A STUDY ON

Renewable Energy in India: Current Trends And Future prospects.

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DEPARTMENT OF PHYSICS

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IN PHYSICS

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I wish her good luck and bright future.

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This is to certify, that the dissertation work submitted by me, entitled, A Study On Renewable energy in India: Current trends and future prospects. submitted to the Department of Physics, Integral University, Lucknow in partial fulfillment of requirement for the award of Master of Science in physics is an outcome of my independent and original work. This project work has not been submitted elsewhere for any other degree or diploma.

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FAIZ AKRAM

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CHAPTER 1

1.1 Introduction

India has a limited source of fossil fuel energy and indiscriminate use of energy can create an energy crisis in the future. Today India has become the most populated country in the world. The increasing population growth leading to uncontrolled development which increased the demand for energy and along with it there has also been a rise environmental pollution and climate change.

To meet this demand and to address climate change concerns, India has been making efforts to increase the share of renewable energy.

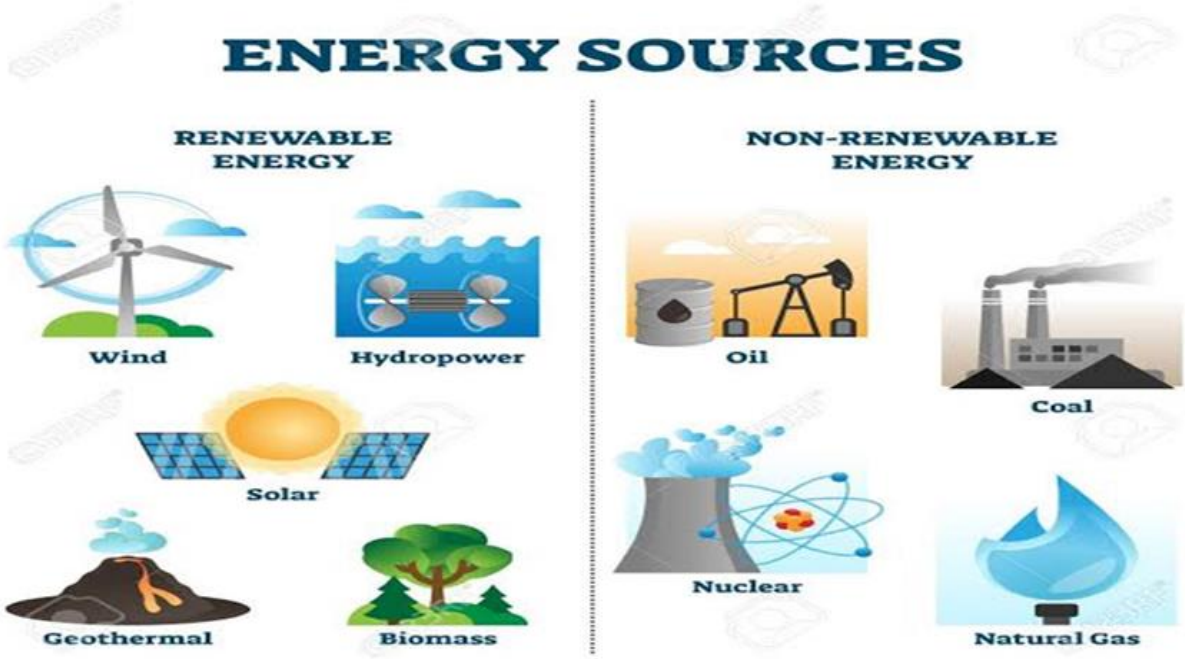


Fig 1.1 Renewable and non-renewable energy resources.

Renewable energy sources such as solar, wind, hydropower, biomass, and geothermal are abundant in India, and the government has taken several initiatives to tap into these sources. India's National Action Plan on Climate Change (NAPCC) outlines a target of achieving 175 gigawatts (GW) of renewable energy capacity by 2022, including 100 GW from solar, 60 GW from wind, 10 GW from bioenergy, and 5 GW from small hydropower.

India has made significant progress towards achieving its renewable energy targets. As of March 2021, India's installed renewable energy capacity stood at 94.4 GW, which is about 25% of its total installed power capacity. Solar energy accounts for the largest share of renewable energy capacity, followed by wind energy.

The government has implemented several policies and schemes to encourage the adoption of renewable energy in India, such as the National Solar Mission, which aims to promote the development of solar power in the country, and the Renewable Purchase Obligation,

which mandates certain entities to purchase a certain percentage of their power from renewable sources.

1.2 Need and significance of study

Studying renewable energy in India is significant for fostering energy security, addressing environmental concerns, promoting sustainable development, unlocking economic opportunities, expanding energy access, driving rural development, and informing policy decisions. By investing in renewable energy research and development, India can transition to a low-carbon and sustainable energy futureThis study has crucial importance due to several reasons:

Energy Security: India is heavily dependent on fossil fuel imports, which makes the country vulnerable to fluctuations in global energy prices and geopolitical tensions. Investing in renewable energy sources such as solar, wind, and hydropower can enhance energy security by reducing reliance on imported fuels.

Environmental Benefits: Renewable energy sources have significantly lower carbon emissions compared to fossil fuels. India, being one of the world's largest greenhouse gas emitters, faces severe environmental challenges such as air pollution and climate change. Shifting towards renewables can mitigate these issues, improve air quality, and contribute to global efforts to combat climate change.

Sustainable Development: Renewable energy aligns with the principles of sustainable development. It offers a long-term solution for meeting energy demands while minimizing environmental impact. By investing in renewables, India can achieve sustainable growth, ensuring that future generations have access to clean and reliable energy sources.

Economic Opportunities: The renewable energy sector presents substantial economic opportunities for India. It can drive job creation, attract investments, and foster technological innovation. Building a robust renewable energy industry can enhance domestic manufacturing capabilities and create a skilled workforce, leading to economic growth and reduced dependency on foreign technologies.

Energy Access: A significant portion of India's population still lacks access to electricity. Expanding renewable energy infrastructure, particularly in rural and remote areas, can provide clean and affordable energy solutions to millions of people. Renewable energy projects can contribute to achieving the goal of universal energy access, empowering communities and improving their quality of life.

Rural Development: India has vast agricultural land and a substantial rural population. Deploying renewable energy technologies in rural areas can facilitate decentralized power generation, reducing transmission losses and improving energy reliability. It can also

enable income generation opportunities through energy entrepreneurship, such as setting up small-scale solar power plants or biomass projects.

Policy Imperatives: The Indian government has set ambitious renewable energy targets to increase the share of renewables in the energy mix. Studying renewable energy helps policymakers understand the challenges, identify effective policy instruments, and develop strategies to achieve these targets. It also supports the formulation of regulations and incentives to promote renewable energy adoption.

The present study aim to gives a detailed analytical approach towards renewable energy status, resources, future prospects and government policies towards renewable energy and sustainable development.

1.2 Objectives:

1. To Study the various renewable energy technologies and their share in total energy generation.
2. To study the comparative growth of renewable to non-renewable energy resources in Indian power sector.
3. To assess the advantages of using renewable energy and its increasing demand in various sectors.
4. To keep an eye on the current trends, and government policies to make speculations about the future of renewable energy.

CHAPTER 2

2.1 Literature Review:

1. Technological Advances in Renewable Energy: Kumar, A., & Bhattacharya, S. (2020). Technological advances and innovation in renewable energy sector.This review paper discusses recent technological advancements and innovations in the renewable energy sector in India. It covers topics such as solar photovoltaics, wind turbines, energy storage systems, and grid integration, providing insights into the state-of-the-art technologies and their potential impact on the Indian energy landscape.

2. Present status and future scope of renewable energies in India: R V Patel in 2019. He gave suggestion to production of energy from all the renewable energy resources with respect to their potential to satisfy the endless energy demand and also for the sustainable development.

3. Renewable Energy Sources, Sustainability Issues and Climate Change Mitigation" by Mohamed El Hadi Cherif and Abdelhamid Djebbar (Renewable and Sustainable Energy Reviews, 2016): This review provides an overview of renewable energy sources, including solar, wind, hydro, geothermal, and biomass. It also discusses the sustainability issues related to renewable energy, such as land use, water use, and biodiversity impacts, as well as the role of renewable energy in mitigating climate change.

