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REVIEW ARTICLE

A REVIEW OF WIND ENERGY IN INDIA - A PANACEA FOR GREENHOUSE GASES

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Abstract

Electrical power demand is ever increasing in India due to rapid development in various sectors. Use of fossil fuels to meet this demand adds to the problem by not only polluting the environment by increasing the emission of green-house gases but also depleting the nonrenewable sources of fossil fuels from the earth. It is therefore important that we focus our attention towards renewable sources of energy. Wind energy is one of the promising sources of clean and green energy which can prove to be reliable and help in meeting the energy demands. There are some challenges and limitations of wind energy. The requirement of a large area for installation of windmills, cost of installation and maintenance are some of the factors which need optimal planning. This paper explores the potential of wind energy in India, the challenges in shifting our dependency from non-renewable to a renewable source and government policies to promote wind energy in India.

Introduction:-

India and all other countries in the world are making concerted efforts to recover from the global pandemic Covid-19. All nations across the globe are concerned about becoming self-sufficient in terms of their energy requirements, along with controlling the ill-effects of pollution and steadily rising global temperature on account of excessive use of fossil fuels to generate that energy. Hence, the need to look for alternative non-polluting sources of energy; wind being one such source.

In India, power generation is one of the major sources of Greenhouse gases (GHG) emissions contributing to about 56% of its total emissions. The national demand for power is expected to reach 2,172 TWh by 2030 from 1,276 TWh in 2021. Hence, there is a dire need to move towards decarbonization of the power sector, which is possible only by way of increasing utilization of Renewable Energy (RE), in industry as well as domestic fronts.

With this vision to decarbonize the power sector, India has expanded its RE capacity in the last one decade by ~4-5 %. India's commitment towards clean energy was further reinstated at the "26th session of the Conference of the Parties (COP26) held in Glasgow, United Kingdom". "India committed **five nectar elements (Panchamrit) [1]** of its climate action:

1. Reach 500 GW Non-fossil energy capacity by 2030.
2. 50% of its energy requirements from renewable energy by 2030.
3. Reduction of total projected carbon emissions of one billion ton by 2030.
4. Reduction of carbon intensity by 45% by 2030, over 2005 level.

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5. Achieving the target of net zero emissions by 2070."

The International Renewable Energy Agency (IRENA) 1.5°C scenario [2], reports "an energy transition grounded in renewable sources and technologies that increases efficiency and conservation is the only way to give us a fighting chance of limiting global warming to 1.5°C by 2050." This would obviously be possible when we are able to increase the share of RE from **16% in 2020 to 77% by 2050.** Hence, a dire need to increase deployment of RE sources, including wind energy. This will also ensure "carbon dioxide (CO2) emissions to net zero by 2050".

The Global Wind Energy Council (GWEC) Global Wind Report 2023 [3]highlights theYear-on-Year growth of 9% inthe total installed global capacity. During 2023-27, thereis a forecast of 680 GW of new capacity being installed, with an additional 1 TW expected by the end of the decade.

Wind Power and Potential in India:-

As we prepare to move into 2025, the winds of change are blowing through India's energy landscape, particularly in the realm of renewables. With a nation fervently striving towardsnet zerogoals and a global call for sustainability, wind energy will play a pivotal role in the coming decade to get India to its 500 GW renewables goal by 2030. The Central Electricity Authority (CEA) prepares the National Electricity Plan (NEP) once every five years, in accordance with the National Electricity Policy. For the ongoing plan period 2022-27 and prospective plan for 2027-32, installed wind capacity is projected to reach 73 GW by 2027 and 122 GW by 2032. To meet this goal, India is aiming to build 140 GW of wind capacity by 2030[4].

In the coming years, wind energy will play a key role for the Indian power sector. India has an experience of over two decades in grid-connected wind energy power. During 2010 – 2020, the Compound Annual Growth Rate (CAGR) of wind energy in India was recorded as 11.39%, while the overall installed electricity capacity witnessed a CAGR of 8.78%[5],with a tremendous slowdown over the next 5 years. The factors that contributed to this stagnancy include:

1. Introduction of competitive bidding,
2. Changes in Wind Energy policies pan-India,
3. Supply Chain disruptions owing to the global Covid-19 pandemic.

