal of $CO_2$ in section 6.2. In section 6.3, $CO_2$ emission reduction is carried out by integrating solar energy generation with conventional power generation. Standard formulas are used to calculate the carbon emission, GHG emission, and emission factors to analyze the results for the proposed scheme using the integration approach. In section 6.5, implementation of the proposed project is carried out using the RETScreen Software. Products along with conclusions are discussed in section 6.6.

## 5.1 INTRODUCTION:

Coal is the most dominant fossil gas used in thermal energy power plants (TPP) for Electricity in India. During the 12$^{th}$ five-year plan, coal-based electricity generation had a 56% contribution of India's ability and sixty-six percentages (66%) of strength, including the diesel, gas with coal technology. Initially, the TPPs were evolved due to the less advancement in renewable technology. After some time, it was realized that producing carbon dioxide emission and the resources for fossil fuel is still limited. $CO_2$ is the predominant pollutants emitted from TPP and is liable for the 60% dangerous greenhouse effect. The installed capacity of coal primarily based on TPP may be limited to 270 GW up to 2032, and it may further lessen slowly to 253 GW due to the integration of RES. Renewable strength is a beneficial choice in the context of the greenhouse effect and energy integration. RETScreen software is used to evaluate $CO_2$ emission and mitigation with electricity generation in coal-based thermal power plants (TPP) in India. Solar radiation and weather facts are also the main contributor to $CO_2$ emission indirectly due to environmental factors.

To date, coal is the primary source of energy generation in India. However, the impact of RES is increasing day by day due to the support of government policies and global acceptance of RES as a better solution with sustainability. In India, TPP uses good quality coal. Due to this, the plant load factor stays 73% up to 2032 and 74% after that. But the drawback with the coal technology is the high emission of other GHG and $CO_2$. The cleaner technology is critical due to low carbon emission, but the IPGC may generate the power at 5600-11000 Cr. Rs. /GW using the thermal, which is relatively costlier too. In 2012 TPP technology contributed to 811 Mt. $CO_2$eq. Emission out of 2074 Mt. strength-related $CO_2$eq emission. With a determined effort for all energy sectors, total Electricity related GHG emission will be around 10848 Mt. $CO_2$eq. In 2047 out of total $CO_2$eq. TPP would make approximately 27.6% or 3002equivalent Mt. $CO_2$eq. The Generation is relatively high. As $CO_2$ is one of the constituents of GHG gases, the total amount of GHG Generation is relatively high in totality in power generation in India. If we research the percentage of GHG emission from thermal power plants (TPP), it could be 20.6%, with total GHG emission of 9882 Mt. $CO_2$eq. [29]. In greenhouse gas emissions, the carbon by-products are; $CO_2$, NOx, SOx, CFCs; all these constituents of GHG influence humanity's health and surroundings. So, there is substantial demand to control the GHG emission and control the emission of all by-products of GHG. It is one of the major concerns because of the fundamental property of GHG gases due to their existence in the atmosphere for a longer time. $CO_2$ molecules are solid, and the average residence time of these molecules is ten years with three years in the troposphere. Emitted $CO_2$ stays in the environment for around one hundred years. One study found that approximately 450ppm concentration of $CO_2$ inside the ecosystem is responsible for warming the temperature by 3.6˚F or 2˚C [340]. It is also identified that due to the immoderate $CO_2$ emission, the temperature of the earth's floor will boom 1.5 - 4˚C up to 2050. So, worldwide efforts are being made by governments, scientists, and environmental experts to find alternative solutions to control $CO_2$ emissions. One of the best alternatives as an eco-friendly system is the use of renewable energy systems. A variety of energy generating technology has been advanced in the last decade to gain renewable strength, and there is a lot of future possibilities yet to be explored. RETScreen software program is used to analyze electricity efficiency in addition to ongoing power evaluation [342]. Besides being a big $CO_2$ emitter, the enterprise has been one of the primary sources of environmental pollution. Nevertheless, problems, including air pollution due to the emissions of $CO_2$ and GHG such as $SO_2$, $NO_X$, and PM, need a lot of attention.

Due to the increased $CO_2$ concentrations in the atmosphere, the atmosphere temperature increases globally approximately in the range of 1.5-2.5˚C. The atmospheric conditions and ecological biodiversity are also affected predominantly, which involved the earth's biological cycle and led to severe diseases in humans [344]. $CO_2$ is the most effective anthropogenic greenhouse fuel, attracting the worldwide atmospheric attention of carbon dioxide and extending from a pre-industrial value of about 280 ppm to 379 ppm in 2005. The atmospheric density of $CO_2$ in 2005 exceeds by 180 ppm to 300 ppm evaluated from ice mushes [345].In addition, it is essential to look insights into the $CO_2$ emission resources and find eco-friendly solutions where $CO_2$ emission may be controlled with sustainable and economically viable solutions. In this context, the main target of this chapter is to look at the two main aspects:

(1) To identify the techno-socio-economic solutions with overall performance to control the $CO_2$emission using other alternative sources of energy such as RES for power generation within the short-mid period (ST/MT) and long-term destiny (LT). These solutions must be looked at from the variations in time-frame, gasoline type, and power plant kind.
(2) To explore the eco-friendly power generation solution in terms of cost concerning the $CO_2$emission by considering the large-scale centralized electricity plant life as a case study. Variations in a power plant in time of energy scale, operational situations, and other environmental factors are considered for analysis. Efforts will be made to reduce the $CO_2$ emission in terms of percentage using the integrated approaches. One of the essential findings is that power depth is the crucial element in mitigating $CO_2$ emission. In contrast, the $CO_2$ emission boom is usually due to the output and structure impact [347]. Lee and Oh used the logarithmic mean Divisia approach in APEC international locations to discover the dominant elements liable for the $CO_2$ emission boom. They determined that populace and capita GDP are dominant elements in $CO_2$ emission increase [348]. Logarithmic Mean Divisia Index (LMDI) and Arithmetic Mean Divisia Index (AMDI) for reading $CO_2$ emission in Greece from 1990 to 2002 is also used in [349]. In the paper, the four factors have been taken responsible for variation in $CO_2$ emissions, such as; energy intensity impact, earnings impact, population impact, and fuel proportion impact [349].

Claudia and Leticia examined the production and energy-related $CO_2$ emission using LMDI in Mexico's steel and iron enterprise from 1970 to 2006 [341]. Gürkan used the Laspeyres index approach for decomposition evaluation of $CO_2$ emission in Turkey during 1970-2006 [343]. Hammond and Norman used decomposition evaluation of $CO_2$ emission associated with power in UK manufacturing industries. They observed that changes in output, fuel blend, power intensity, and business shape, and electricity emission factor have contributed to the mitigation of carbon emission and electricity intensity reduction is the primary thing in mitigating $CO_2$ emission [350]. A tested decomposition analysis by Log–Mean Divisia Index (LMDI) approach is made to know the $CO_2$ emission because of its acceptable properties in this context [351]. The global industry manufacturing in 2030 is expected to be about 3500 Mt./year [352]. In petroleum refineries, McKinsey & group expected that emission of $CO_2$ from downstream rectification in 2030 would even be near to 1.50 Gt./year [353]. Catalytic crackers and furnaces/boilers account for 16% and 65% of whole refinery $CO_2$ emissions, respectively [354]. Methods for the reduction of $CO_2$ are discussed in the next section of this chapter.

## 5.2 METHODS OF REDUCTION OF $CO_2$

Based on the literature review in Chapter 2, several alternatives have been identified to reduce $CO_2$. To date, there is no full-proof solution for the reduction of $CO_2$, but using the hybrid eco-friendly energy generation models, some improvements have been achieved.

Some ways of reducing $CO_2$ emission and GHG emission are as follows:

(1) Reducing $CO_2$ emission using RES power generation such as energy efficiency, solar energy, wind energy, biomass power, biofuels, waste to energy, tidal energy, and wave energy, etc., for electrical power generation.

(2) Reducing $CO_2$ emissions using integrated RES with Thermal Power Generation Plants.

(3) Reducing $CO_2$ emissions by saving electrical energy.

(4) Reducing $CO_2$ emissions by replacing existing old Thermal Power Generation Plants with Ideal New Plants.

(5) Reducing $CO_2$ emissions by using Heat Exchanger Network (HEN) technology in Thermal Power Generation Plants.

(6) Reducing $CO_2$ emissions by using MPPT Inverter technology for maximum solar energy power generation.

(7) Reducing $CO_2$ emissions by using Battery Storage Systems (BSS) for solar energy generation.

(8) Reducing $CO_2$ emission by making attractive government policies, incentives, and subsidies to promote and develop RES power generation.

This set of ways mentioned above may lead to significant improvement in controlling GHG emissions. $CO_2$ emission may also be prevented because $CO_2$ is the central portion of GHG. One method for reducing $CO_2$ emission is based on RES power generation using solar energy, wind energy, biomass power, biofuels, waste to energy, tidal energy, and wave energy, etc., for electrical power generation. It means that these alternative energy sources may be found suitable and alternative for reducing $CO_2$ emission.

Another solution for reducing $CO_2$ emissions in the same direction is based on integrated Renewable Energy Sources (RES) with Thermal Power Generation Plants. This choice may also lead to significant improvements in this area. Efforts may be tried to reduce electric energy consumption using various means of technological solutions and grid-based solutions to reduce $CO_2$. Now a day, several grid-based and IoT-enabled solutions are available in the market, which has shown tremendous improvements in the reduction of energy consumption. So, saving energy in one way and replacing the existing old Thermal Power Generation Plants with Ideal New Plants may be considered as another solution in a similar direction.

Some studies have shown the reduction of $CO_2$ emissions by Heat Exchanger Network (HEN) technology in Thermal Power Generation Plants. This solution may be an additional way for power saving or removal of $CO_2$ emission due to less heat exchange. Maximum Power Point Tracking (MPPT) is another technique used for controlling emission in Inverter Technology for Solar power. Reducing $CO_2$ emissions by MPPT for Inverter technology may be used for maximum solar energy power generation. So alternatively, it also reduces the emission of $CO_2$. In the same direction, Battery Storage Systems (BSS) for solar energy generation may also be one alternative for the reduction of $CO_2$ emission and GHG. Apart from using different schemes and eco-friendly hybrid solutions, attractive government policies, incentives, and subsidies for the promotion and development of RES power generation may also lead to innovative ideas for the reduction of $CO_2$ emission. In the next section of this chapter, integration of solar energy generation with conventional power generation-based techniques is reported.