4. State-of-the-Art of Concentrated Solar Power (CSP) Technologies" by Chao Wang, Yulong Ding, and Jianhua Zhao (Renewable and Sustainable Energy Reviews, 2019): This review focuses specifically on concentrated solar power (CSP) technologies, which use mirrors or lenses to concentrate sunlight onto a small area to generate heat, which can then be used to generate electricity. The review covers the different types of CSP technologies, their performance, and their potential for cost reduction.

5.Wind Energy Technologies" by S. S. Mishra, R. K. Das, and P. C. Panda (Renewable and Sustainable Energy Reviews, 2017): This review provides an overview of wind energy technologies, including horizontal-axis and vertical-axis wind turbines, offshore wind turbines, and small wind turbines. It also discusses the challenges associated with integrating wind energy into the grid, such as intermittency and variability.

6.f **Photovoltaic Solar Energy Technology"** by M. A. Green, K. Emery, Y. Hishikawa, and W. Warta (Energy and Environmental Science, 2018): This review covers the technology and performance of photovoltaic solar energy systems, which convert sunlight directly into electricity using semiconductor materials. The review includes a discussion of the different types of solar cells, such as crystalline silicon, thin-film, and organic, as well as their efficiency and potential for cost reduction.

7. Biomass Energy Technologies: Risks and Opportunities" by Mario A. Rosato and Mirella L. Di Lorenzo (Renewable and Sustainable Energy Reviews, 2017): This review provides an overview of biomass energy technologies, which use organic matter such as wood, crop residues, and municipal waste to generate heat and electricity. The review covers the different types of biomass conversion technologies, their efficiency, and their potential for sustainability and environmental impacts.

8. "Recent advancement in power system" by Dharani Kumar naren 14 feb. 2022.India is a country having a population of over 1.38 billion with a population share of over 17.7% of the global population. It is facing a massive challenge in providing consumers with sufficient energy supplies at an affordable cost. In the present scenario, the power sector is like a commodity market, electricity must be economical and reliable.

According to Majid and Kumar The primary objective for deploying renewable energy in India is to advance economic development, improve energy security, improve access to energy, and mitigate climate change. Sustainable development is possible by use of sustainable energy and by ensuring access to affordable, reliable, sustainable, and modern energy for citizens. Strong government support and the increasingly opportune economic situation have pushed India to be one of the top leaders in the world's most attractive renewable energy markets. The government has designed policies, programs, and a liberal environment to attract foreign investments to ramp up the country in the renewable energy market at a rapid rate. It is anticipated that the renewable energy sector can create a large number of domestic jobs over the following years.

9. Renewable Energy Potential in India: Jhariya, D., & Tiwari, G. N. (2020). Renewable energy potential and prospects in India: A review. Renewable and Sustainable Energy Reviews, 131, 109968. This review examines the renewable energy potential of India, considering solar, wind, biomass, and hydropower resources. It provides insights into the challenges and opportunities associated with the harnessing of renewable energy sources in the Indian context.

11. Policy and Regulatory Framework: Balachandra, P., & Ravindranath, D. (2019). Renewable energy policies in India: A review. Renewable and Sustainable Energy Reviews, 101, 143-154.

This study provides an overview of the policy and regulatory framework governing renewable energy in India. It analyzes the effectiveness of various policies, incentives, and initiatives taken by the government to promote renewable energy deployment and highlights the gaps and challenges that need to be addressed.

12. Socio-economic Impacts of Renewable Energy: Arora, A., & Bansal, V. (2020). Socio-economic impact of renewable energy deployment in India: A systematic review. Renewable and Sustainable Energy Reviews, 120, 109676.

This systematic review examines the socio-economic impacts of renewable energy deployment in India. It explores the effects on employment generation, rural development, energy access, and community participation, shedding light on the broader implications of renewable energy adoption in the Indian context.

13. Challenges and Opportunities: Suman, A., & Tiwari, G. N. (2021). Challenges and opportunities in the Indian renewable energy sector: A comprehensive review. Renewable Energy. This comprehensive review article presents an overview of the challenges and opportunities faced by the Indian renewable energy sector. It covers aspects such as financing, grid integration, technological limitations, policy implementation, and public awareness, providing insights into the key factors influencing the growth of renewable energy in India.

CHAPTER-3

3.1 Methodology

The objective of this study is to comprehensively analyze the status, potential, and challenges of renewable energy in India. The methodology employed here incorporates a combination of quantitative and qualitative approaches to gather and analyze relevant data. This methodology outlines the step-by-step process to conduct the study effectively.

The study begins by conducting thorough literature review to gain a comprehensive understanding of the existing knowledge, research, and policies related to renewable energy in India. Review academic papers, reports, government publications, and relevant studies to establish a foundation for the study.

3.3 Data Collection:

Identify and collect secondary data relevant to the study. Secondary data can be collected from government databases, industry reports, research papers, and other credible sources. Ensure the data collected is reliable, up-to-date, and covers various aspects of renewable energy, such as installed capacity, generation, policies, technologies, economics, and environmental impact.

3.4 Data Analysis:

Perform a quantitative and qualitative analysis of the collected data to identify trends, patterns, and relationships. This analysis will provide insights into the current state and potential of renewable energy in India.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Energy Status in India:

According to the recent reports, India has become the most populous country in the world. And is globally ranked 3rd in consumption of energy. In terms of installed capacity and investment in renewable energy. India is the third-largest energy consumer in the world, behind China and the United States. The country's energy mix is dominated by coal, which accounts for about 237,279 MW and % of total share is 57.7%. While the same total renewable energy share is 178,790 MW with percentage of share.

Fossil fuel energy	237,269 MW	57.7%
Renewable energy	178,790 MW	42.3%
Total installed capacity	**416,059 MW**	**100%**

Table 4.1

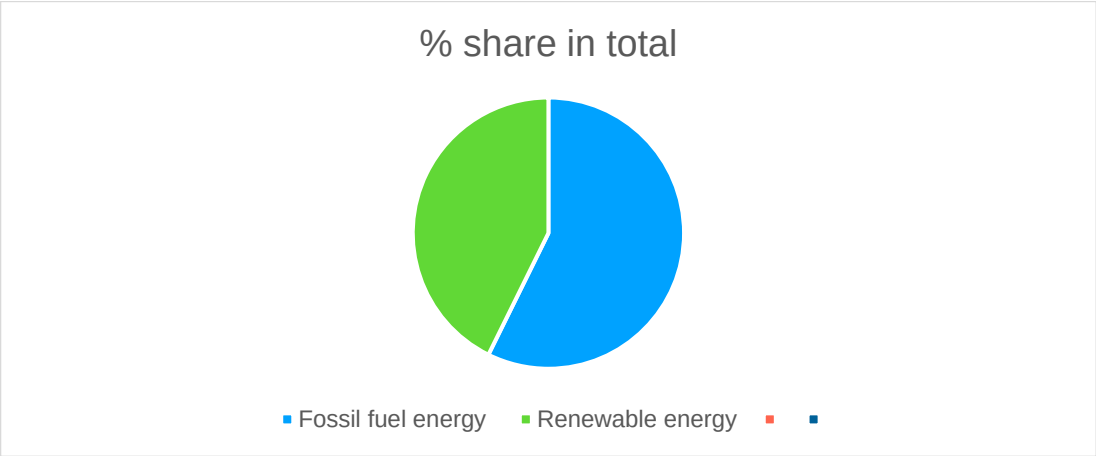


Figure 1Installed Generation Capacity as on 31/03/2023

Source- Ministry of power (Government of India).

4.2 Why we need to switch to renewable energy:

For thousands of years, we have been burning fossil fuels to get energy. Burning of coal, petroleum and other fossil fuel producing Environmental pollution and climate change. The need to switch to renewable energy has become increasingly urgent due to several pressing environmental, economic, and social factors Apart from this, there are many such reasons from which we come to know that we should switch from non-renewable energy to renewable energy. Here are some key reasons why transitioning to renewable energy sources is crucial.

1. Long term affordability
2. Better for eco system
3. Inexhaustible energy sources
4. Greater accessibility
5. Energy security

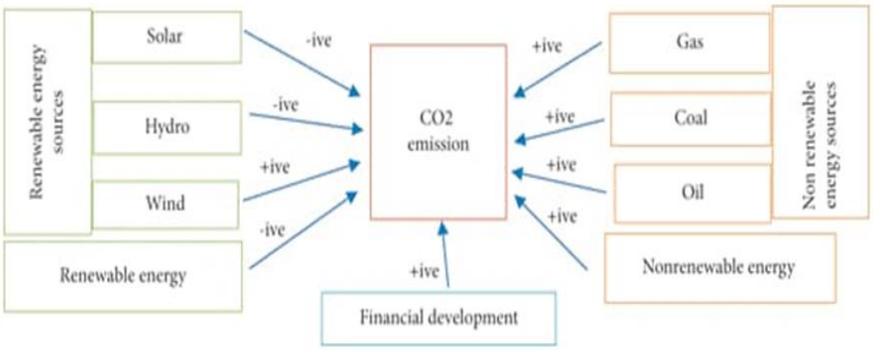


Fig 4.3 Co_2 emission from different energy sources.