As on May 2024[6], India stands fourth in the world (after China, USA and Germany) with a cumulative **installed wind power capacity** of **46.4 GW.** Wind power in India accounts for 10% of the total installed capacity and 46% of the total renewable capacity [7]. The FY 2022-23 witnessed the commissioning of 2.8 GW of onshore wind capacity, the highest since 2017, with most of the wind power capacity being spread across the southern, western, and northwestern states [8]. According to the National Institute of Wind Energy (NIWE), Chennai, "the overall wind energy potential of India increases to 695 GW at 120m as against 302GW at 100 m height above the local ground level." [7].

Additionally, the GWEC estimates an additional 22.8 GW of onshore wind capacity between 2024 and 2028, on account of more than 13 GW of wind projects in the pipeline as of September 2023, and additional 37 GW of wind capacity by 2030.

There are more than 800 wind power plants set up by Wind Energy companies in India. Gujarat, Karnataka, and Tamil Nadu are the leading wind-energy producing states in India. The list of the largest Wind Energy farms in India is given below in Table 1 [9]:

Table 1:- Largest Wind Energy farms in India [9]

Sl. No.	Wind Power Plant	Installed Capacity (MW)
1	Muppandal Wind Power Plant, Kanyakumari	**1500**
2	Jaisalmer Wind Park, Jaisalmer	**1064**
3	Brahmanvel windfarms, Dhule	**528**
4	Kayathar, Tamil Nadu	**300**
5	Dhalgaon windfarms, Maharashtra	**278**
6	Vankusawade Wind Park, Maharashtra	**259**

7	Vaspet, Maharashtra	**144**
8	Tuljapur, Maharashtra	**126**
9	Beluguppa Wind Park, Andhra Pradesh	**100.8**
10	Mamatkheda Wind Park, Madhya Pradesh	**100.5**

Wind Energy Potential in India:-

As per the recent Wind resource assessment by NIWE, in India, across the nation, there is a gross wind power potential [10-13] of 302 GW at 100 m above ground level (agl), 695.50 GW at 120 m agl, and 1,164 GW at 150 m agl. Most of this potential exists in seven windy states, as shown and tabulated below: -

Table 2:- Wind Energy Potential in India.

S.No.	State	WindPotential at 100m abovegroundlevel (in GW)	WindPotential at 120m above groundlevel (in GW)
1.	Gujarat	84.43	142.56
2.	Karnataka	55.85	124.15
3.	Andhra Pradesh	44.22	74.90
4.	Maharashtra	45.39	98.21
5.	Tamil Nadu	33.79	68.75
6.	Rajasthan	18.77	127.75
7.	Madhya Pradesh	10.48	15.40
8.	Other States andUnion Territories (UTs)	9.28	43.78
Total		**302.25**	**695.50**

State-wise wind power generation in India
Source: Wind-energy-potential-of-states-768x768.png (768×768)

In December 1952, Council of Scientific and Industrial Research(CSIR) initiated a project to explore the possibilities of harnessing wind power in the country [14] and investigating the available resources to harness wind energy [15]. They carried out wind velocity surveys and estimated India's wind energy capacity [16]. All these gave an impetus to the development of wind power in India.

According to Ministry of New and Renewable Energy (MNRE) [17], following are the **Best Performing States for harnessing wind energy:**

a. Wind Power Potential (in GW) at **120 m Above Ground Level:**

Gujrat (142.56), Rajasthan (127.75), Karnataka (124.15), Maharashtra (98.21), and Andhra Pradesh (74.90).

Wind Power Potential (in GW) **at 150 m Above Ground Level**:

b. Rajasthan (284.25), Gujarat (180.79), Maharashtra (173.86), Karnataka (169.25), and Andhra Pradesh (123.33).

Table 3:-Best Performing States: Wind Energy Production in India as on September 30, 2024[17].