### 5.3 INTEGRATION OF SOLAR ENERGY GENERATION WITH CONVENTIONAL POWER GENERATION

This section covers the proposed scheme to reduce $CO_2$ emissions. –RETScreen model is used for mitigation analysis of GHG emission reduction by examining the profile of GHG emission, which provides a baseline in respect of the bottom case. Mitigation capability of –GHG emissions‖ annually is obtained within the –RETScreen‖ via Greenhouse gas emission reduction analysis worksheet by equation

$$\Delta_{GHG} = (e_{base} - e_{prop})E_{prop}(1 - \lambda_{prop})(1 - e_{cr}) \qquad (5.1)$$

Where $e_{ver}$, prop, base, $E_{prop}$ and $\lambda_{prop}$ are the –GHG emission‖ discount credit settlement rate, proposed case –GHG emission‖ issue, base case –GHG emission‖ element, proposed case yearly power produced, and a fraction of energ y lost in T & D for the proposed subject [360].

The Transmission & Distribution losses for the proposed case and bottom case gadget are deemed nil (for off-grid and water-pumping SPV applications). The following equation defines the base case GHG emissions factor (described as the defined mass of greenhouse gas emissions consistent with the unit (kWh) of Electricity produced), base.

$$e_{base} = (e_{CO_2} GWP_{CO_2} + e_{CH_4} GWP_{CH_4} + e_{N_2O} GWP_{N_2O})\frac{1}{\eta} * \frac{1}{1-\lambda} \qquad (5.2)$$

Where $e_{CO_2}$, $e_{CH_4}$, and $e_{N_2O}$ are the $CO_2$, $CH_4$, and $N_2O$ factors of emissions, respectively, fuels are considered. $GWP_{CO_2}$, $GWP_{CH_4}$, and $GWP_{N_2O}$ are the respective global warming potentials for $CO_2$, $CH_4$, and $N_2O$. $\lambda$ is the fraction of power loss in transmission and distribution, and $\eta$ is the GHG conversion performance. The international warming ability of gasoline and –GWP‖ describes the strength of a GHG in evaluating $CO_2$. In RETScreen, $CO_2$ is assigned with a GWP of 1. In contrast, GWP for $CH_4$ and $N_2O$ may be defined with the aid of the consumer in traditional evaluation or through the software program in most evaluations is given in Table 5.1 [361].

Table 5.1 Global Warming Potentials (GWP) for 100 Year Time Horizon [361]

| **Greenhouse gases** | **GWP** |
|---|---|
| Carbon dioxide (CO2) | 1 |
| Methane (CH4) | 21 |
| Nitrous Oxide (N2O) | 310 |
| Hydro-fluoro carbons (e.g., HFC 134a) | 1300 |
| Perfluoro carbon (e.g., CF4) | 6500 |
| Sulfur Hexafluoride (SF6) | 23,900 |

Annual greenhouse gas emission calculation for a power plant and the eco-friendly-based solution may be considered one of the comparison parameters for analyzing the proposed solution. Suggested solutions that can control the annual greenhouse gas emission may be regarded as viable solutions for long-term planning and the integration of RES models. Here we can consider the base case as standard conventional energy technology such as coal vs. proposed claims based on clean energy technology developed using the integration of traditional along with RES methods. In our case study, we have taken solar energy as the RES method for analysis. Most of the studies have used the tones of $CO_2$ produced per year as measuring parameters. In some of the studies, $CH_4$ and $N_2O$ emissions are converted into equivalent $CO_2$ emissions in their global warming potential.

Annual GHG emission reduction (CO2) in tonnes is calculated as

$$[(\text{BaseCaseGHGemissionfactor}(CO_2)\text{perMWhintonnes}) - (\text{proposedcaseGHGemissionfactor}(CO_2)\text{perMWhintonnes})] \times \text{EndUseannualenergydelivered (MWh)} \quad (5.3)$$

Performance of the energy plant can be monitored using PV type module, Charge Controller with Inverter, and maximum power point tracker (MPPT). Following five training PV cell technologies may also be considered primary contributing factors; CdTe type, CIS/CIGS type, rising PV type, Group III–V type, and Silicon type. Traditionally for most valuable effectively, Si and GaAs mono-crystalline solar cellular are suitable [352-364]. In Photovoltaic machine 1-axis and 2-axis solar monitoring shine, platen packages share 22.3% and 25.2% enhancement inside the annual power manufacturing serially compared to the constant flat plate gadget [365-370]. To acquire most solar strength, an MPPT mechanism is required, which moves consistent with the temperature, load, and irradiance [371]. MPPT is applied to support the running voltage of the array to a value that maximizes the output of the array. Another factor of Inverter with charge controller is applied to transform of Direct Current (DC) power saved in batteries into the Alternative Current (AC) power and controller are applied for regulating the cost and discharge cycle of the storm. In general, we use an ON-GRID Inverter having 70–96% efficiency [355-369]. Table 5.2 shows the PV Type module characteristics for standard solar power generation technology. Module efficiency is identified in terms of different module types such as; Mono–Si, Poly-Si, CIS, CdTe, a-Si. Here Table 5.2 show the relationship between the PV module type and ($\eta r$%) Module Efficiency, Tn (°C) and $\beta p$ (%/°C).

Table 5.2 PV Type Module characteristics for standard technology

| PV Type Module | ($\eta_{r\%}$) Module Efficiency | Tn (°C) | $\beta_p$ (%/°C) |
|---|---|---|---|
| Mono –Si | 13 | 45 | 0.40 |
| Poly-Si | 11 | 45 | 0.40 |
| CIS | 7.5 | 47 | 0.46 |
| CdTe | 7 | 46 | 0.24 |
| a-Si | 5 | 50 | 0.11 |

For better visibility and understanding, the relationship between the PV module type and (ηr%) Module Efficiency, Tn (°C) and βp (%/°C) are given in Fig. 5.1.

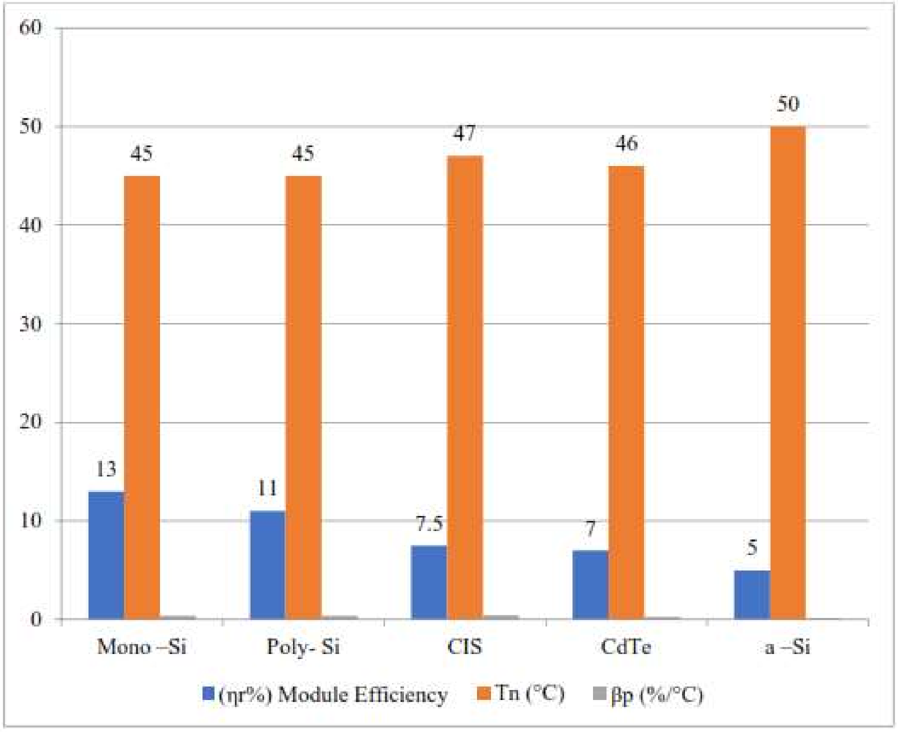


Figure 5.1 PV Type Module characteristics for standard technology

Table 5.3 shows the data record sheet for CO2 Emitted (mg/Nm3) (tons), Fuel Consumption (kg) oil, Fuel Consumption (Mt.), and Coal Electricity (Million kWh) collected from the PANKI power plant between 2012 to 2014.

Table 5.3 Reference data at NTPC Panki (Kanpur) power plant.

| Years | Months | Day | Begin | End | Duration (Days) | CO2 Emitted(mg/Nm$^3$)(tons) | Fuel Consumption (kg)oil | Fuel Consumption (Mt.)Coal | Electricity y (Million kWh) |
|---|---|---|---|---|---|---|---|---|---|
| 2012 | 8 | 31 | 01-08-2012 | 31-08-2012 | 31 | 407680 | 588 | 66467 | 74.672 |
| 2012 | 9 | 30 | 01-09-2012 | 30-09-2012 | 30 | 203840 | 606 | 60022 | 67.432 |
| 2012 | 10 | 31 | 01-10-20'12 | 31-10-2012 | 31 | 225792 | 301.43 | 88218 | 99.108 |
| 2012 | 11 | 30 | 01-11-2012 | 30-11-2012 | 30 | 256760 | 415.5 | 81743 | 93.808 |
| 2012 | 12 | 31 | 01-12-2012 | 31-12-2012 | 31 | 225792 | 485.9 | 51114 | 56.841 |
| 2013 | 1 | 31 | 01-01-2013 | 31-01-2013 | 31 | 431200 | 832.41 | 58311 | 63.054 |
| 2013 | 2 | 28 | 01-02-2013 | 28-02-2013 | 28 | 407680 | 173.86 | 35931 | 40.675 |
| 2013 | 3 | 31 | 01-03-2013 | 31-03-2013 | 31 | 225792 | 115.73 | 43295 | 49.293 |
| 2013 | 4 | 30 | 01-04-2013 | 30-04-2013 | 30 | 288120 | 512.52 | 83594 | 57.226 |
| 2013 | 5 | 31 | 01-05-2013 | 31-05-2013 | 31 | 284200 | 399.75 | 79488 | 95.772 |
| 2013 | 6 | 30 | 01-06-2013 | 30-06-2013 | 30 | 225792 | 711.355 | 56701 | 52.788 |
| 2013 | 7 | 31 | 01-07-2013 | 31-07-2013 | 31 | 288120 | 585.3 | 70810 | 88.888 |
| 2013 | 8 | 31 | 01-08-2013 | 31-08-2013 | 31 | 281200 | 786.43 | 66467 | 77.678 |
| 2013 | 9 | 30 | 01-09-2013 | 30-09-2013 | 30 | 225792 | 358.5 | 60022 | 82.238 |
| 2013 | 10 | 31 | 01-10-2013 | 31-10-2013 | 31 | 431200 | 124.45 | 88218 | 28.472 |
| 2013 | 11 | 30 | 01-11-2013 | 30-11-2013 | 30 | 431200 | 145.96 | 81743 | 44.78 |
| 2013 | 12 | 31 | 01-12-2013 | 31-12-2013 | 31 | 203840 | 119 | 51114 | 51.617 |
| 2014 | 1 | 31 | 01-01-2014 | 31-01-2014 | 31 | 225792 | 104.43 | 58311 | 52.319 |
| 2014 | 2 | 28 | 01-02-2014 | 31-02-2014 | 28 | 255760 | 155.44 | 35931 | 42.09 |
| 2014 | 3 | 31 | 01-03-2014 | 31-03-2014 | 31 | 235200 | 104.43 | 51114 | 52.319 |

Figs.5.2, 5.3, and 5.4 show the daily solar radiation, daily solar radiation with temperature, and monthly solar radiation, respectively, at the project location. Fig. 5.5 shows baseline $CO_2$ emitted and target $CO_2$ emitted in our proposed system. Table 5.6 represents the proposed project location climate data on a monthly basis.