Another problem with fossil fuel Energy resources is that there is limited quantity available which will end after the time. The answer to all problems is shifting towards renewable Energy resources

4.4 Renewable Energy Resources in India

Renewable energy is energy that is generated from natural resources that are replenished constantly, such as sunlight, wind, rain, tides, and geothermal heat

The International Energy Agency defines renewable energy saying.

‘‘Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.’’.

India is determined to becoming one of the world’s leading clean energy producers. The Government of India has already made several provisions, and established many agencies that will help it to achieve its goal.

Solar energy

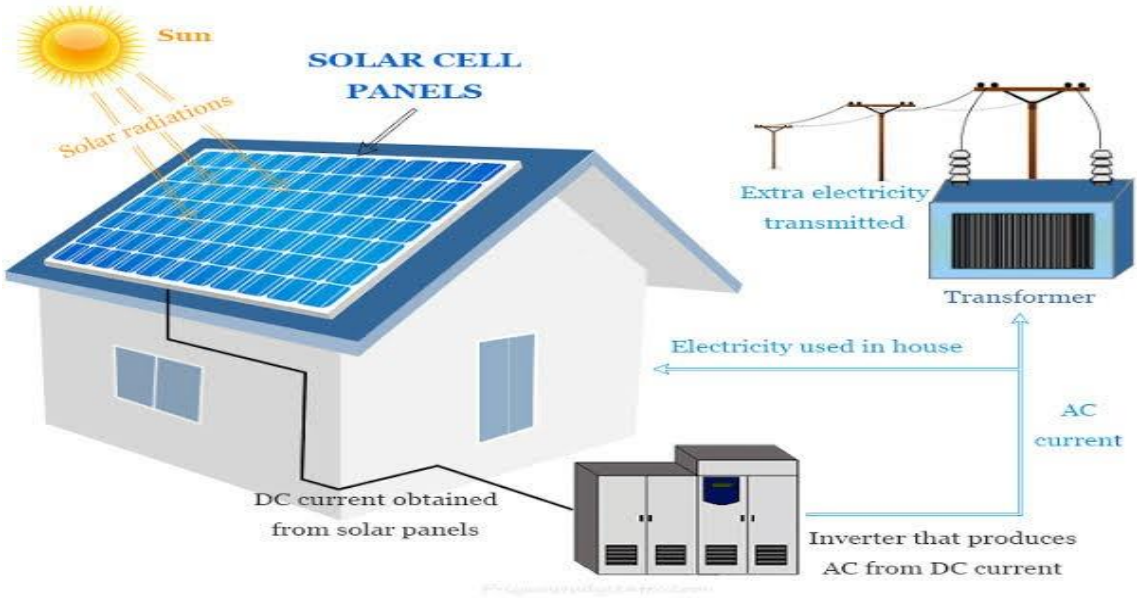


Figure 2transformation of solar energy into electrical energy

Solar energy is the most abundant permanent energy resource on earth and it is available for use in its direct (solar radiation) and indirect (wind, biomass, hydro, ocean, etc.) forms. Solar energy, experienced by us as heat and light, can be used through two routes: the thermal route uses the heat for water heating, cooking, drying, water purification, power generation, and other applica- tions; the photovoltaic route converts the light in solar energy into electricity, which can then be used for a number of purposes such as lighting, pumping, communications, and power supply in un electrified areas.

Solar energy conversion and photovoltaic cell

Solar energy conversion refers to the process of converting sunlight into usable forms of energy, such as electricity or heat. One of the key technologies used for solar energy conversion is the photovoltaic (PV) cell, also known as a solar cell.

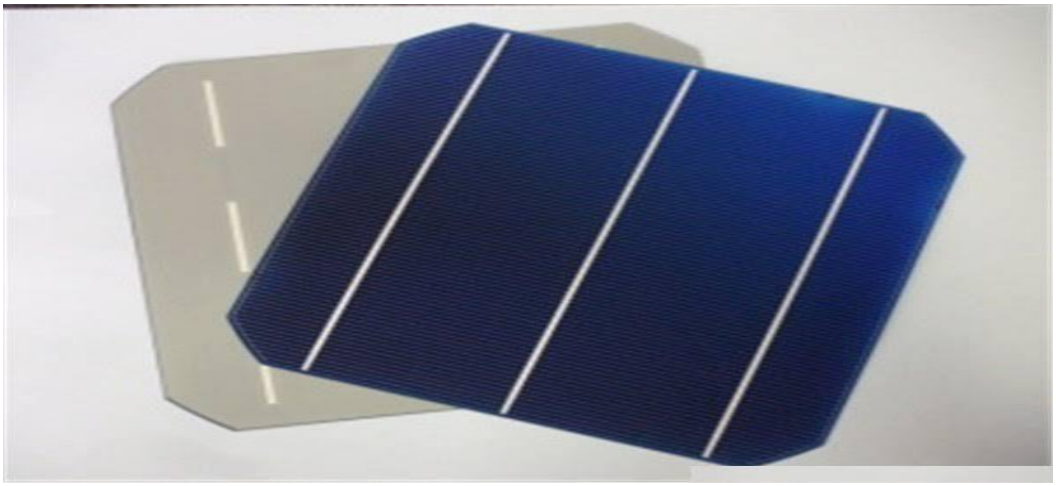


Figure 3 photovoltaic cell

Photovoltaic cells are devices that directly convert sunlight into electrical energy through the photovoltaic effect. They are typically made from semiconductor materials, such as silicon, which have the ability to generate an electric current when exposed to light. Here's a general overview of how a photovoltaic cell works.

Absorption of sunlight: Solar cells are typically made of semiconductor materials, such as silicon. When sunlight falls on the solar cell, it consists of photons (particles of light) that carry energy. The semiconductor material in the solar cell is designed to absorb photons from the sunlight.

Generation of electron-hole pairs: When a photon is absorbed by the semiconductor material, it transfers its energy to an electron in an atom of the material. This energy causes the electron to break free from its atom, leaving behind a "hole" or a positively charged space. The freed electron and the hole are referred to as an electron-hole pair.

Separation of charges: The electron-hole pair generated by the absorbed photon needs to be separated for electricity to be generated. This is achieved by the internal structure of the solar cell, which typically consists of two layers: the p-type (positively charged) layer and the n-type (negatively charged) layer. The junction between these two layers is called the p-n junction.

Electron flow: Due to the internal electric field created by the p-n junction, the freed electrons are pushed towards the n-type layer, while the holes are pushed towards the p-type layer. This creates a flow of electrons, known as a current, which can be harnessed as electricity.

Collection of current: Metal contacts placed on the top and bottom of the solar cell collect the current generated by the flow of electrons. The current can then be extracted from the solar cell and used to power electrical devices or stored in batteries.

Fig 4.6 Nagarjuna Sagar Dam and the 810 MW pumped storage hydroelectric power plant on the Krishna River.