S. No.	State	Installed Wind Energy (in MW)
1.	Gujrat	12209.18
2.	Tamilnadu	11042.44
3.	Karnataka	6564.36
4.	Maharashtra	5214.28
5.	Rajasthan	5195.82
6.	Andhra Pradesh	4096.65
7.	Madhya Pradesh	2844.29
8.	Telangana	128.10
9.	Kerela	63.50
10.	Others	4.30
Total		**47362.92**

In 2011, TERI University, New Delhi[18], was the first to assess the potential for wind farms in the country. Their claim that this potential was more than 2,000 GW was re-validated by Lawrence Berkley National Laboratory, US (LBNL). Later, MNREset up a committee [19] to reassess the potential through the National Institute for Wind Energy [20, 21].On account of a consistent, steady, and swift wind flow, commencing from Gujarat, Maharashtra, and Karnataka, to Tamil Nadu and Andhra Pradesh, the Western States of India have a greater wind potential. Tamil Nadu was the largest producer of Wind energy in India till mid-2023. In the past six years, Gujrat has reported a staggering 10-times increase in its' wind power generation capacity by tapping its' renewable resources. As of September 30, 2024, "Gujarat is more than 1000 MW ahead of Tamil Nadu in installed wind capacity", which is reflected in terms of a share of 26% as against Tamil Nadu's wind capacity (around 23% share) [17, 22 – 27].

In FY 2022–23, the 71.814 TWh electricity generated was 4.43% of the total from wind power, which is 10% of the total installed capacity[28]. The Capacity Utilization Factor(CUF) during the past 5 years varied between 14% - 19.6%. During the months from May to September, which coincide with the southwest monsoon, annual wind generation is ~70%. In India, during the non-monsoon period, solar power generation is complementary to wind power[29]. In terms of pricing, nearly 60% of the wind power generated during the night time was equal to the stored solar power [30].

Wind Farms or Wind Parks:-

Wind energy is a type ofkinetic energythat is associated with natural wind or air flows in the earth's atmosphere. Wind turbines utilize this kinetic energy of the naturalwindto generate electricity by first converting it into mechanical power, which is subsequently converted into electrical power for generating electricity.

A wind farm, also known as a Wind Park or Wind Power Station or Wind Power Plant, is a collection of wind turbines grouped together in a particular location that are used collectively for the generation of electricity. These Wind farms are spread out over hundreds of square kilometers in area. Regular farming and various other activities are also possible in the land between these wind turbines in a wind farm.

There are two types of Wind farms/ Wind Parks that are established to generate Wind energy.

A. Onshore Wind Farm

1. The power is generated by the Wind Turbines that are located on land and use the natural energy of the wind to generate electricity.
2. These farms are generally located in areas where there is low conservation or habitat value.
3. Some of the biggest Onshore Wind Farms in India are Muppandal Wind Power Plant, Kanyakumari, and Jaisalmer Wind Park, Jaisalmer.

B.Offshore Wind Farm

1. When wind over openwater, like theoceans, is used to generate power, it is referred to as Offshore Wind Farms.
2. These Wind farms are constructed in water bodies where higher wind speeds are available to harness.
3. These are generally built 50 feet below the surface of the water and at least 200 nautical miles away from the coast.

Wind Farms Worldwide:

Among the countries with some of the **largest Onshore wind farms are** the United States, India, and China. Germany, the United States, Denmark, Spain, and India collectively contribute 80% of the world's installed wind energy capacity. Some of the largest operational wind power plants located in countries like the United States, India, and China are tabled below in Table 4 [31 – 45]:

Table 4:- Top 10 largest operational wind power plants across the globe [31 – 45].

S. No.	Wind PowerPlant	Place	Installed Capacity (MW)
1.	Gansu (Jiquan)Wind Farm [31-34]	Gansu province, China	10450
2.	Alta Wind Energy Center[35, 36]	California, United States	1548
3.	Muppandal wind farm [37]	Tamil Nadu, India	1500
4.	Qiji Wind Farm	Qinghai, China	1300
5.	Markbygden Wind Farm [38]	Norrbotten, Sweden	2000
S. No.	**Wind PowerPlant**	**Place**	**Installed Capacity (MW)**
6.	Jaisalmer Wind Park [39,40]	Rajasthan, India	1064
7.	Fosen Vind [41, 42]	Norway	1057
8.	Western Spirit Wind [43]	United States	1050
9.	Traverse Wind Project [44]	United States	998
10.	Los Vientos Wind Farm [45]	United States	912

Wind Farms in India:

Wind Energy Plants in India are a vital component of the country's renewable energy landscape. India has been actively investing in wind energy to diversify its energy sources, reduce greenhouse gas emissions, and meet its growing energy demands. The wind power production facilities in India with production capacity > 100 MW are tabulated in Table 5 [46 – 56].