Fig. 5.2 shows the daily solar radiation at Panki Power Plant from the year 2012 to 2014 using the NASA dataset. Fig. 5.3 shows the daily solar radiation on a daily basis with the temperature at Panki Power Plant for the year 2011using the NASA dataset. Fig. 5.4 show the solar radiation at Panki Power Plant on a monthly basis for the year 2013 to 2014 and 2014-2015 during the same months using the NASA dataset to understand the relative change in term of radiation. It is clear from the figure that monthly solar radiation potential was nearby to each other from Feb to April at Panki Plant. On the other side, it was found higher for next year at some places and further decreased in the month of Nov. to Jan. 2014.Fig. 5.5 shows the baseline $CO_2$ emission and target $CO_2$ emission at Panki Power Plant in Kanpur. Baseline prediction for $CO_2$ emission was approx. 10,000 mg/$Nm^3$in the month of Aug.2012 and reduced to a further 9000 mg/ $Nm^3$in the month of March 2014. On the other side, the target was achieved as approx. 7,800 mg/ $Nm^3$ in the month of August 2012 to 7000 mg/ $Nm^3$ in the month of March 2014.Fig. 5.6 shows CO2 emission (mg/ $Nm^3$)(tons) from 2012 to 2014. In Fig. 5.7, Fuel Consumption (kg)oil is shown for the same period, i.e., from the year 2012 to 2014.

