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REVIEW: WIND ENERGY IN DEVELOPING COUNTRIES: OVERCOMING ECONOMIC AND INFRASTRUCTURAL BARRIERS

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Abstract: Wind energy, a type of renewable energy and the most green and efficient energy holds a tremendous potential to address energy challenges in developing countries. This paper elaborates and traverse the economic and infrastructural barriers that hinder the widespread adoption of wind energy in major areas. It also examines the various strategies and solutions to overcome the barriers and also emphasizes the importance of international cooperation, policy reforms and technology transfer. Various case studies of different developing countries have been taken into consideration for the solutions to be arrived.

Index Terms **- barriers, international cooperation, solutions, wind energy.**

I. INTRODUCTION

Wind energy is one of the most potential and promising sources of renewable energy, offering an environmentally sustainable solution to the energy challenges faced by developing countries. As the nation strive steady economic growth and improved living standards, the energy demands are to be met and which it becomes a barrier for the government. Wind energy, a viable solution due to its abundance, affordability, minimal greenhouse emission and cause lesser harm to the wildlife. It is considered as the viable option even though its initial cost is high. There are many successful integrations into the regions and is often hindered by various economic and infrastructural barriers. This paper aims to explores into the intricacies of these barriers, shedding light on the challenges that impede the widespread adoption of wind energy in developing countries. It also looks into a spectrum of strategies and solutions, which play a crucial role of international cooperation, policy reforms and technology transfer in overcoming the obstacles. This paper highlights the potential of wind energy as an impetus for sustainable development in these regions.

II. ECONOMIC BARRIERS

2.1 Initial Capital Costs

One of the primary economic barriers to the adoption of wind energy in developing countries is the substantial initial capital investment required. Wind energy projects requires several cost-intensive components such as gearbox, tower etc, including the procurement and installation of wind turbines, the development of transmission infrastructure, and land acquisition. For nations with limited financial resources and competing investment priorities, and lower area availability the financial burden can pose a significant challenge.

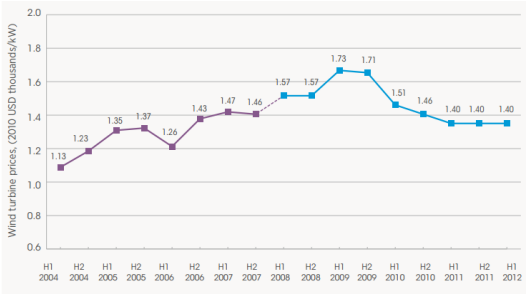

Fig1. Rise and drop of costs of wind turbines [1]

To address this challenge, international financiers play a pivotal role. These financiers provide loans, foreign direct investment, which provide financial support for the setup of wind energy projects. Developing countries can actively seek partnerships with international organizations and donor countries to secure funding. Additionally, the involvement of the private sector through public-private partnerships can help distribute the financial responsibility and reduce the burden on governments.[1]

2.2 Financing and Investment Risks

2.2.1 Navigating Investment Risks in Unstable Environments

The critical economic barrier revolves around the risks associated with investing in wind energy projects, especially in regions where there is an unstable environment such as earthquakes or floods or political opposing or volatility. Investors consider about potential for substantial financial losses due to changes in government policies or sudden shifts in market conditions. Mitigating these risks requires the establishment of stable and transparent regulatory frameworks. Governments can implement attractive incentives, such as tax breaks, feed-in tariffs, and streamlined permitting processes, to encourage private sector investment. These incentives provide assurance to investors, making wind energy projects more financially viable and appealing.

2.2.2 Access to Markets

Developing countries may struggle to access international markets for renewable energy credits or carbon offsets. This limitation restricts their ability to tap into additional revenue streams, which can be instrumental in offsetting initial investment costs and ensuring the long-term sustainability of wind energy projects. To address this challenge, developing nations should actively engage in mechanisms that facilitate the trade of renewable energy credits and participation in international carbon markets. By aligning their energy production with global sustainability goals, these countries can generate additional income, making wind energy projects more economically viable in the long run.