1. **Gondal in Gujarat** has the tallest wind turbine of 3 MW with hub height of 160 m [25]. In November 2022 [22, 24], the single largest wind turbine of 5.2 MW capacity was installed in the State at 120 m hub height.
2. **Muppandal Wind Farm** at Tamilnadu isthe largest wind power plant in India, with a capacity of 4.2 MW, with nearly 3000 wind turbines, and was installed in October 2022. In November 2022 [24], a wind turbine of 5.2 MW capacity at 120 m hub height installed inMundra,Gujarat surpassed this installation. Of the total wind installed capacity of 7633 MW in Tamil Nadu, the Muppandal windfarm has a total capacity of 1500 MW. The farm reported electricity generation to the tune of 9.521 GWh with 15% CUP during the fiscal year 2014–15.
3. **VankusawadeWind Park** is a wind energy facility situated near Koyana Reservoir and about 40 kilometers away from Satara town in Maharashtra's Satara District. It is positioned on a lofty mountain plateau at an elevation of 1,150 m. This wind farm harnesses wind energy with a capacity of 350 kilowatts (kW), culminating in a combined power production of 210 MW.

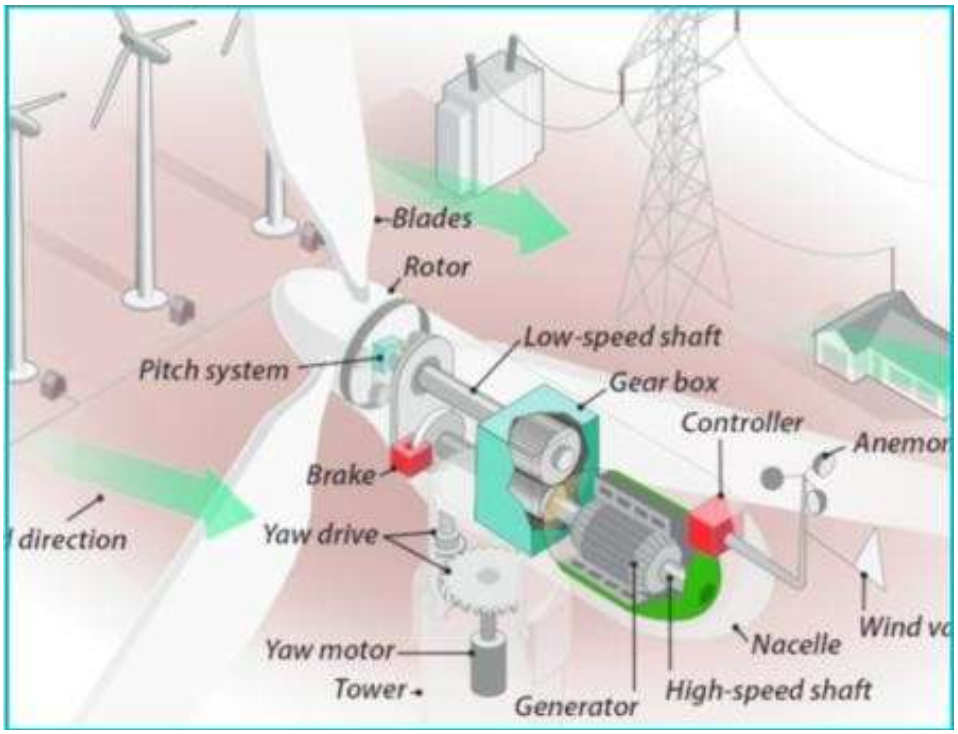
Table 5:- Largest wind power production facilities in India (>100 MW) [46 – 56].