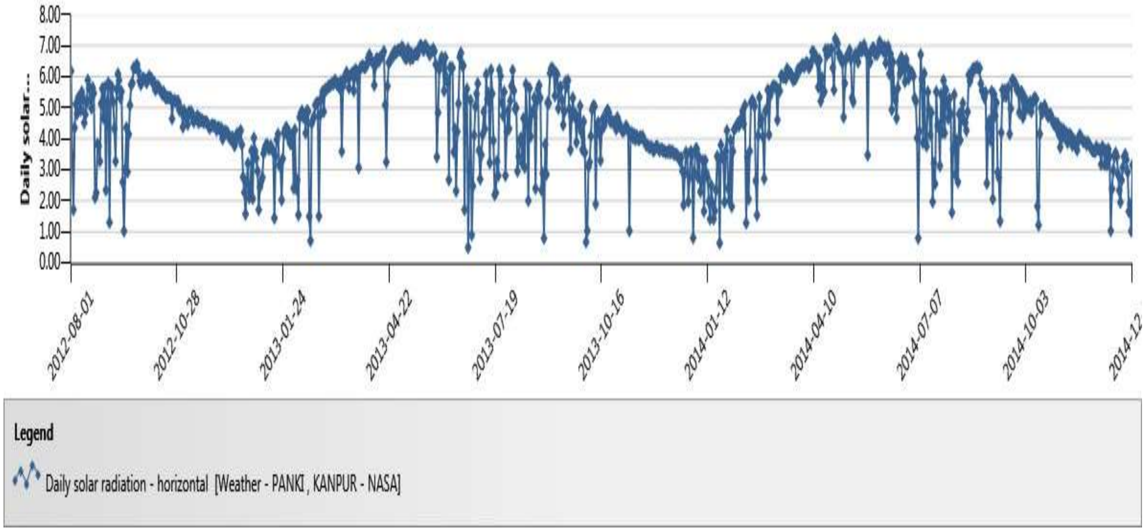


Fig.5.2 Solar radiation at Panki (Kanpur) on day basis

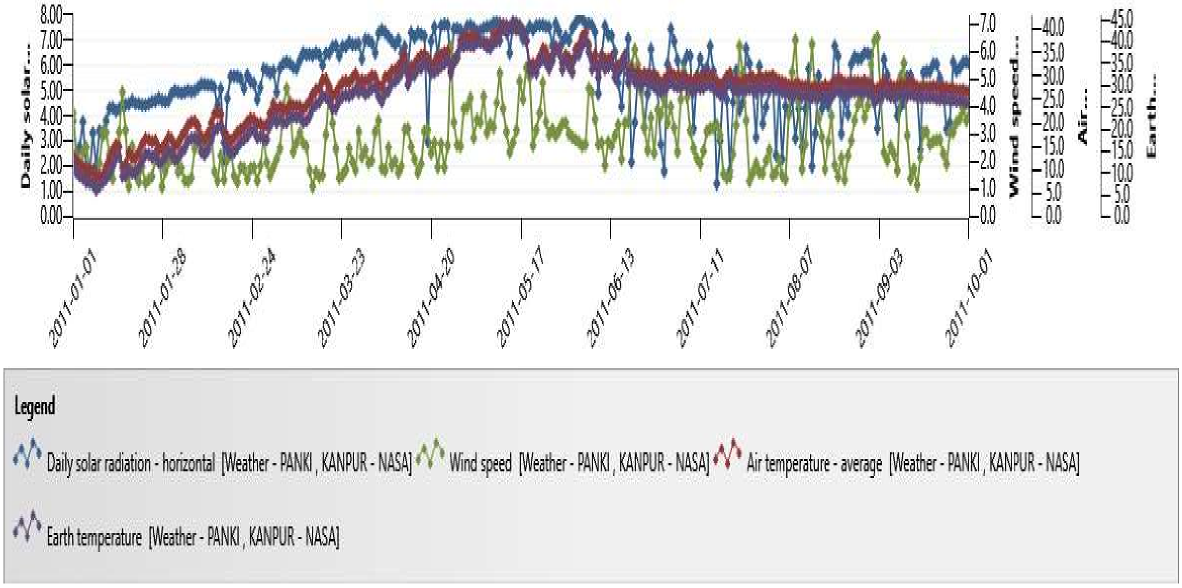


Fig. 5.3 Solar radiation on a daily basis with temperature

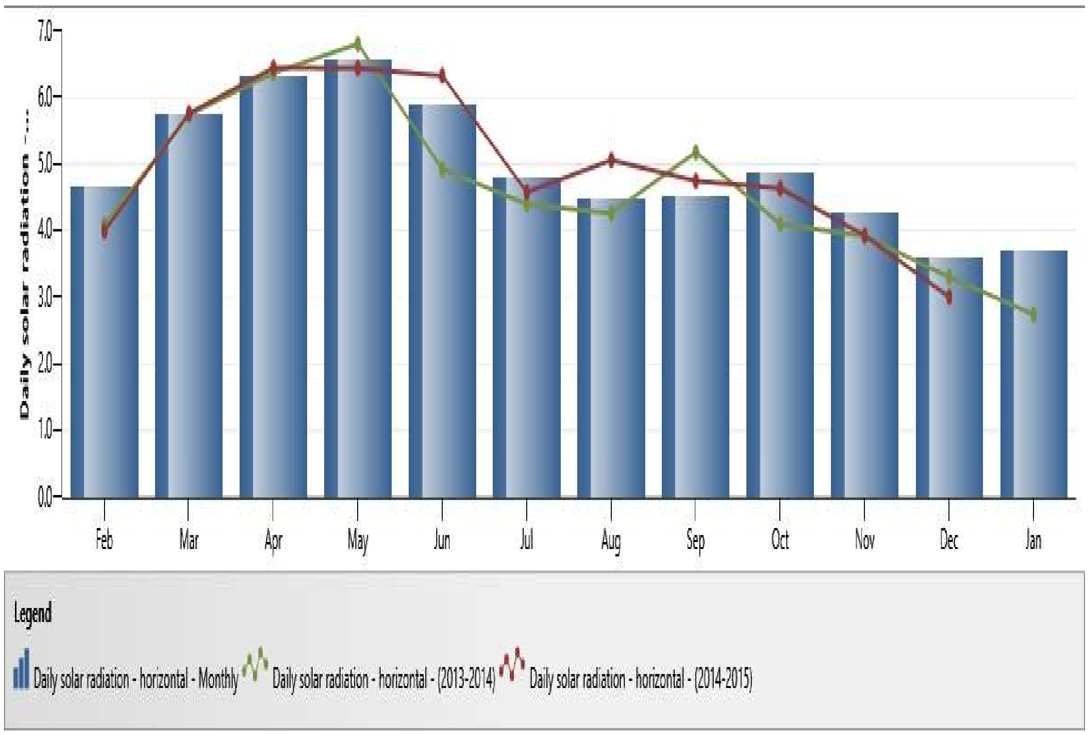


Fig. 5.4 Solar radiation Panki (Kanpur)on a monthly basis

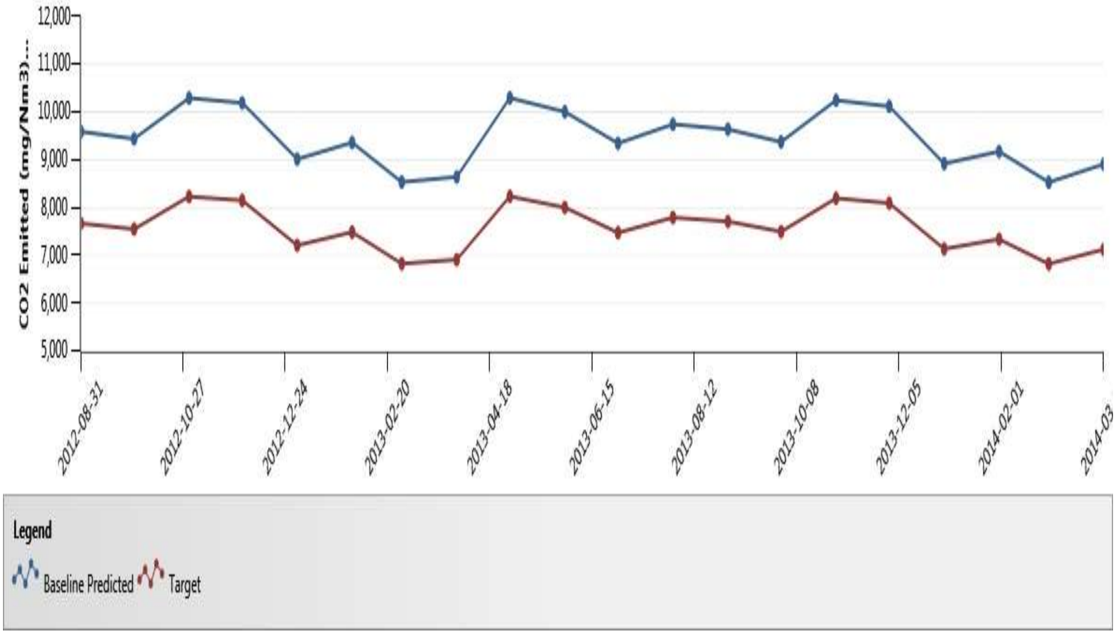


Fig. 5.5 Baseline CO2 emitted, and target CO2 emitted

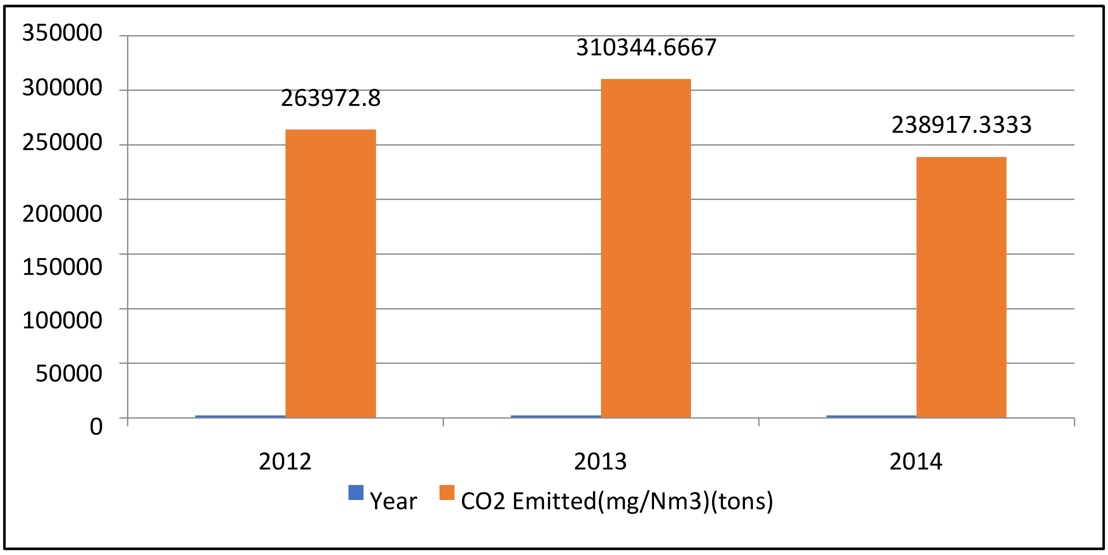


Fig 5.6 CO2 Emitted (mg/$Nm^3$)(tons) from 2012 to 2014

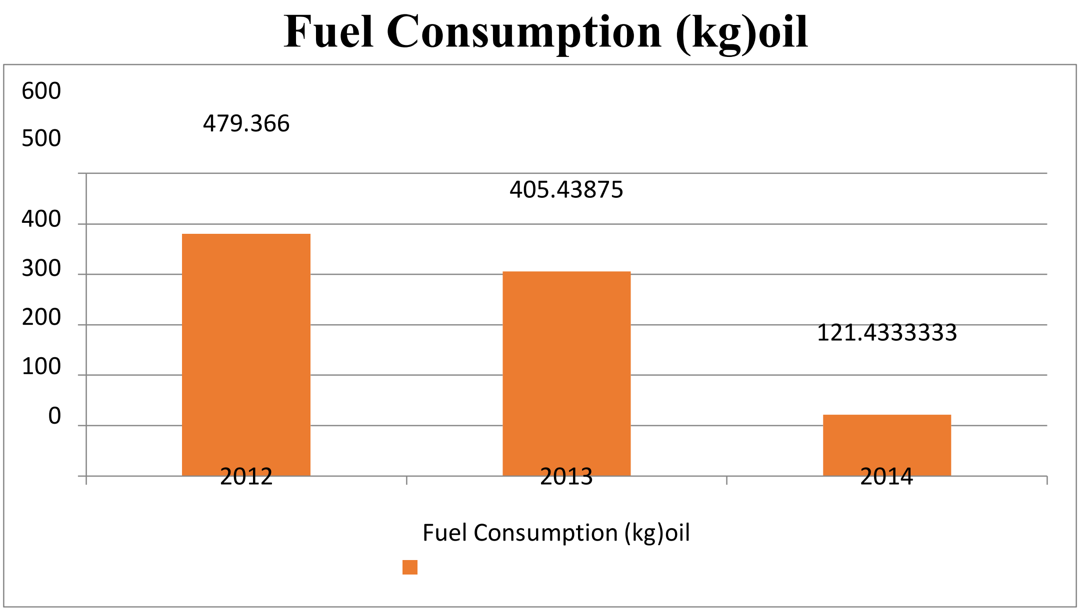


Fig 5.7 Fuel Consumption (kg)oil from 2012 to 2014

Fig 5.8 shows Fuel Consumption (Mt.) of Coal from the year 2012 to 2014. We have also analyzed the Electricity Generation (Million kWh) with respect to this amount of coal consumption from 2012 to 2014, as shown in Fig. 5.9.

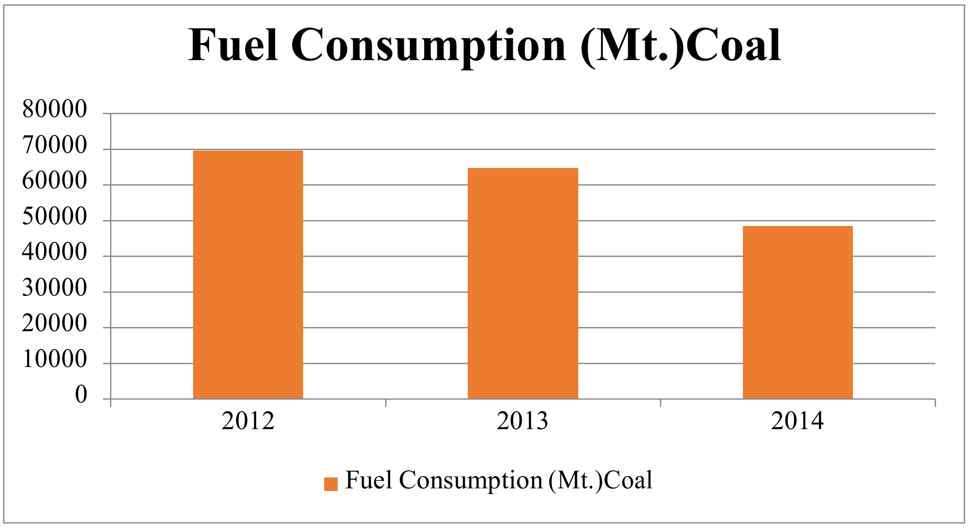


Fig 5.8 Fuel Consumption (Mt.) Coal from 2012 to 2014

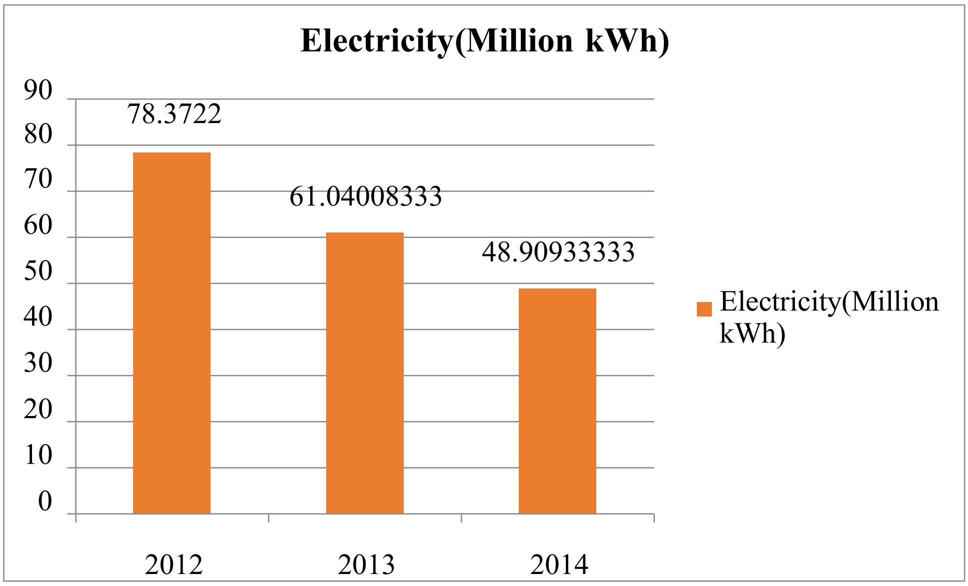


Fig 5.9 Electricity Generation (Million kWh) from 2012 to 2014

It is evident from Fig. 5.9 that initially, the Electricity Generation was about 78.3722 Million kWh which has reduced to 48.909 Million kWh because the plant runs for fewer hours as compared to the year 2012. It was found that in the year 2012 plant run maximum period and that's why it produced the more Electricity. In addition to this, fuel consumption is also matching in Fig. 5.8 with the result of 6.9 because as the plant executed for less period that's why it has consumed less amount of coal during the year 2013 and 2014 respectively.

Weather data for climate for the proposed project location (Panki Thermal Power Plant, Kanpur) is reported in Table 5.4 with respect to the ―Air temperature °C (Ground), Relative humidity % (Ground), Atmospheric pressure kPa (NASA), Daily solar radiation – horizontal kWh/m²/d (NASA), Earth temperature °C (NASA), Wind speed m/s (Ground), Heating degree-days °C-d (Ground), Cooling degree-days °C-d (Ground)‖ during different months of the year 2013 and same can also be seen from reference Table 5.3 for all 12 months of the year 2013. Thereafter we have observed the same plant for all the above-mentioned parameters during the entire year. According to Table 5.3, the maximum amount of $CO_2$ Emitted was 431200 (mg/Nm3)(tons) in the month of Jan., October, and November 2013, and on the other side minimum amount of $CO_2$ Emitted was 203840 (mg/Nm3)(tons) in the month of December 2013. However, the maximum amount of Electricity generated was 95.772 Million kWh in the month of May 2013 by generating the $CO_2$ Emission 284200 (mg/ $Nm^3$)(tons) after simulating the same in the RETScreen software with embedding the solar energy system as the integrated part with basic fuel like oil and coal. It is concluded that for the thermal power plant, more Electricity can be generated by the integration of a solar system with less amount of $CO_2$ emission. The distribution of air temperature °C (Ground) for the Year 2013 at Panki Power Plant is shown in Fig. 5.10. Relative humidity % (Ground) for the Year 2013 at Panki Thermal Power Plant is shown in Fig. 5.11. Atmospheric pressure kPa (NASA) for the Year 2013 at Panki Power Plant is shown in Fig. 5.12. ―Daily solar radiation – horizontal kWh/m²/d (NASA)‖ for the Year 2013 at Panki Power Plant is shown in Fig 5.13. Earth temperature °C (NASA) for the Year 2013 at Panki Power Plant is shown in Fig. 5.14. Wind speed m/s (Ground) for the Year 2013 at Panki Power Plant is shown in Fig. 5.15. Cooling degree-days °C-d (Ground) for the Year 2013 at Panki Power Plant is shown in Fig. 6.16. Now we can conclude based on Fig. 5.17 that there is a strong correlation between the $CO_2$ Emitted (mg/ $Nm^3$)(K tonnes) and Electricity

(Million kWh) for all twelve months from January to December 2013. After the detailed analysis of the Panki Thermal Power Plant organized by NTPC, we draw the outline of the conventional case of power generation as shown in Fig 5.18. It is clearly shown that the more the use of fossils fuel, the more the $CO_2$ emission, and the same is also identified from Panki Plant Data. Now to reduce the $CO_2$ emission, it is suggested that reduction in fossil fuel and integration of renewable energy technologies is a better idea, as shown in Fig 5.19. The proposed methodology is discussed in the next two sections of this chapter for further analysis on energy generation plants. In the next section of this chapter, problem formulation for $CO_2$ emission reduction calculation is written.