III. INFRASTRUCTURAL BARRIERS

3.1 Grid Integration

An essential infrastructural barrier lies in outdated or inadequate electricity grids that struggle to accommodate intermittent renewable energy sources like wind power. These grids were primarily designed for conventional energy sources and may lack the flexibility required for seamless integration of renewables. Addressing this issue necessitates significant investment in grid infrastructure upgrades and expansion. These upgrades should include the integration of advanced technologies, such as smart grids, which enhance the grid's capability to handle the intermittent nature of wind energy. Furthermore, the deployment of energy storage solutions can store excess wind energy for use during periods of low wind, ensuring a continuous and reliable power supply.

Fig2. Grid integration [20]

3.2 Technical Expertise

Developing countries often face a shortage of technical expertise and a skilled workforce needed for the successful planning, installation, and maintenance of wind energy systems. This knowledge gap can impede the efficient and sustainable operation of wind farms. To bridge this gap, capacity-building programs should be instituted. These programs should focus on education and training for local technicians, engineers, and researchers. Partnerships with experienced international firms can facilitate knowledge transfer and skill development, enabling local teams to take the lead in wind energy projects.

3.3 Land and Infrastructure Availability

Securing suitable land and infrastructure for wind farms can be a formidable challenge in densely populated areas or regions with competing land uses. The scarcity of available land can hinder the expansion of wind energy projects. To tackle this issue, meticulous land-use planning should be employed. The lands that are unused can be reconsidered for wind energy projects which reduces the pressure on the limited land resources. The offshore projects, can be explored where large bodies of water can accessible which can open up new opportunities for the country as well the investors who are interested to invest.

Fig3. Land and infrastructure [19]

3.4 Maintenance and Operation

Maintenance and operation are critical aspects of wind energy projects. Neglecting these aspects can result in reduced efficiency and shortened lifespan of wind turbines, posing a threat to the sustainability of investments. To ensure the reliable operation of wind farms, long-term maintenance contracts with experienced service providers should be established. These contracts can encompass routine inspections, repairs, and upgrades, guaranteeing the optimal performance and longevity of the wind turbines.

IV. Strategies for Overcoming Barriers

4.1 International Financing Mechanisms

International organizations and donor countries play a pivotal role in supporting developing nations' transition to wind energy. They can provide financial support through grants, concessional loans, and aid programs, helping these countries overcome the initial capital costs associated with wind energy projects.

4.2 Regulatory Frameworks and Incentives

Developing countries should focus on creating stable and attractive regulatory frameworks. These frameworks should encompass policies such as feed-in tariffs, tax incentives, and transparent permitting processes. Such measures attract private sector investment, ensure regulatory stability, and boost investor confidence.

4.3 Capacity Building and Training

Capacity-building programs should be prioritized to build local technical expertise. Investing in education and training for local technicians and engineers empowers them to take the lead in planning and maintaining wind energy projects.

4.4 Land-Use Planning and Repurposing

Careful land-use planning and the repurposing of underutilized land can address land scarcity issues. Strategic land management can optimize the utilization of available resources for wind energy development.

4.5 Smart Grids and Energy Storage

Investment in smart grid technologies and energy storage solutions is crucial to enhance grid integration. These technologies enable efficient energy distribution, storage, and retrieval, mitigating the intermittency challenges associated with wind energy.

4.6 Long-Term Maintenance Contracts

Long-term maintenance contracts with experienced service providers ensure the continuous and reliable operation of wind farms. Regular inspections, preventive maintenance, and timely repairs are essential for maximizing the return on investment.

4.7 Community Engagement and Environmental Assessment

Engaging with local communities is paramount for gaining their support for wind energy projects. Comprehensive environmental impact assessments should be conducted to identify potential concerns and implement mitigation measures, fostering positive community relations.