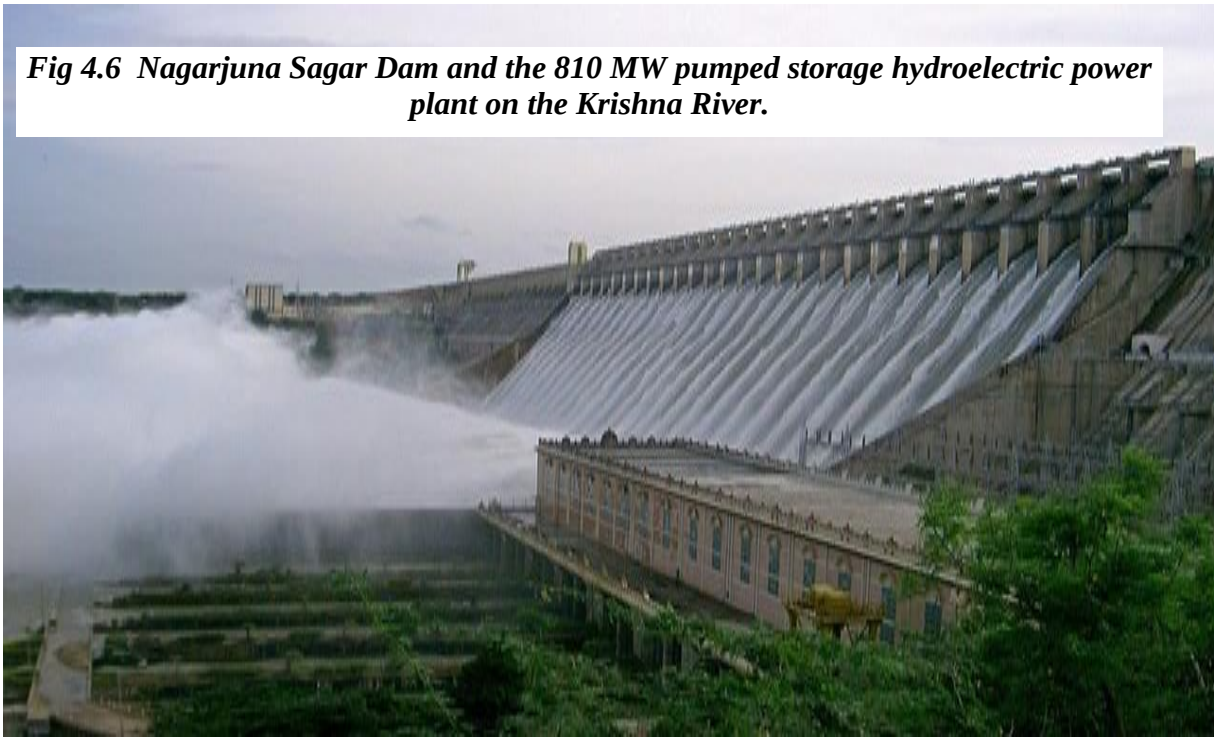


Fig 4.6 Nagarjuna Sagar Dam and the 810 MW pumped storage hydroelectric power plant on the Krishna River.

The efficiency of a solar cell refers to the amount of sunlight it can convert into usable electricity. Factors such as the material properties, design, and manufacturing processes affect the efficiency of a solar cell. Advances in technology aim to improve efficiency and reduce costs, making solar power more accessible.

By connecting multiple solar cells together, solar panels or modules are created, which can generate higher amounts of electricity for practical applications such as residential, commercial, and utility-scale solar power systems.

4.5 Hydro Energy

Hydro energy also known as hydroelectric power or hydropower, is a form of renewable energy derived from the gravitational force of flowing or falling water. It involves harnessing the energy of water in motion to generate electricity.

The basic principle behind hydro energy is the conversion of the potential energy of water at a higher elevation into kinetic energy as it falls or flows downhill. This kinetic energy is then used to rotate turbines, which drive generators to produce electricity. Hydroelectric power plants are typically constructed near rivers, dams, or other water sources with significant elevation differences. There are two primary types of hydroelectric power plants:

Impoundment Systems: These are the most common type of hydroelectric power plants. They involve the construction of dams to create reservoirs or impoundments. Water is

stored in the reservoir behind the dam and released through large pipes called penstocks. As the water flows through the penstocks, it drives turbines, which generate electricity.

Run-of-River Systems: Unlike impoundment systems, run-of-river power plants do not require large reservoirs. Instead, they use the natural flow of the river to generate electricity. A portion of the river's flow is diverted through a channel or a penstock, which drives the turbines. The water is then returned to the river downstream.

Hydro energy offers several advantages as a renewable energy source. It is a clean and sustainable form of energy, as water is continually replenished by natural processes such as rainfall and snowmelt. It produces minimal greenhouse gas emissions compared to fossil fuel-based power generation. Additionally, hydroelectric power plants provide flexibility in adjusting power output to meet fluctuating electricity demands.

We can say hydro energy plays a crucial role in global renewable energy production and has the potential for further development as a sustainable and reliable source of electricity.

4.6 Wind energy

Wind energy refers to the electrical power generated from harnessing the kinetic energy of the wind. It is a renewable source of energy that has been utilized for centuries, dating back

Fig 4.7 The largest wind farm of India in Muppandal, Tamil Nadu.

to the use of windmills for various purposes such as grinding grain and pumping water. However, in modern times, wind energy is predominantly harnessed through wind turbines to generate electricity on a large scale

Wind turbines are tall structures equipped with large blades, which rotate when exposed to the force of the wind. The rotating blades spin a generator, converting the kinetic energy of the wind into electrical energy. This electricity can be used to

power homes, businesses, and industries, or it can be integrated into the electrical grid for wider distribution.

The advantages of wind energy include its renewable nature, as wind is an abundant and inexhaustible resource. It is a clean form of energy production, as wind power does not emit greenhouse gases or other pollutants during operation, contributing to reduced carbon emissions and mitigating climate change. Wind energy projects also create job opportunities and support local economies.

4.7 Biomass energy

Biomass energy refers to the energy derived from organic matter, such as plants, wood, agricultural waste, and even some animal byproducts. It is a renewable energy source because it is derived from recently living organisms or their waste materials. Biomass can be used to produce heat, electricity, and even transportation fuels.

There are several methods of utilizing biomass for energy generation:

Fig 4.7 The largest wind farm of India in Muppandal, Tamil Nadu

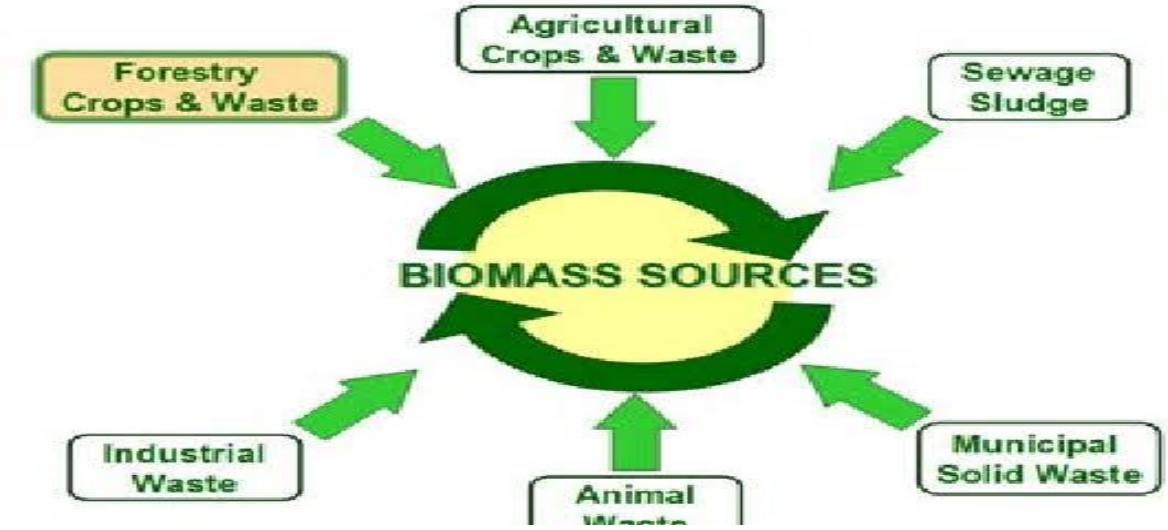


Figure 5biomass energy resources

Direct Combustion: Biomass can be burned directly to produce heat or steam, which can then be used for heating buildings, generating electricity through steam turbines, or powering industrial processes.

Cogeneration: This involves the simultaneous production of electricity and useful heat from biomass. The heat generated during electricity generation can be captured and used for heating purposes, maximizing the overall energy efficiency.

Anaerobic Digestion: This process involves the decomposition of organic materials in the absence of oxygen, producing biogas (mainly consisting of methane) that can be used for heat and power production. The remaining material, called digestate, can be used as a fertilizer.

Biochemical Conversion: Biomass can be converted into liquid fuels, such as ethanol and biodiesel, through biochemical processes. This typically involves breaking down the biomass into sugars or oils, which can then be fermented or chemically processed to produce fuels.

Thermal Conversion: Biomass can be converted into gaseous or liquid fuels through thermal processes such as pyrolysis and gasification. These processes involve heating the biomass in the absence of oxygen to produce syngas, which can be used for electricity generation or further processed to produce liquid fuels.

Biomass energy has the advantage of being carbon-neutral or having lower net carbon emissions compared to fossil fuels. This is because the carbon dioxide released during the combustion or decomposition of biomass is offset by the carbon dioxide absorbed by plants during their growth. However, it is essential to manage biomass resources sustainably to avoid negative environmental impacts and ensure the overall sustainability of biomass energy production.