Table 5.4 Weather data for climate for the proposed project location (Panki Thermal Power Plant, Kanpur)

| Months | Air temperature °C (Ground) | Relative humidity % (Ground) | Atmospheric pressure kPa (NASA) | Daily solar radiation – horizontal kWh/m²/d (NASA) | Earth temperature °C (NASA) | Wind speed m/s (Ground) | Heating degree-days °C-d (Ground) | Cooling degree-days °C-d (Ground) | Electricity(Million kWh) | CO2 Emitted (mg/Nm³)(tons |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 14.2 | 0.756 | 99.84 | 3.72 | 16.76 | 1.6 | 117.8 | 130.2 | 63.054 | 431200 |
| Feb | 18 | 0.661 | 99.59 | 4.67 | 21.48 | 2 | 115.58 | 224 | 40.675 | 407680 |
| Mar | 23.5 | 0.521 | 99.21 | 5.75 | 29.12 | 2.4 | 114.72 | 418.5 | 49.293 | 225792 |
| Apr | 29.5 | 0.411 | 98.79 | 6.32 | 35.56 | 2.4 | 116.16 | 585 | 57.226 | 288120 |
| May | 32.4 | 0.467 | 98.39 | 6.57 | 36.49 | 2.6 | 125.59 | 694.4 | 95.772 | 284200 |
| Jun | 32.2 | 0.614 | 98.08 | 5.91 | 33.96 | 2.6 | 137.56 | 666 | 52.788 | 225792 |
| Jul | 29.9 | 0.801 | 98.15 | 4.8 | 30.3 | 2.5 | 150.3 | 616.9 | 88.888 | 288120 |
| Aug | 29.3 | 0.838 | 98.35 | 4.48 | 28.86 | 2.3 | 101.96 | 598.3 | 77.678 | 281200 |
| Sep | 28.2 | 0.825 | 98.73 | 4.52 | 27.71 | 1.9 | 96.41 | 546 | 82.238 | 225792 |
| Oct | 25.4 | 0.731 | 99.26 | 4.87 | 25.91 | 1.2 | 80.41 | 477.4 | 28.472 | 431200 |
| Nov | 20.2 | 0.69 | 99.67 | 4.27 | 22.02 | 1.1 | 71.22 | 306 | 44.78 | 431200 |
| Dec | 15.8 | 0.728 | 99.9 | 3.6 | 17.52 | 1.2 | 68.2 | 179.8 | 51.617 | 203840 |