S. No.	Power Plant	Location	State	Capacity (MWe)
1.	Kutch Wind Farm	Kutch	Gujrat	11,500

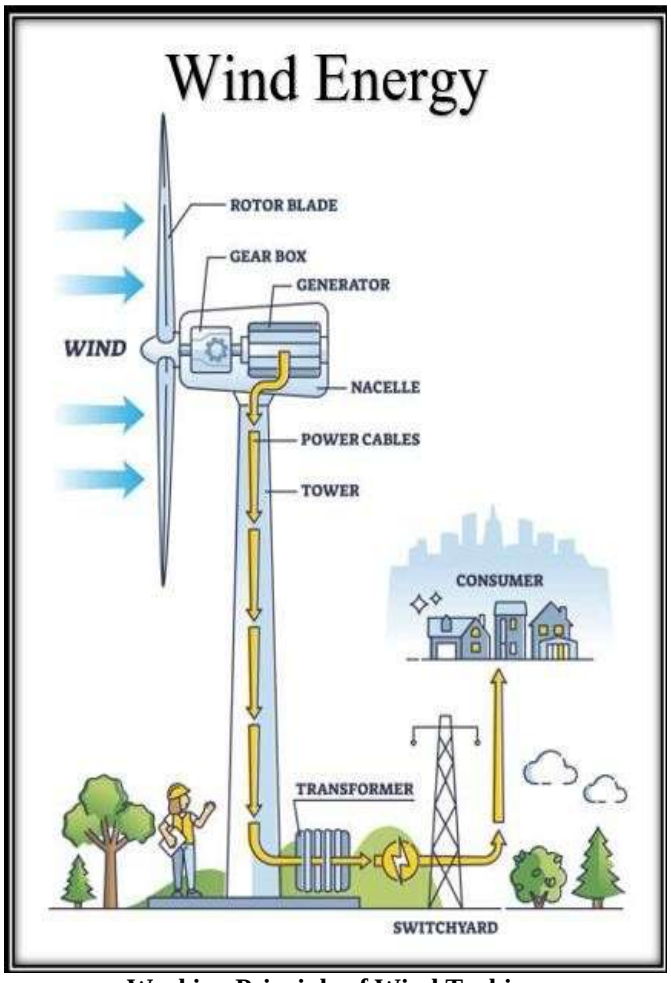
2.	Muppandal Wind Farm	Kanyakumari	Tamilnadu	1500
3.	Jaisalmer Wind Farm	Jaisalmer	Rajasthan	1064
4.	Brahmanvel Wind Farm	Dhule	Maharashtra	528
5.	Kayathar	Tutcorin	Tamilnadu	300
6.	Dhalgaon Wind Farm	Sangli	Maharashtra	278
7.	Vankusavade Wind Farm	Satara District	Maharashtra	259
8.	Vaspet	Vaspet	Maharashtra	144
9.	Tuljapur	Osmanabad	Maharashtra	126
10.	Sipla	Jaisalmer	Rajasthan	102
11.	Saeame	Jamnagar	Gujrat	101
12.	Beluguppa Wind Park	Beluguppa	Andhra Pradesh	100.8
13.	Mamatkheda Wind Park	Mamatkheda	Madhya Pradesh	100.5
14.	Anantpur Wind Park	Nimbagallu	Andhra Pradesh	100

Wind Energy Mechanism:-

1. Wind blowing in theatmosphererotates the blades of the rotor of a Wind turbine.
2. The rotor is attached to a low-speed shaft. As the rotor revolves, so does this shaft. A brake on the low-speed shaft is used to stop the blades.
3. The low-speed shaft is coupled to a big gear. This gear rotates along with the shaft.
4. The big gear is entwined with a smaller gear, which rotates faster than the larger gear. This is due to the gear ratio.
5. The sluggish spinning of the turbine blades gets accelerated to around 1500 revolutions per minute (rpm) by the small gear.
6. Another shaft attached to the small gear is a high-speed shaft which is connected to the generator.
7. A powerful magnet in action near a wire converts mechanical energy into electrical energy in the generator.
8. An anemometer and a wind vane send data to a control box in the nacelle. This information is used by controllers on the ground to spin the nacelle or switch the turbine on and off.
9. The size of the turbine and the length of its blades helps determine the amount of wind energy that can be harvested from a particular windmill.