4.8 Geothermal energy

Geothermal energy derived from the heat stored within the Earth's core. It is a clean and sustainable energy source that harnesses the natural heat produced by the Earth's internal processes. The word "geothermal" is derived from the Greek words "geo" meaning "Earth" and "thermos" meaning "heat."

Fig 4.7 The largest wind farm of India in Muppandal, Tamil Nadu

The Earth's interior is incredibly hot, with temperatures reaching several thousand degrees Celsius in the core. This heat originates from the residual heat of the planet's formation and the ongoing radioactive decay of elements such as uranium, thorium, and potassium within the Earth's mantle and crust.

Geothermal energy is utilized by extracting the heat from underground reservoirs of hot water or steam. The heat can be accessed through natural geothermal features such as geysers, hot springs, and volcanic regions, or by drilling wells into deep geothermal reservoirs. The extracted heat can be used directly for heating applications or converted into electricity through various technologies.

There are three main types of geothermal power plants:

Dry Steam Power Plants: These plants utilize steam directly from geothermal reservoirs to drive turbines, which generate electricity.

Flash Steam Power Plants: These plants bring high-pressure hot water from the reservoir to a flash tank, where the pressure is reduced, causing the water to "flash" into steam. The steam is then used to drive turbines and produce electricity.

Binary Cycle Power Plants: These plants use lower temperature geothermal resources by passing hot water or steam through a heat exchanger. The heat is transferred to a secondary fluid with a lower boiling point, such as isobutane or isopentane, which vaporizes and drives a turbine to generate electricity.

Geothermal energy offers several advantages, including being a continuous and reliable source of power, producing minimal greenhouse gas emissions, and having a small land

footprint compared to other energy sources. It can be used for heating and cooling purposes in addition to electricity generation. However, the availability of suitable geothermal resources is limited to specific regions around the world, and the cost of exploration and drilling can be relatively high.

4.9 Tidal energy

Tidal energy is a form of renewable energy that harnesses the power of ocean tides to generate electricity. While India has significant potential for tidal energy due to its long coastline, the development of tidal energy projects in the country has been relatively limited as of my knowledge cutoff in September 2021. However, I can provide you with some information based on the status and potential of tidal energy in India up to that point:

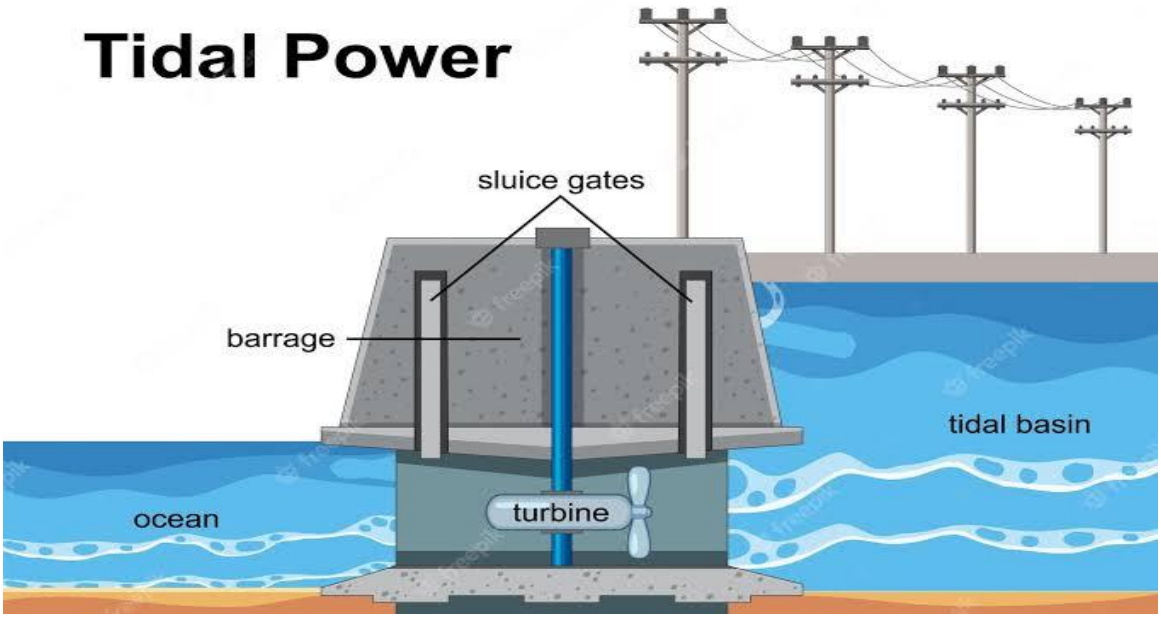
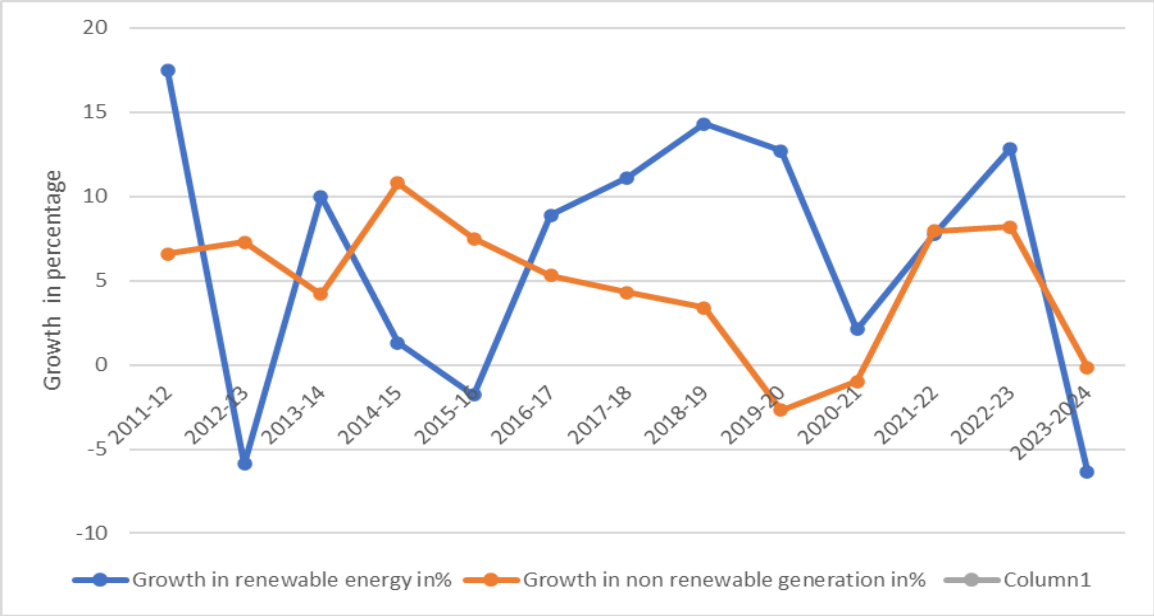


Figure 6 Tidal energy electricity conversion diagram

Potential: India has a coastline of over 7,500 kilometers, offering immense potential for tidal energy generation. The Gulf of Kutch in Gujarat and the Gulf of Cambay in the state of Gujarat are considered to be particularly promising areas for tidal energy projects due to their significant tidal range.

Tidal Power Plants: As of 2021, India had one operational tidal power plant called the Gulf of Kutch Tidal Energy Plant. It is a 50 MW tidal power project located in the Gulf of Kutch, Gujarat. This plant utilizes the tidal variation in the Gulf to generate electricity. Research and Development: The Indian government has shown interest in developing tidal energy and has supported research and development in this field.

Comparative growth of renewable to non-renewable energy resources in Indian power sector.



Annual growth in power generation during recent years

The Overall generation (Including generation from grid connected renewable sources) in the country has been increased from 1110.458 BU during 2014-15 to 1173.603 BU during the year 2015-16, 1241.689 BU during 2016-17, 1308.146 BU during 2017-18, 1376.095 BU during 2018-19, 1389.121 BU during 2019-20, 1381.855 BU during 2020-21, 1491.859 BU during 2021-22 and 1624.465 BU during 2022-23. The above graphical data shows that renewable energy is an emerging sector in the Indian energy sector.