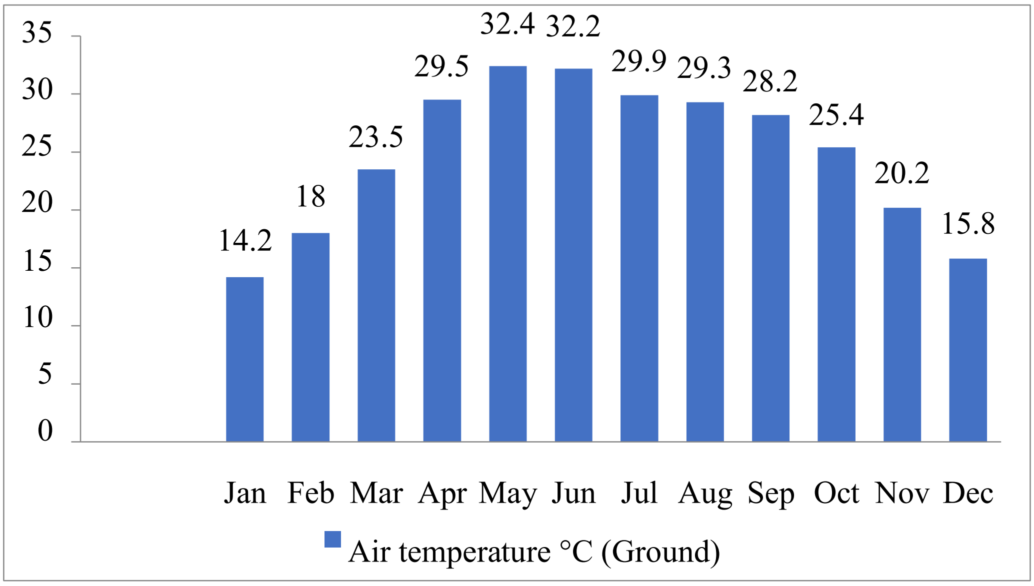


Fig. 5.10 Air temperature °C (Ground) for the Year 2013 at Panki Power Plant

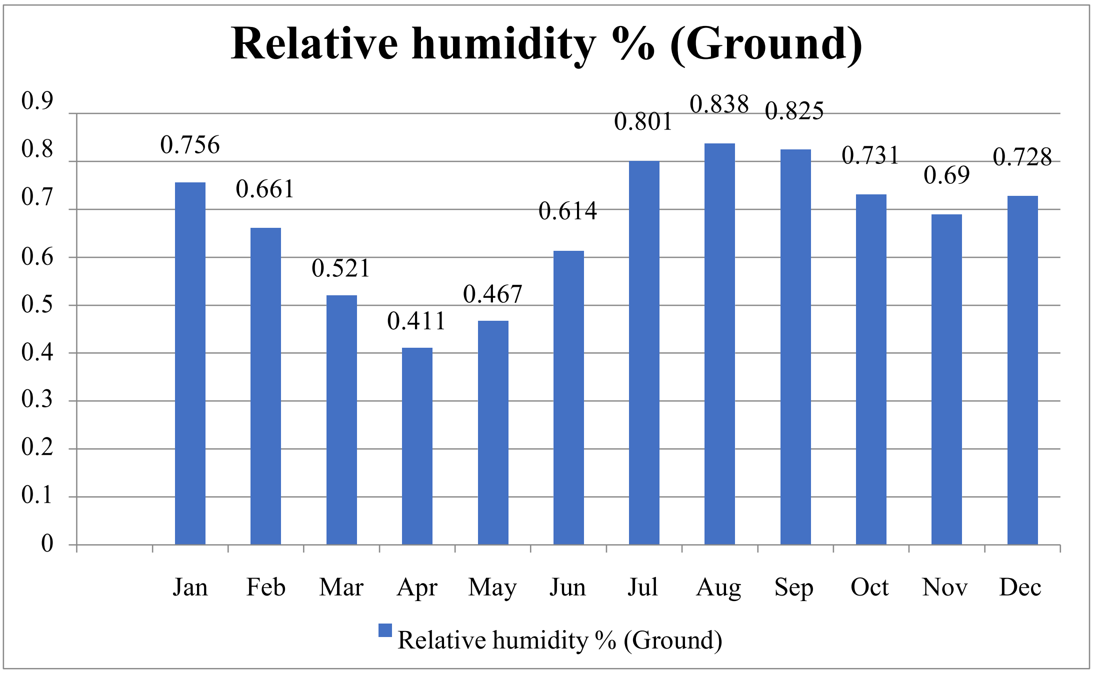


Fig. 5.11 Relative humidity % (Ground) for the Year 2013 at Panki Power Plant

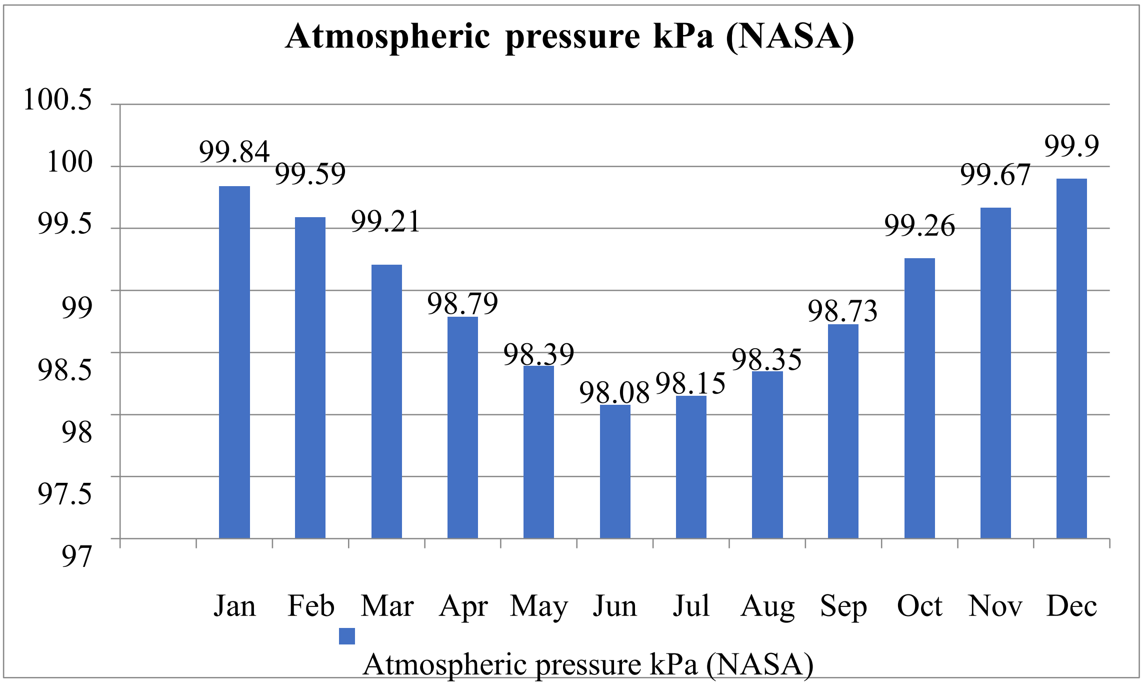


Fig. 5.12 Atmospheric pressure kPa (NASA) for the Year 2013 at Panki Power Plant

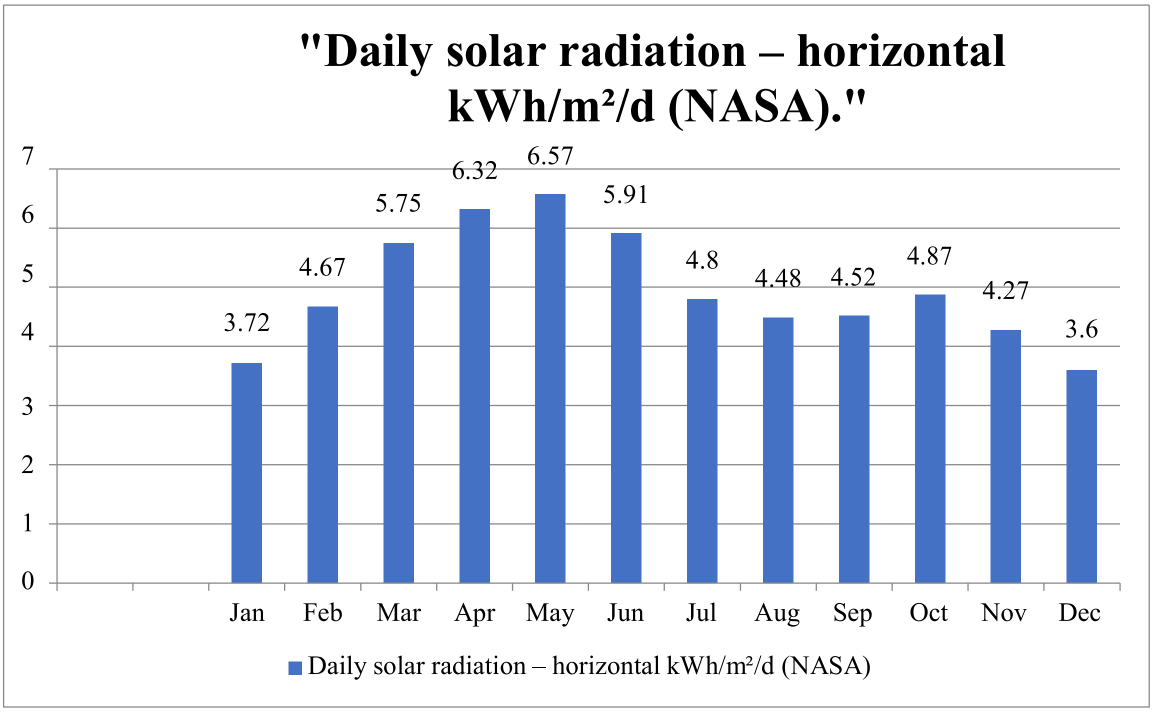


Fig. 5.13 –Daily solar radiation–horizontal kWh/m²/d (NASA)‖ for the Year 2013 at Panki Power Plant

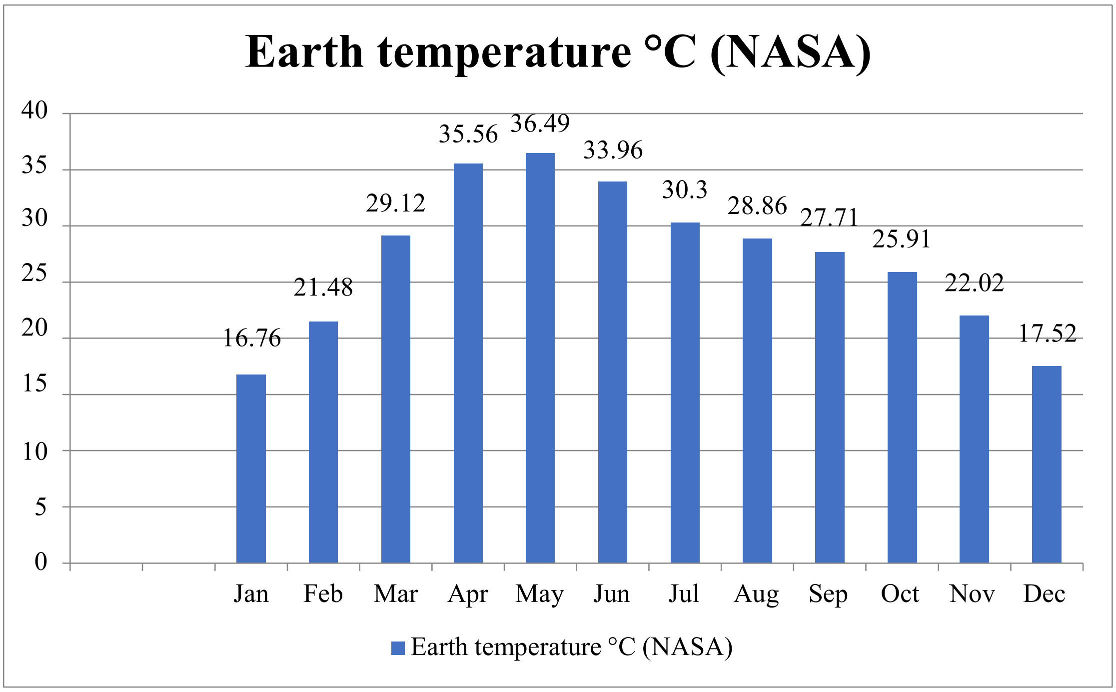


Fig. 5.14 Earth temperature °C (NASA) for the Year 2013 at Panki Power Plant

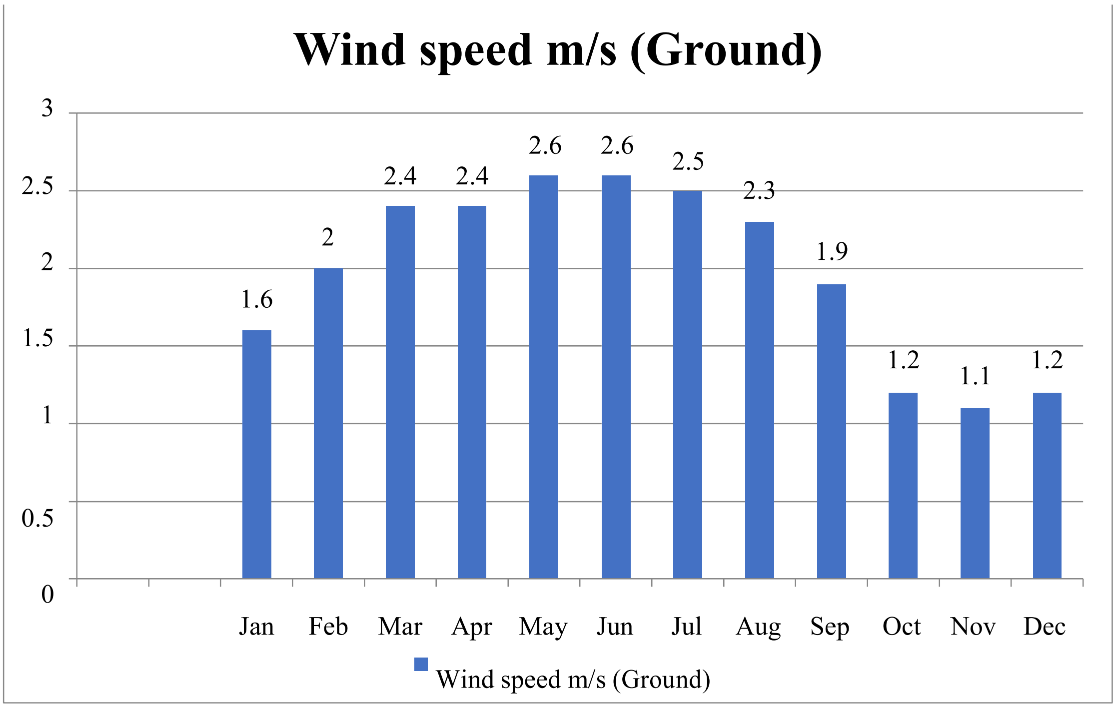


Fig. 5.15 Wind speed m/s (Ground) for the Year 2013 at Panki Power Plant

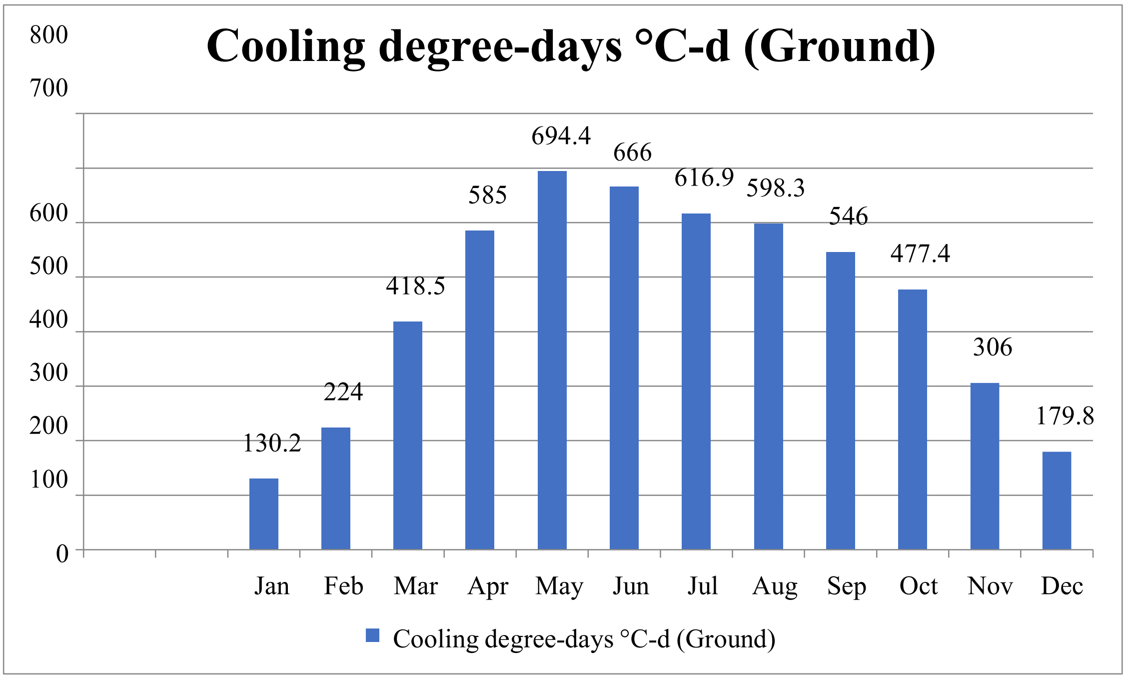


Fig. 5.16 –Cooling degree-days °C-d (Ground)‖ for the Year 2013 at Panki Power Plant