Flow Diagram of Generation of Wind Power
Source: https://actionrenewables.co.uk/wp-content/uploads/turbines-diagram.png



Working Principle of Wind Turbine
Source: https://th.bing.com/th/id/OIP.e9KZAv31fGNcDc_AJKPEJgAAAA?rs=1&pid=I mgDetMain

Importance of Wind Energy in India:-
To become self-sufficient in production of energy, in countries like India, which import coal or oil, alternative sources such as wind energy need to be harnessed.

The importance of Wind energy can be understood in the following points:
1. **Pollution saving potential of wind energy** is extremely high as the electricity produced from it produces no CO_2 emissions and hence does not contribute to thegreenhouse effect.
2. **High Wind Energy Potential of India:** The National Institute for Wind Energy (Chennai) has found that the western states have larger potential due to the stable, steady, and speedy wind flow starting from Gujarat, Maharashtra, Karnataka to Tamil Nadu and Andhra Pradesh.
3. **Depleting non-renewable sources of energy**: Due to the extensive extraction of fossil fuels and other non-renewable, finite energy sources, it is the need of the hour to harness alternate and renewable sources of energy like Wind energy.

Advantages of Wind Energy:-
The benefits of Wind Energy in India, includes:
1. **Environmentally Friendly**: Power plants that burn fossil fuels like coal generate particulate matter (PM2.5, PM10), nitrogen oxides, and sulphur dioxide, which pollute the atmosphere. These are harmful not only to human health, but also dent the nations' economy. Wind energy, on the other hand, is non-polluting and environmentally sustainable.

2. **Low-Cost Energy**: The upfront high cost of installing wind turbines have high returns as the energy they produce is cheap and the cost of power produced remains fixed for a longer period, unlike gasoline.
3. **One-time Investment**: The generation of wind energy is continuous, unlike generation from other sources like coal or petroleum. Hence, investment never becomes idle.
4. **Nil Input Cost**: The wind supply around the earth is plentiful and unrestricted. So, its input is a sustainable resource.
5. **Job Creation**: Wind energy production is generating jobs. More individuals are working in wind energy companies in India, and one of the fastest growing job markets is for wind turbine technicians.

Disadvantages of Wind Energy:-

Besides advantages, Wind Energy has some disadvantages too which includes -

1. **Threat to Wildlife**: The development of Wind farms on a large scale in a remote region may pose harm to neighboring wildlife. Wind turbines can harm the birds and animals around the area.
2. **Noise disturbances**: Although wind energy is non-polluting, the turbines may be quite noisy. People who live nearby frequently complain about the enormous noise produced by wind turbines.
3. **Unpredictable nature of Wind**: The biggest disadvantage of wind energy is that it is impossible to forecast the movement of the wind. As a result, turbines cannot create electricity on demand, but only when the wind is blowing strongly enough.
4. **Region Specific**: Wind turbines are ideal for generating power incoastal areasthat receive wind all year. As a result, countries that lack coastal or hilly locations are unable to benefit from wind power.
5. **Wind Turbine Syndrome**: Wind turbine syndrome and wind farm syndrome have been labeled as pseudoscience and are phrases for the supposed negative human health impacts of wind turbine proximity.

Offshore Wind Energy and Challenges:-

1. In contrast to onshore, in offshore Wind generation plants, wind turbines are installed in seawater.
2. India is surrounded by water on three sides and has a coastline of about 7,600 km (Mainland). This presents a good potential for offshore wind energy generation. Initial assessment of the coasts of Gujarat and Tamil Nadu estimates offshore wind energy potential to be about 70 GW.
3. The challenges associated with the generation of Wind energy from Offshore sites includes [57– 59]:

a) **Expensive**: Energy from Offshore sites is more expensive than Onshore wind and Solar power. The per megawatt cost of the Offshore wind turbine is estimated to be two to three times the cost of Onshore wind turbines.
b) **Poor Financial Position of DISCOMS**: Distribution companies (DISCOMS) in India have been unable to build the required infrastructure to transition to renewable energy sources. They are, therefore, running into losses and it would not be profitable for them to buy electricity from Offshore Wind farms.
c) **Turbine manufacturing infrastructure**: Offshore wind turbines require longer blades and transporting them from the location of manufacturing over long distances increases the cost considerably, which renders the power generated to be expensive and not viable.
d) **Adverse Environmental Impacts**: Wind turbines in offshore sites pose a threat to the habitat of wildlife, fish, and plants. The spinning turbine blades can be dangerous to flying wildlife like birds and bats.
e) **Lack of Subsidies and Incentives**: Incentives have aided Europe's offshore wind energy development over the years. In India, such assistance is lacking.

Challenges:-

Challenges continue to deter the shift to wind energy as a preferred source of energy! According to the GWEC report [60], “Despite positive policy and regulatory momentum, the current onshore wind forecast through the end of the decade still leaves a sizable gap between wind market growth and the government’s 140 GW target of installed capacity by 2030”.

1. **Wind power vs. other low-cost energy sources**: Currently, wind and solar power plants / projects are more economical as compared to gas, geothermal, coal, or nuclear facilities. However, wind projects are not cost-competitive in locations that are not windy enough. The only means by which the cost of nextgeneration technology[61] can be reduced is by improvements in manufacturing and a better understanding of wind plant physics.
2. **Ideal Wind sites are often in remote locations:** Demand for energy is maximum in urban areas, which posea sizable challenge to harness the wind energy generated in far-off located wind farms. Upgrading the nation’s

transmission network and connectivity to such areas could significantly reduce the costs of wind energy, for the users on land.

3. **Energy from wind machines is considered "intermittent,"** because normally winds do not blow strongly enough to produce power all the time. Hence electricity generated from wind machines cannot be the stand-alone source of electricity and must always have a backup supply from another source.
4. **Turbines produce noise and alter visual aesthetics:** Compared to conventional power plants, wind farms impact the environment more on account of the noise produced by the turbine blades and its' visual impact on the landscape.
5. **Impact on local wildlife** is another area of major concern. Although not enough research exists in this area to completely rule out the ill-effects of wind farms, there is a need to minimize wind-wildlife interactions. Advancements in technologies with proper implementation can reduce the impact of wind turbines on wildlife.
6. **Supply chain disruptions** have occurred over the past few years, caused by Covid-19 pandemic and the recent geopolitical tensions of the Ukraine war. As a consequence, the costs of existing pipeline projects have significantly increased globally.
7. Turbine costs have aggravated on account of a recent surge in Goods and Services Tax (GST).
8. Challenges posed due to time-delay in execution of pipeline projects, on account of frequent changes in grid augmentation, land allocations, and other related regulations.
9. Competitive bidding levels and rapid inflation pose a risk to many projects in the pipeline, hence impeding progress.

Government Policies and Initiatives to Promote Wind Energy [62 – 64]:-

Several enabling policies of the Government of India confirm its intention of adding and enhancing the existing wind capacity in the country. Some of these initiatives are:

1. Under the "**Policy for Repowering of the Wind Power Projects, 2016"**, an additional interest rate rebate of 0.25% over existing rebates is provided to new projects financed by IREDA.
2. **"Guidelines for Disposal of Fiber Reinforced Plastic (FRP)"** issued by theCentral Pollution Control Board (CPCB)will ensure responsible waste management and protection of the environment.
3. "**National Wind-Solar Hybrid Policy, 2018"**provides a framework for promotion of large grid connected wind-solar PV hybrid systems.
4. **National Offshore Wind Energy Policy**with an objective to develop offshore wind energy in the IndianExclusive Economic Zone (EEZ)along the Indian coastline of 7600 km. The project FOWIND (Facilitating Offshore Wind in India) will identify potential zones for development of offshore wind power in India and support R&D activities in this area.
5. Encouraging private sector investments and concessional custom duty and exemption on certain components of wind electric generators.
6. For wind and solar projects commissioned by March 2022, to encourage the inter-state sale of wind power, the inter-state transmission charges and losses have been waived off.
7. **T**he National Institute of Wind Energy, Chennai, will provide the necessary t**echnical support, which will** include resource assessment and identification of potential sites.
8. "N**ew RPO trajectory**, Green Open Access Rules, General network access rules, strategy for offshore Wind", will provide the necessary impetus to bring new players to the market.
9. MNRE shall award 37 GW of offshore Wind tenders in the States of Gujarat and Tamil Nadu by 2030.
10. **The "Make in India" initiative**, will provide cost-competitiveness for investment in manufacturing of Wind Turbine Generator (WTG) OEMs. This will further ensure a place for our products in the global market.