SOURCE	2014-2015		2017	2018	2019	2020	2021	2022	2023
HYDRO	138.3		129.3	131.2	143.7	165.4	160.6	162.1	176.2
SOLAR	4.6		12.1	25.9	39.3	50.1	60.4	73.5	102.1
WIND	28.2		46.0	52.7	62.0	64.6	60.1	68.6	71.81
BIOMASS	15.0		14.2	15.3	16.4	13.9	14.8	16.1	16.2
OTHER	0.4		0.2	0.4	0.4	0.4	1.6	2.3	2.53
TOTAL	191.0		204.1	228.0	261.8	294.3	297.5	322.6	365.6
RENEWABLE ENE	17.28%		16.25%	17.50%	19.19%	21.25%	21.67%	21.73%	22.60%

R G Y %									

The Ministry of New and Renewable Energy (MNRE) has been involved in promoting tidal energy and exploring its feasibility along the Indian coastline.

Feasibility Studies: Feasibility studies have been conducted to assess the potential for tidal energy generation in various locations along the Indian coast. These studies help in identifying suitable sites for tidal energy projects and estimating their economic viability.

Challenges: The development of tidal energy in India faces several challenges. These include high capital costs, technological limitations, environmental impacts, and the need for extensive infrastructure. The unpredictable nature of tides and their intermittent availability also pose challenges for harnessing tidal energy effectively.

It's worth noting that the information provided is based on my training data up to September 2021, and the status of tidal energy projects in India may have progressed since then. For the most up-to-date information, I recommend consulting recent reports, government sources, or relevant news articles.

Growth in renewable energy sector.

According to world Energy Outlook 2021 report India stands 4th globally in Renewable Energy Installed Capacity (including Large Hydro), 4th in Wind Power capacity & 4th in Solar Power capacity.

Table 4.2

Year wise renewable energy generation in TWh.

Data source-Ministry of New and Renewable Energy's Renewable Energy

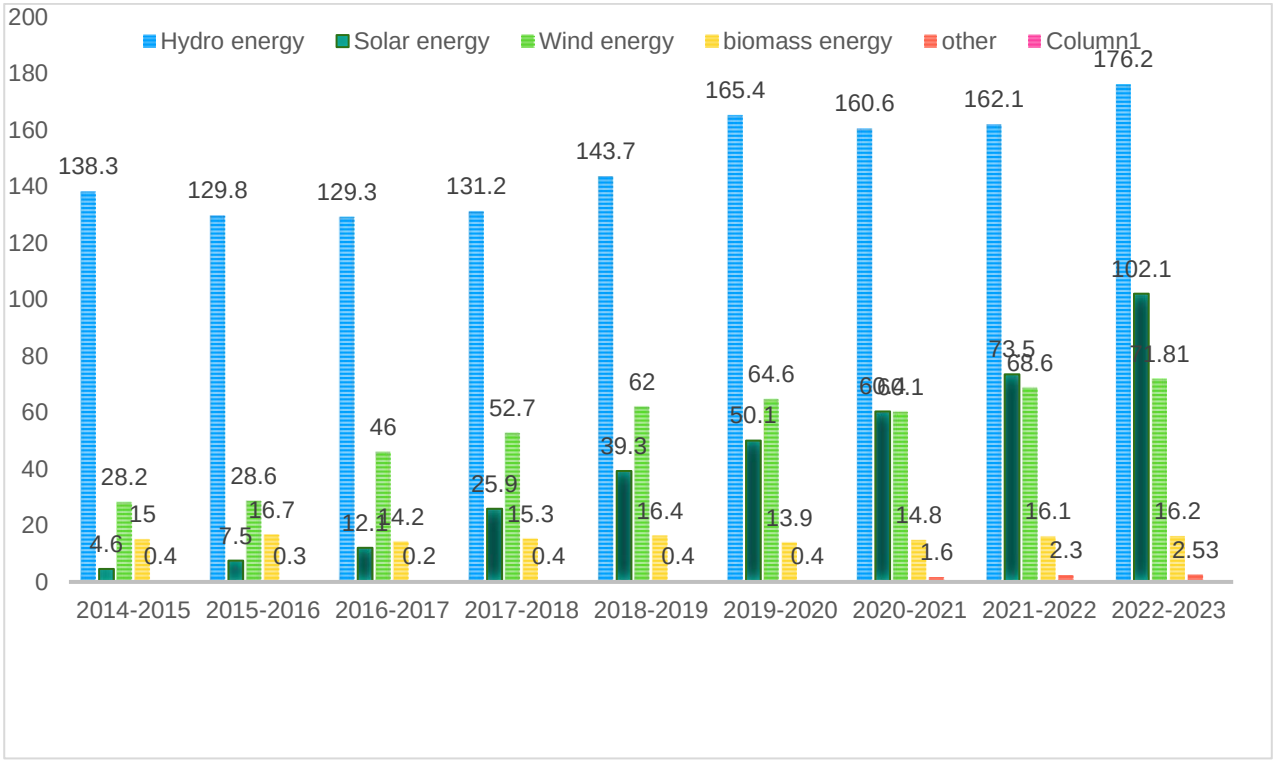


Figure 7:*Year wise graphical represents of renewable energy generation in TWh*

India has witnessed a significant growth in renewable energy over the past decade, solidifying its position as one of the world's leading countries in the sector. This growth can be attributed to a combination of government initiatives, favorable policies, falling costs, and increasing public awareness of the need for clean and sustainable energy sources.

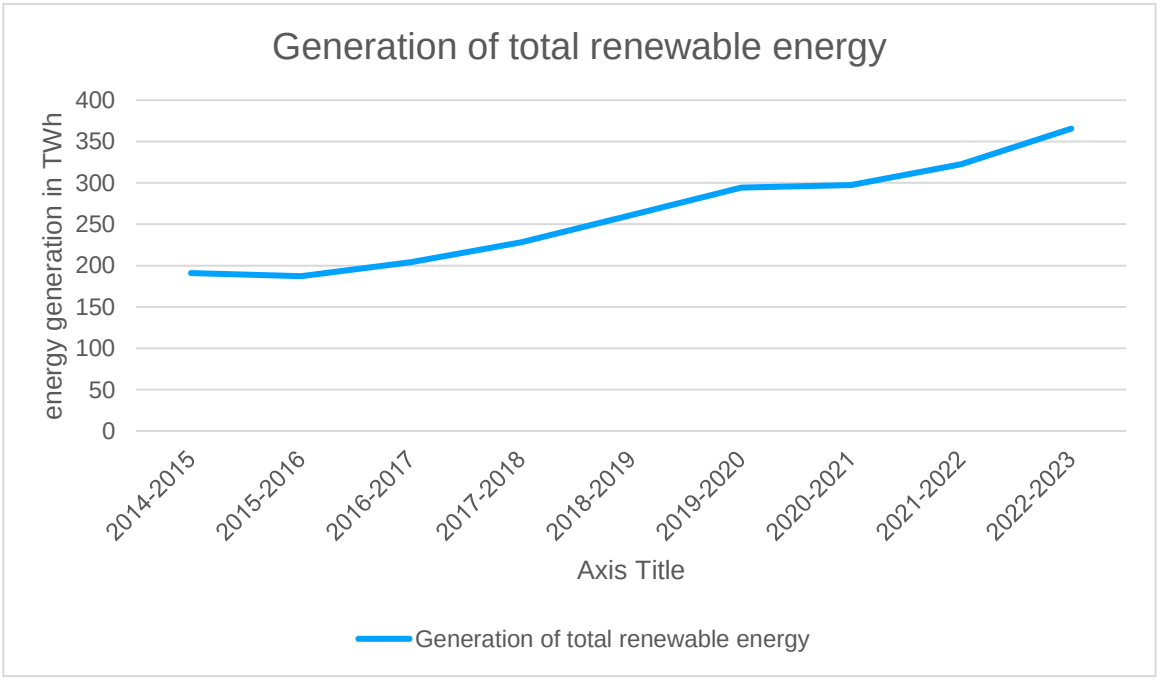


Figure 8Growth of renewable energy resources in India over the last 10 years

One of the key driving factors behind India's renewable energy growth is the government's ambitious target of achieving 500 gigawatts (GW) of renewable energy capacity by 2030. This target, which includes solar, wind, biomass, and small hydro projects, has propelled the country towards rapid expansion in the renewable sector.

Solar energy has been at the forefront of India's renewable energy revolution. The country has a vast solar potential due to its geographical location, receiving abundant sunlight throughout the year. The government has launched various initiatives and policies such as the Jawaharlal Nehru National Solar Mission and the Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM) scheme to promote solar power generation. As a result, India has witnessed a significant increase in solar installations, with its solar capacity crossing 47 GW in 2023.