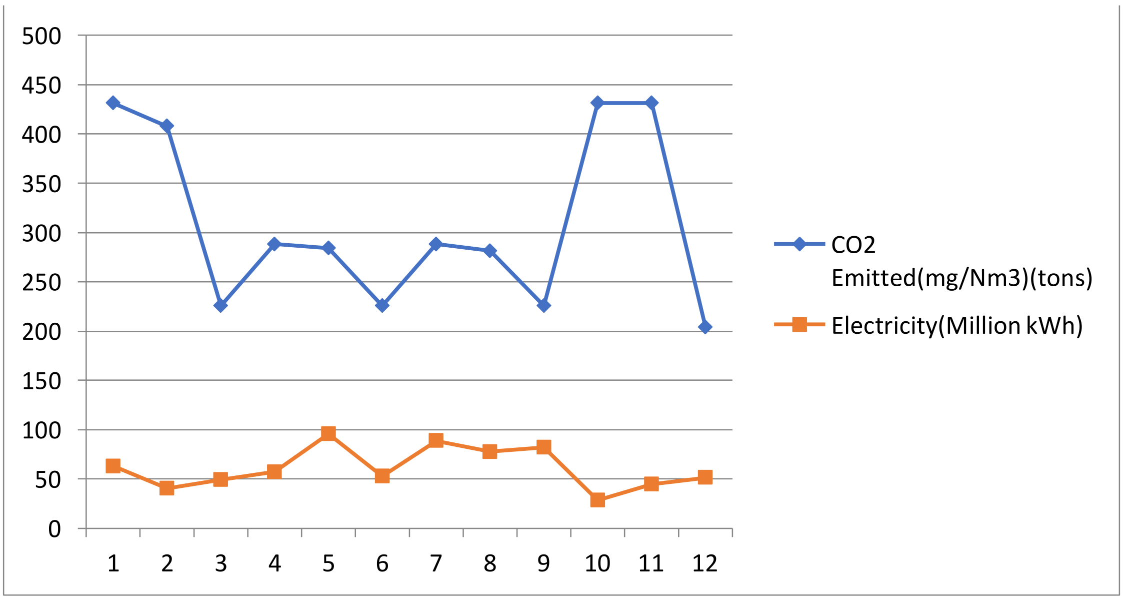


Fig. 5.17 Relationship between the $CO_2$ Emitted (mg/Nm3)(K tones) and Electricity(Million kWh)

## 5.4 PROBLEM FORMULATION FOR CARBON DIOXIDE ($CO_2$) REDUCTION

In this section, the problem formulation for $CO_2$ emission reduction is mentioned by considering the thermal power plant at Panki (Kanpur) as a case study. ―RETScreen‖ software is used for project analysis and GHG emission from Panki thermal power station. Fig 5.20 shows the map with mission vicinity and regional local weather knowledge vicinity with ―RETScreen‖ analysis. Fig 5.21 presents a proposal involving the CO2 emission with gasoline consumption and electrical energy generation. Fig 5.22 suggests the relation of CO2 emission with coal and oil consumption [2].

"RETScreen" software is applied to evaluate the greenhouse gas emissions from coal primarily based thermal electricity station of NTPC organized Thermal Power Plant at Panki, Kanpur. GHG emission for the Panki strength plant is calculated by the equation [42].

$$GHG\ emission\ per\ unit\ electricity\ production = \sum_{i=1}^{n}\left[\frac{GHGemission}{\sum_{i=1}^{n} electricityproduction}\right] \qquad (5.4)$$

Where I represent each individual electricity unit in the database GHG emissions- calculated for each plant in $CO_2$eq

Electricity production- calculated for each plant/unit is measured in GWh [42-43].

## 5.5 IMPLEMENTATION USING RETSCREEN

In this section, implementation of the proposed scheme is carried out by integrating solar energy along with coal and diesel. The results obtained are finally analyzed in terms of the analytical approach. During the implementation of the proposed scheme, RETScreen software is used. –RETScreen‖ is a precise a modern software tool to assess greenhouse gas emission reduction, lifecycle prices, energy production evaluation. The GHG evaluation has been accomplished using the Clean Energy Project Analysis in –RETScreen‖ software device. Energy to the grid is the array electricity decreased with the aid of inverter losses. Energy added to the grid can be decided by the following two equations [370].

$$E_g = E_A * \eta_{inv} \quad (5.5)$$

$$E_d = E_g * \eta_{ab} \quad (5.6)$$

Where $E_g$, $E_A$, $E_d$, and are energy available to the grid, energy produced by array, energy delivered to the grid, inverter efficiency, and PV energy absorption rate, respectively.

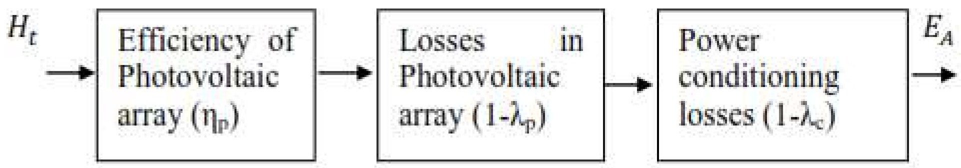


Fig. 5.18 Flow chart of Photovoltaic array model

The average array efficiency ($\eta_p$) depends on the average module temperature Tc as [28].

$$\eta_p = \eta_r [1 - \beta_p (T_c - T_r)] \quad (5.7)$$

Where $\beta_p$ is the temperature coefficient for PV type module efficiency, and $\eta_r$ is the module efficiency at reference temperature Tr. Tc depends on mean monthly ambient temperature Ta can be determined by [370]

$$Tc - Ta = [219 + (832 * Kt)] * \left(\frac{T_n - 20}{800}\right) \quad (5.8)$$

Where Tn is normal operating cell temperature, and it is the monthly cleanness index. For standard technologies following values can be assumed as in Table 5.2. GHG emission in terms of equivalent $CO_2$ for the Panki power plant is calculated by the following equation with data given in Table 5.5 [372].

$$GHG_{Fuel_i} = G_{CO2} + G_{CH4} * 21 + G_{N2O} * 310 \left(\frac{0.0036}{\eta_{Fuel}(1 - J_{T-D})}\right) \quad (5.9)$$

$$GHG_{Coal} = 1.069, \quad GHG_{Diesel} = 0.975, \quad GHG_{Solar} = 0$$

Table 5.5 represents $CO_2$ emission with fuel consumption in the present case of the Panki Power plant. Table 5.6 represents $CO_2$ emission with fuel consumption in the proposed case of the Panki Power plant. Fig. 5.21 shows the fuel Type relationship for Coal and Diesel for the Present case of the Panki (Kanpur) Power plant to demonstrate the $CO_{2eq}$ emission. Fig 5.22 represents $CO_2$ emission with fuel consumption and electricity generation in the present case. As discussed in the previous section about the proposed methodology, we have integrated solar with coal and diesel. Results using RETScreen are analyzed after integration of solar along with coal and diesel, as reported in Table 5.6.

Table 5.5 $CO_2$ emission with fuel consumption of Panki (Kanpur) Power plant

| Fuel Type | Coal | Diesel |
|---|---|---|
| Fuel Participation (%) | 92.4 | 7.6 |
| GCO2 (Kg/GJ) | 94.6 | 74.1 |
| GCH4(Kg/GJ) | 0.002 | 0.002 |
| GN2O (Kg/GJ) | 0.003 | 0.002 |
| ηFuel (%) | 35 | 30 |
| J T-D. (%) | 8 | 8 |
| GHGFuel (tCO2/MWh) | 1.069 | 0.975 |

$$Ceq = \frac{92.4}{100} * 1.069 + \frac{7.6}{100} * 0.975 = 1.0618 \frac{tCO2}{MWh}$$

Fig. 5.19 Fuel Type relationship for Coal and Diesel for Present case of Panki (Kanpur) Power plant

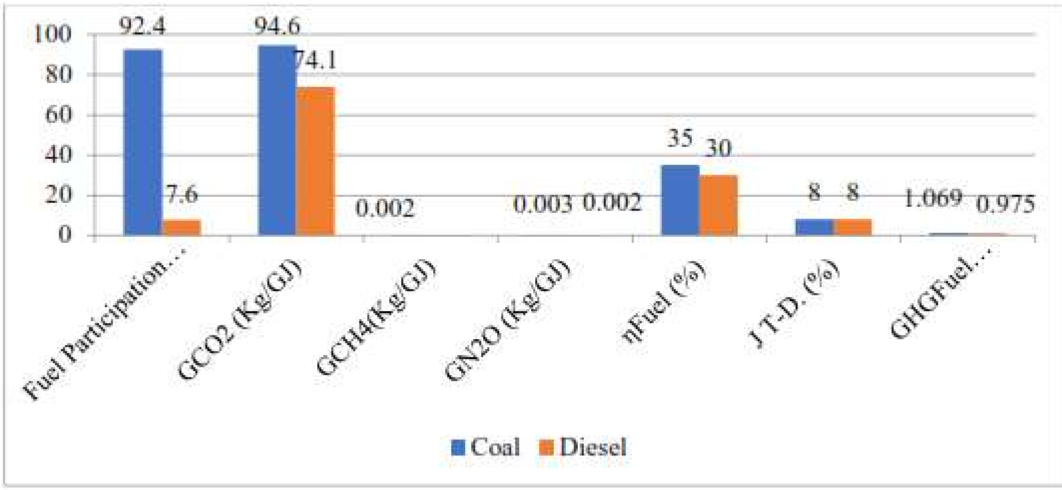

Table 5.6 Proposed case of system integration

| Fuel Type | Coal | Diesel | Solar |
|---|---|---|---|
| Fuel Participation % | 69.77 | 7.6 | 22.63 |
| GCO2 (Kg/GJ) | 94.6 | 74.1 | 0 |
| GCH4(Kg/GJ) | 0.002 | 0.002 | 0 |
| GN2O(Kg/GJ) | 0.003 | 0.002 | 0 |
| ηFuel (%) | 35 | 30 | 19 – 44 |
| J T-D (%) | 8 | 8 | 8 |
| GHG Fuel (tCO2/MWh) | 1.069 | 0.975 | 0 |

For a better visibility, we have also shown the results using RETScreen after integration of solar along with coal and diesel in Fig. 6.23. Now the calculation for the $CO_2$ emission is carried for the estimated data taken for the period of 2012 to 2032 using RETScreen Software. We have integrated solar energy along with coal and diesel to understand the change in $CO_2$ emission. Calculation using the proposed scheme is shown below:

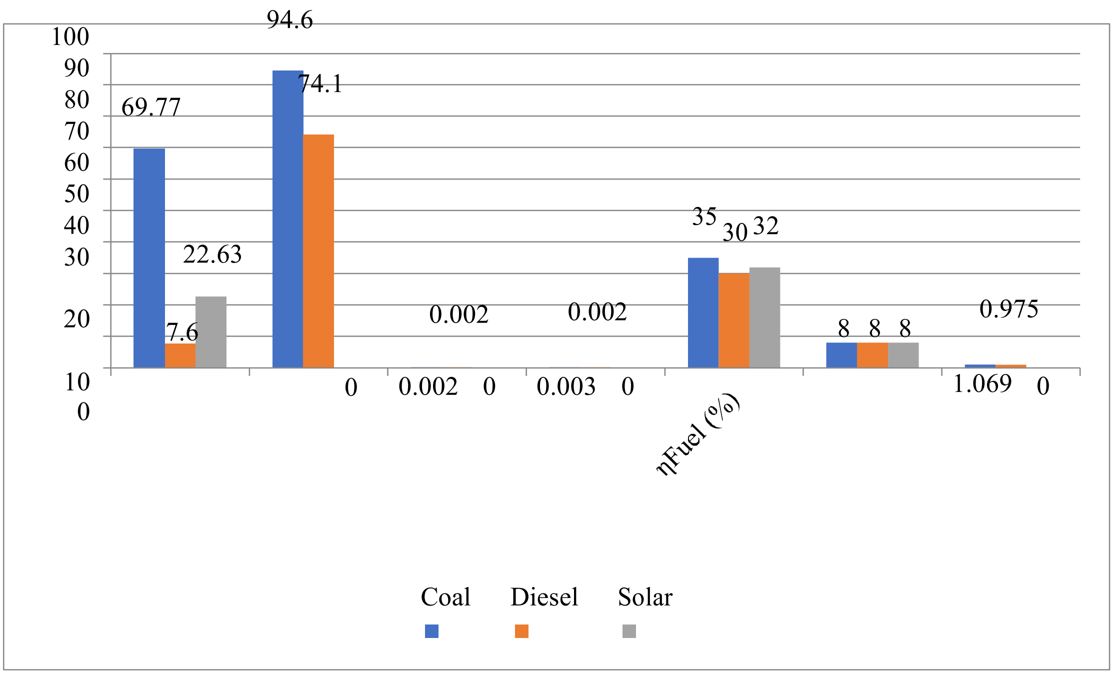


Fig. 5.20 Proposed case of system integration using Solar along with Coal and Diesel

$CO_2$ emitted for the period of 2012 – 2032 [355].

Time period (Hrs) = 20*12*30*24=172800 Hrs

Here based on the formula for the data shown in Table 6.5, $C_{eq}$ is calculated as 1.0618.

$$Ceq = \frac{92.4}{100} * 1.069 + \frac{7.6}{100} * 0.975 = 1.0618 \frac{tCO2}{MWh}$$

Now Ceq is taken as 1.0618 for calculation of $CO_2$ emitted for 100 MU and 172800 Hrs time period.

$CO_2$ emitted for 100 MU in time period with conventional system = 1.0618*100*172800= 18347904 tCO2

So, without using the proposed scheme, the calculated value of $CO_2$ emission is 18347904 $tCO_2$.Now we will calculate the $CO_2$ emission using an integrated approach by using solar energy. Here, the same time period is considered for analysis and 100MU for the proposed scheme. Here based on the formula for the data shown in Table 6.6, $C_{eq}$ is calculated as 0.8144.

$$Ceq = \frac{69.77}{100} * 1.069 + \frac{7.6}{100} * 0.975 + \frac{22.63}{100} * 0 = .8144 \frac{tCO2}{MWh}$$

Now Ceq is taken as 0.8144 for calculation of $CO_2$ emitted for 100 MU and 172800 Hrs time period using the integrated approach by Solar system in the proposed case. $CO_2$ emitted for 100 MU in the time period with the proposed case

= 0.8144*100*172800

= 14072832 tCO2

Now, we have evaluated the percentage change of $CO_2$ emission in the proposed case using the integrated approach by considering the Solar system in RETScreen Software.

Reduction in $CO_2$ emission with proposed case (%)

$$=\left(\frac{18347904 - 14072832}{18347904}\right) * 100$$

= 23.30%

So, we have achieved a tremendous improvement with 23.30% in terms of $CO_2$ reduction using the proposed approach by integrating the solar system along with the thermal energy system.

## 5.6 RESULT AND DISCUSSION

The desired result of the integrated solar PV with the coal-based thermal power plant is accomplished with a reduction of 23.30% in terms of $CO_2$ emission. $CO_2$ emitted for 100 MU in 172800 Hrs time period with conventional system is calculated as 18347904 $tCO_2$ and $CO_2$ emitted for 100 MU for the same time period with the proposed case is calculated as 14072832 $tCO_2$. As a result, the following research outcomes are identified in this chapter based on the proposed scheme experimentation.

1. Our proposed scheme may be considered as one of the supplement research to fulfill the demand of developing countries' requirements to reduce carbon dioxide emission.
2. Proposed work can be considered as a guideline and benchmark to make policies by Indian authorities for Low-carbon Economy.
3. As we have identified that there is scope for reduction in carbon dioxide emission, more research must be initiated in the same direction by integrating different combinations of RES systems along with the existing energy generation systems in India.
4. Renewable Energy Sources are less harmful to humans and the environment both; the eco-friendly system must be proposed in collaboration with environmental and electrical engineers for better analysis of RES-based integrated solutions in real-life implementation.
5. Proposed solution may be a low-cost, sustainable and eco-friendly solution to control the emission of GHG in the coming time.

Finally, it is explored that there is a strong need to expand the collaboration in terms of strength to integrate the renewable energy systems with current energy systems for future improvements. In the future, integrated approaches may also help in generating better efficiency along with keeping the environment safe. Governments have to boom the global collaboration for R&D efforts in renewable and green energy tasks for controlling GHG emission in the real-life scene.

# CHAPTER 6
# SUMMARY OF FINDINGS AND FUTURE DIRECTIONS FOR RESEARCH

## 6.1 SUMMARY

Achieving sustainable development goals and sustainable energy for all will be a challenging task on global warming and the local scales. Government and practitioners will need analytical tools to support their energy access. An attempt has been made in this thesis to develop a method for comparing electrical power generation options together with a series of guidelines for funding allocation and appropriate technology selection for energy access. The objective of this thesis is to develop a power generation system approach to eco-friendly energy systems. To protect the environment, we need to develop a more eco-friendly system. Therefore, the distributive nature of the future energy systems will be the need of coming years. Also, some new approaches for power generation may be adopted through renewable energy. The new approach will reduce the $CO_2$ emissions and better reliability in frequency stabilization and restoration may be achieved. Energy access planning needs appropriate metrics. Those are needed to understand the current energy access status and the success of past programs to plan future energy access plans.

The eco-friendly approach will help in understanding future systems development. This approach offers a RETScreen where new technologies can be used to manage the system better. This is beneficial in electrical power generation. Strategies to manage these systems can be explored through an eco-friendly approach.

India is classified as an "emerging market" by the World Bank. The demand for additional electrical energy is growing in tandem with the growth of the economy. Demand for transportation fuels is also growing. Currently, two-thirds of the generation capacity is dependent on fossil fuels, while the remaining third is based on hydropower. Nonetheless, India has been endowed by nature with vast resources of renewable energy in the form of solar, wind, biomass, and small hydro, among others. Indeed, the technological ability of these renewable energy sources exceeds the installed generation capacity currently available. India is committed to the advancement of clean energy technologies. This helps us expand the use of renewable energy throughout the country to meet the increasing demand of rural residents.

Renewable energy products and services are being deployed in India in response to the country's desire to reduce its reliance on imported energy. India was ranked first in a study by Deutsche Bank that ranked countries according to their attractiveness for outsourcing and offshoring. India is a developing country that is providing environmentally sustainable services to millions of people. India is endowed with over 150,000 MW of renewable energy potential, but renewable energy only accounts for a small fraction of installed capacity. India's renewable energy sector has the potential to create high-quality employment for experts. Extending the electric power grid between all states and neighboring nations can boost international trade and cooperation on the subcontinent and meet electricity demand.

Eco-friendly system approaches provide clean and safe energy resources as compared to conventional energy. It requires less time for equipment erection and commissioning. It has low operating costs due to the non-requirement of fuel and low maintenance cost. We can also diminish the pollution of the environment by producing the electricity necessary to fuel our home with the help of eco-friendly methods. And a pollution-free atmosphere is the most precious heritage that we can leave to our next generations. Globalization has been playing a major role in both low and high carbon growth since it started. International trade and investment are expanding global production, raising greenhouse gas emissions, but at the same time, they have also helped to promote the low-carbon economy. The increasingly global integration of economy and market for products such as solar and wind power components have helped to reduce their costs dramatically.

Renewable energy sources are less reliable because of the dependence of renewable energy on the weather for power sources. Solar cells need clear skies and sunshine to convert heat into electricity. Hydroelectricity needs rain for dams to provide adequate water head. Wind turbines require speedy wind to run the blades. The availability of these sources depends upon suitable weather. If the weather is not favorable at any time, the availability of electricity may disrupt. The power production from these renewable energy resources is unpredictable and inconsistent.

Moreover, the cost of renewable energy technology is more than traditional fossil fuel because of the underdevelopment technology. The efficiency of the systems we build is not very high. The solar panel has only about 30-40% of efficiency in the most advanced system. So a lot of costs are involved in setting it up.

It is proposed that each government office install biomass, the solar, wind, and other renewable energy generation systems. Additional national-level organizations could be created to raise public awareness about renewable energy. Financial assistance and sponsorship can be given for the research and development of renewable energy technologies. Both urban residential and commercial establishments should be required to install solar water heating systems. The use of biofuels and other environmentally friendly fuels in automobiles can be promoted. Loans and incentives for renewable energy enterprise establishment should be manageable. Incentives for buyers and manufacturers of renewable energy equipment should be produced, especially in rural areas. Energy crop cultivation on marginal and degraded land can be encouraged.

All options for establishing an independent renewable energy power plant should be considered. Energy-efficient low-wattage/high-luminous-intensity lamps (CFL/LED) can be used. It is important to encourage equipment with a high power factor. Electrical equipment should be serviced and maintained regularly. To mitigate energy losses, intelligent power factor correctors should be encouraged.

## 6.2 FUTURE SCOPE OF RESEARCH WORK

Due to the complex existence of ecosystems, they do not always follow a linear succession course. They are constantly evolving, sometimes rapidly and sometimes slowly. An ecosystem's area can range greatly from microscopic to massive. A single tree has no impact on the forest ecosystem classification but is extremely important to the species that live in and on it. There is an immediate need to move from fossil fuel-based energy systems to renewable resources to reduce dependence on depleting fossil fuel reserves and mitigate climate change caused by Carbon Dioxide (CO2). Additionally, renewable energy can generate a large number of job opportunities at all levels, especially in rural areas. By providing a realistic image of India's vast renewable energy potential, it is possible to attract foreign investment and usher in a Green Energy Revolution.

The Government of India has set an ambitious goal of installing 175 GW of renewable energy capacity by 2022, including 100 GW of solar, 60 GW of wind, 10 GW of bio-energy, and 5 GW small hydropower. As of March 2018, a total of 70 GW of renewable energy capacity had been installed, including 34.04 GW of wind energy, 21.65 GW of solar energy, 9.5 GW of bioenergy, and 4.48 GW of small hydroelectricity. With 70 GW of installed renewable energy capacity, renewable energy accounts for more than 20% of the country's total installed capacity. There is every reason to believe that the government's renewable energy generation reaching 40% of total installed capacity in the country by 2032 will be met.

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