Addressing the Challenges - The Way Forward [3, 65]:-

The full potential of wind resources in India can be unlocked only when the key issues and challenges are well defined and concrete steps are taken in the coming years to resolve the same. Only then wind deployment can be accelerated in a sustainable manner.

1. The 'Green Energy Open Access' will promote generation, purchase, and consumption of green energy, increasing awareness and demand from commercial & industrial (C&I) customers.
2. Ensuring compliance of the wind Renewable Purchase Obligation (RPO) to support the uptake of wind power, and aggregate trajectories set by states to overall targets of the country.
3. Easing supply chain challenges in project implementation, and account for commodity price fluctuation to support the timely and cost-efficient commissioning of projects.

4. To sustain and expand wind-based power generation from Onshore and Offshore Wind farms, the Government must streamline permission procedures, including land allocation and grid connection projects.
5. **Innovative grants** to encourage domestic prototype development, testing, Research and Development (R&D), to boost local investment in supply chain and support scale-up of wind manufacturing in India.
6. **Provisioning of lower import duties** for raw materials and certain work-inprogress goods such as non-standard steel, permanent magnets, and balsa wood for a globally competitive manufacturing cost in India for export-oriented opportunities.
7. Both Central and State Governments should consider the **"design and implementation of Wind Exports Corridors"** for enhanced logistics support and lower trade barriers for domestic manufacturers under Leverage Free Trade Agreements (FTAs) with the US, Australia, UAE, UK, EU etc.
8. To undertake **repowering of Onshore Wind projects at an early stage by upgrading technology** before the end of project lifetime for maximum productivity.
9. To encourage Wind and Solar **hybrid project PPAs** with DISCOMs which will facilitate in meeting peak requirements and help in addressing their financial health.
10. **A targeted Production Linked Incentive (PLI) scheme** for the Wind sector to increase vertical integration of the domestic manufacturing industry for more self-sufficiency and improve quality of local components for domestic and export markets.
11. **Diversifying and expanding the local ecosystem for Offshore Wind** through institutional and financial measures such as tax holidays and duty waivers to boost India's participation in Offshore Wind logistics in outside markets such as Sri Lanka and South East Asia.
12. To **aim for "From Local Wind Power to Global Export Hub"** by implementing a strong plan and scaling up the transition at home and demonstrating to the G20 members and other countries how the transformative social, environmental, industrial, and economic benefits are brought by Wind and Renewable Energy.

Conclusion:-

Overall, India's growing wind industry holds multiple domestic and international opportunities. The recent acceleration of domestic growth, combined with a forecast demand supply gap in the global supply chain, creates favourable dynamics for the country. The power from green sources such as Wind and Solar are aimed to fulfill several goals such as energy security, economic development, climate change mitigation, rural development, and employment generation.

India's continued focus on expanding its wind energy capacity, both Onshore and Offshore, is pivotal as it leads the transition towards sustainable and renewable energy sources, aligning with its commitment to global environmental goals and its ambitious national energy strategies.

The long-term drivers for Wind continue to be strong in India, as the country shifts towards competitive technologies and low-carbon growth. Increasing the share of Wind and Solar energy in the power mix now takes precedence to play a leading and constructive role in carrying out the clean energy transition and achieving long-term energy security.

India would continue to push itself towards its climate goals for the Paris Agreement and Panchamrit announced during the COP26 conference. The longterm objective of achieving carbon neutrality by 2070 will require a significant push to phase out and replace existing coal generation capacity with RE over the next four decades and reduce the current pipeline of new coal and fossil fuel capacity.

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