Wind energy also plays a crucial role in India's renewable energy mix. The country has favorable wind resources, particularly along its coastal regions and hilly terrains. The government has implemented supportive policies such as feed-in tariffs, competitive bidding, and tax incentives to encourage wind power development. India has surpassed 40 GW of installed wind capacity, making it the fourth-largest wind power market globally. In addition to solar and wind, India has been focusing on other forms of renewable energy as well. The government has promoted biomass energy generation through various schemes, incentivizing the use of agricultural and urban waste for power production. Small hydroelectric projects have also contributed to the renewable energy landscape, harnessing the power of flowing water in rivers and streams.

Furthermore, the Indian government has been encouraging investment in the renewable energy sector by providing financial incentives, tax benefits, and simplifying regulations. This has attracted both domestic and international players to invest in renewable energy projects across the country.The growth of renewable energy in India has not only contributed to reducing the country's dependence on fossil fuels but also helped in mitigating greenhouse gas emissions and addressing climate change concerns. Moreover, it has provided employment opportunities, particularly in rural areas, and improved access to electricity in remote regions. While significant progress has been made, India still faces challenges in terms of grid integration, land acquisition, financing, and policy implementation. However, with continued government support, technological advancements, and the increasing affordability of renewable energy sources, India's transition towards a sustainable energy future is expected to continue at a rapid pace.

Solar energy is rapidly surpassing coal energy in India

In recent years, solar energy has indeed experienced significant growth in India, rapidly surpassing coal as a source of energy. This shift can be attributed to various factors such as government policies, declining solar costs, environmental concerns, and the need for energy diversification.

India, as one of the world's largest consumers of coal, has been grappling with the adverse effects of coal-based power generation, including air pollution, greenhouse gas emissions, and the depletion of fossil fuel reserves. To address these issues, the Indian government has been actively promoting renewable energy sources, particularly solar power, through various initiatives and policy frameworks.

One of the key drivers of solar's success in India has been the declining costs associated with solar technology. The prices of solar panels and related equipment have significantly dropped over the years, making solar energy a more economically viable option. This cost reduction, coupled with government incentives and subsidies, has attracted investments in solar projects and encouraged the development of large-scale solar farms.

The Indian government has set ambitious renewable energy targets, aiming to achieve 175 gigawatts (GW) of renewable capacity by 2022, with a substantial focus on solar power. The "National Solar Mission" launched in 2010 aimed to promote the development of solar energy and achieve 100 GW of solar capacity by 2022. Subsequently, the target was increased to 450 GW by 2030. These targets have spurred the growth of solar energy in India, attracting both domestic and foreign investors.

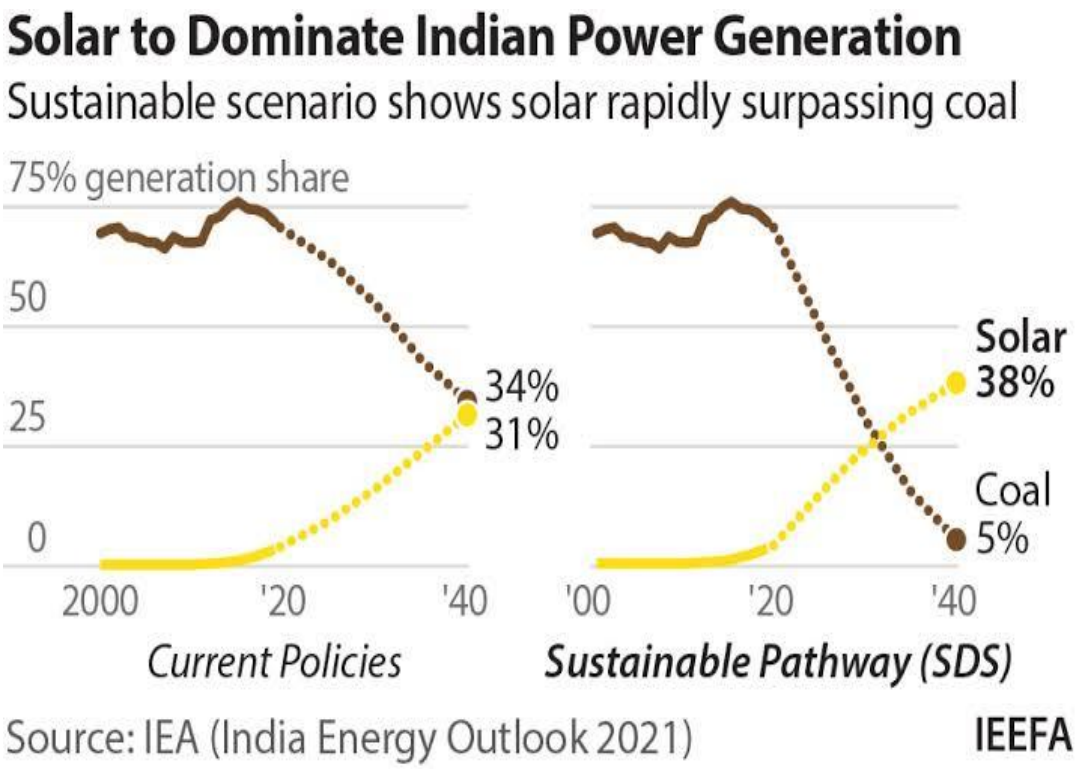


Figure 9solar to dominate Indian power generation

Furthermore, the Indian government has implemented policies to encourage solar adoption, such as long-term power purchase agreements (PPAs) and competitive bidding processes. These measures have provided a stable investment environment and reduced uncertainties

for solar project developers. The introduction of tax incentives, subsidies, and favorable financing options has also facilitated the expansion of solar energy in the country.

The environmental advantages of solar power have also contributed to its rapid growth. India, like many countries, faces challenges related to air pollution and climate change. By embracing solar energy, India can reduce its reliance on coal-fired power plants, leading to a significant reduction in greenhouse gas emissions and air pollution. Solar power helps India mitigate the adverse environmental impacts associated with coal, improving air quality and public health.

The transition from coal to solar energy is a significant milestone for India's energy sector. While coal will continue to play a role in the country's energy mix, the rapid growth of solar power signifies a fundamental shift towards cleaner and more sustainable energy sources. The adoption of solar energy has created employment opportunities, enhanced energy security, and positioned India as a global leader in renewable energy.

However, it's important to note that challenges remain. The intermittency of solar power and the need for effective energy storage solutions are areas that require further attention. Additionally, the infrastructure and grid integration of renewable energy sources need to be strengthened to ensure a smooth transition. Nonetheless, India's progress in surpassing coal energy with solar power serves as an inspiring example for other countries seeking to transition to cleaner energy alternatives.

Advantages of renewable energy over fossil fuel energy.

Renewable energy an essential component of a sustainable and resilient energy system, contributing to a cleaner environment, combating climate change, fostering economic growth, and enhancing energy security and independence

Environmental Sustainability: One of the key advantages of renewable energy is its minimal environmental impact. Unlike fossil fuels, renewable energy sources produce little to no greenhouse gas emissions, reducing air pollution, mitigating climate change, and preserving the planet's natural resources.

Reduction of Greenhouse Gas Emissions: Renewable energy plays a crucial role in combating climate change by significantly reducing the release of greenhouse gases. Wind, solar, hydro, and geothermal energy systems generate electricity without emitting carbon dioxide or other harmful pollutants, helping to reduce the overall carbon footprint.

Energy Security and Independence: By diversifying energy sources, renewable energy enhances energy security and independence for countries. Reliance on fossil fuels, often imported from other nations, can make countries vulnerable to price fluctuations and geopolitical tensions. In contrast, renewable energy resources are widely available and can be harnessed locally, promoting self-sufficiency and reducing dependency on foreign energy sources.

Job Creation and Economic Growth: The renewable energy sector is a major driver of job creation and economic growth. Investments in renewable energy projects, such as the construction and maintenance of wind farms, solar installations, and biomass facilities, stimulate employment across various skill levels and sectors. This industry expansion can revitalize local economies and foster innovation, positioning countries at the forefront of the global clean energy transition.

Cost Competitiveness and Price Stability: Over the past decade, renewable energy technologies have experienced substantial cost reductions, making them increasingly competitive with conventional energy sources. Solar and wind power, in particular, have achieved grid parity in many regions, meaning their costs are comparable to or lower than traditional fossil fuel-based electricity. Moreover, renewable energy provides price stability due to the abundance and predictability of its resources, unlike fossil fuels, which are subject to price volatility.

Improved Public Health: The transition to renewable energy can have significant health benefits. By reducing the use of fossil fuels, which emit pollutants linked to respiratory diseases, cardiovascular issues, and other health problems, renewable energy contributes to cleaner air and improved public health outcomes. This can lead to lower healthcare costs and an overall improvement in the quality of life.

Sustainable Development: Renewable energy aligns with the principles of sustainable development, promoting a harmonious balance between economic growth, social equity, and environmental protection. By adopting renewable energy solutions, countries can address energy poverty, provide access to electricity in remote areas, and improve the well-being of communities while preserving natural resources for future generations.

These benefits make renewable energy an essential component of a sustainable and resilient energy system, contributing to a cleaner environment, combating climate change, fostering economic growth, and enhancing energy security and independence.

CHAPTER 5

Conclusion and recommendations.

India has made significant strides in promoting renewable energy in recent years, aiming to reduce its dependence on fossil fuels and mitigate the impact of climate change. Numerous studies have been conducted to assess the potential and impact of renewable energy sources in the country. Here are some key conclusions from earlier studies:

Solar Energy: Solar power has emerged as a leading renewable energy source in India. Studies have shown that India has enormous solar potential due to its geographic location and abundant sunlight. Solar energy projects have demonstrated a positive impact on the country's energy mix, providing clean and sustainable power to both rural and urban areas.

Wind Energy: Wind power has also gained momentum in India, with the country being one of the world's top wind energy producers. Studies have highlighted the significant potential for wind energy generation in coastal and hilly regions. India's wind power sector has shown substantial growth and has the potential for further expansion.

Hydropower: Hydropower has been a traditional source of renewable energy in India. Studies have examined the feasibility of small and large-scale hydropower projects, considering factors such as water availability, environmental impact, and social

considerations. India has significant potential for hydropower generation, although studies also highlight the need for sustainable and environmentally-friendly practices.

Bioenergy: Studies have explored the potential of bioenergy sources such as biomass and biogas in India. Bioenergy projects can utilize agricultural waste, organic matter, and livestock waste to generate electricity and heat. These studies have emphasized the importance of sustainable feedstock supply chains and efficient conversion technologies for bioenergy projects.

Policy and Investment: Numerous studies have assessed the policy frameworks and investment opportunities in the renewable energy sector in India. These studies have underscored the significance of supportive government policies, favorable regulations, and financial incentives to attract private investments and accelerate the growth of renewable energy.

It's important to note that the renewable energy landscape is continually evolving, and new studies and developments are emerging regularly. For the most up-to-date and accurate information on renewable energy studies in India, I would recommend referring to recent research papers, reports from reputable organizations, and government publications.

Overall, India currently focuses on renewable energy for achieving energy security and promoting sustainable economic development and also concerned to addressing climate change issues.

Future prospects:

The future prospects of renewable energy in India are highly promising. India has been making significant strides towards transitioning to a cleaner and more sustainable energy sector. The government, along with various stakeholders, has implemented several policies and initiatives to promote renewable energy deployment and reduce dependence on fossil fuels. Here are some key aspects that highlight the future prospects of renewable energy in India.

Ambitious Renewable Energy Targets: India has set ambitious renewable energy targets to be achieved by 2030. The country aims to have 450 gigawatts (GW) of renewable energy capacity, including 280 GW of solar power, 140 GW of wind power, 10 GW of biomass, and 5 GW of small hydro power. These targets reflect a strong commitment to scaling up renewable energy generation.

Declining Costs: The costs of renewable energy technologies, particularly solar and wind, have been steadily declining over the years. This cost reduction, coupled with advancements in technology and economies of scale, makes renewable energy more economically viable and competitive with conventional energy sources. As a result,

renewable energy is expected to become the preferred choice for new power generation capacity in India.

Favorable Policy Environment: The Indian government has implemented several policy measures to promote renewable energy adoption. These include financial incentives such as subsidies, tax benefits, and concessional financing, as well as simplified procedures for project approvals and grid connectivity. The policy framework provides stability and predictability for investors, attracting both domestic and foreign investments in the renewable energy sector.

Strong Solar Potential: India is blessed with abundant solar resources, and the country has been leveraging this advantage by rapidly expanding its solar power capacity. The falling solar module prices, coupled with favorable policies like solar parks, rooftop solar installations, and solar energy auctions, have facilitated the growth of solar energy. India has emerged as one of the leading solar power producers globally.

Wind Energy Expansion: India has a vast coastline and favorable wind conditions in several regions, presenting enormous potential for wind energy. The government has implemented policies to promote wind energy projects, including feed-in tariffs, competitive auctions, and the development of wind energy zones. The continued growth of wind power, along with technological advancements in wind turbines, will contribute significantly to India's renewable energy targets.

Energy Storage Solutions: One of the challenges with renewable energy is intermittency, as solar and wind power generation depend on weather conditions. However, the advancement of energy storage technologies, such as batteries, pumped hydro storage, and thermal energy storage, will help overcome this challenge. Energy storage systems will enable better integration of renewable energy into the grid and provide a reliable and consistent power supply.

Job Creation and Economic Growth: The renewable energy sector has the potential to create a significant number of jobs across various segments, including manufacturing, installation, operation, and maintenance. The expansion of the renewable energy industry will not only contribute to job creation but also stimulate economic growth, attract investments, and foster innovation and research and development.

Climate Change Mitigation: India is committed to reducing its greenhouse gas emissions and combating climate change. Renewable energy plays a crucial role in mitigating carbon emissions and transitioning to a low-carbon economy.

By expanding renewable energy capacity, India can significantly reduce its reliance on fossil fuels, decrease air pollution, and contribute to global efforts in mitigating climate change.

Considering these factors, the future prospects of renewable energy in India appear bright. The country is well-positioned to become a global leader in renewable energy deployment, contributing to a cleaner and more sustainable energy future.

References

a. Ministry of New and Renewable Energy, Government of India. Available: https://mnre.gov.in

b. Ministry of Power, Government of India. http://powermin.nic.in

c. Competitive assessment of Indian wind power industry: A five forces model" Muhammad Irfan D, Zhen-yu Zhao, Munir Ahmad.

1. Non conventional energy resources by professor NB Khan.

d. .Ktiar, A., & Bhattacharya, S. (2020). Technological advances and innovation in renewable energy sector: A review. Renewable and Sustainable Energy Reviews, 117, 109480.

e. .Renewable Energy Sources, Sustainability Issues and Climate Change Mitigation" by Mohamed El Hadi Cherif and Abdelhamid Djebbar (Renewable and Sustainable Energy Reviews, 2016.

f. Jhariya, D., & Tiwari, G. N. (2020). Renewable energy potential and prospects in India: A review. Renewable and Sustainable Energy Reviews, 131, 109968.

g. Balachandra, P., & Ravindranath, D. (2019). Renewable energy policies in India: A review. Renewable and Sustainable Energy Reviews, 101, 143-154.

h. Arora, A., & Bansal, V. (2020). Socio-economic impact of renewable energy deployment in India: A systematic review. Renewable and Sustainable Energy Reviews, 120, 109676.

i. Suman, A., & Tiwari, G. N. (2021). Challenges and opportunities in the Indian renewable energy sector: A comprehensive review. Renewable Energy.

j. Renewable Energy Sources in India: Current Status, Challenges, and Future Prospects" (2019) by R. P. Saini.

k. Renewable Energy in India: Status and Future Prospects" (2020) by R. Kumar and A. K. Singh.
l. Renewable Energy Potential and Policies in India" (2021) by S. Banerjee.

m. Renewable Energy in India: Policies, Trends, and Future Prospects" (2018) by K. K. Bhatia, et al.
n. Renewable Energy Technologies and their Potential in India" (2019) by N. Dhingra.

o. "Renewable Energy Development in India: Analysis of Policy and Implementation Challenges" (2021) by A. Choudhary and A. Kumar.

p. Renewable Energy Scenario in India: Challenges and Opportunities" (2020) by A. R. Bodkhe and A. S. Bhaskar.

q. Renewable Energy in India: A Review" (2021) by S. Mohanraj, et al.
r. Renewable Energy Technologies in India: Current Status and Future Prospects" (2022) by R. K. Singh, et al.

s. "Renewable Energy Deployment in India: Progress, Challenges, and Policy Recommendations" (2022) by M. Tiwari, et al