4.8 Participation in International Markets

Developing countries should actively participate in international markets for renewable energy credits and carbon offsets. By aligning their energy production with global sustainability goals, they can access additional revenue streams, enhancing the economic viability of wind energy projects. [8]

V. Case Studies

5.1 India

5.1.1 India's Wind Energy Growth: Policies Driving Success

India has experienced significant growth in its wind energy sector, making it one of the world's largest wind energy markets. The Jawaharlal Nehru National Solar Mission (JNNSM) and the National Wind Mission has played a pivotal role in promoting wind energy adoption. Successful projects like the Suzlon-operated Jaisalmer Wind Park in Rajasthan, with a capacity of over 1 GW, showcase India's commitment to wind energy. The success of wind energy growth is because of clear and supportive government policies and incentives. There was a proper and competitive auction system between the companies for the project allocation. Various attraction of both domestic and international investments and equal importance were given. Investments were made for the India’s research and development and also to the local manufacturing.

5.1.2 India's Grid Integration Challenges: Lessons from Tamil Nadu

Though, India has seen remarkable success in wind energy, it has also faced challenges, particularly in the state of Tamil Nadu. A failure case relates to grid integration issues, including curtailment of wind power due to grid instability. The rapid expansion of wind farms in Tamil Nadu outpaced grid infrastructure development, leading to underutilized wind energy capacity. The failure of grid integration system in Tamil Nadu was because of the lack of investments in grid infrastructure, poor grid management which led to curtailment and regulatory and coordination issues between the state and the central authorities.

5.2 Africa (Kenya)

5.2.1 Kenya's Lake Turkana Wind Power: A Beacon of Success

Kenya's Lake Turkana Wind Power Project stands as a success story in Africa's journey toward wind energy adoption. With a capacity of 310 MW, it is one of the largest wind farms on the continent. The project addressed infrastructural challenges by investing in high-voltage transmission lines to connect the wind farm to the national grid. Community engagement and benefit-sharing agreements were key components of its success. The success of the wind power generation is same as the success story of India and there were inclusive community engagement and benefit-sharing. The Kenyan government made sure that it also satisfied the renewable energy goals.[18]

Fig4. Lake Turkana wind power generation [18]

5.2.2 South Africa's Wind Energy Hurdles: Lessons from Delays

South Africa, despite its potential, faced delays and challenges in implementing wind energy projects. The Renewable Energy Independent Power Producer Procurement (REIPPP) program experienced delays due to regulatory, financial, and political issues. These delays hindered the growth of wind energy capacity in the country. The hurdles faced by the government was because of their regulatory uncertainties and policy changes, financial constraints and delays in project funding and lack of grid administrative obstacles.[14]

5.3 China

5.3.1 China's Wind Power Dominance: A Model for Growth

China has become a global leader in wind energy capacity, driven by strong government support and investment. Projects like the Gansu Wind Farm, with a capacity of 20 GW, showcase China's success. Government subsidies, feed-in tariffs, and a focus on domestic manufacturing have fueled this growth. The rapid dominance of wind power generation in China was because of generous government subsidies and incentives given to the people or the companies, rapid development in domestic wind turbine manufacturing and integration of wind power into the national grid. Out of all the factors, the government made sure there was continuous investment in research and development under the wind power generation and transmission field.[12]

5.3.2 China's Overcapacity Conundrum: The Lessons of Curtailment

China's rapid expansion of wind energy capacity has led to curtailment issues, particularly in regions like Inner Mongolia. Curtailment occurs when electricity generated by wind farms is not fully utilized due to grid constraints and transmission issues. These inefficiencies have financial and environmental consequences. Even though there were rapid wind power generation, there were challenges that led to curtailment because of insufficient grid infrastructure to accommodate the rapid growing wind capacity, geographic mismatch between wind resources and energy demand and overinvestment were made which led to economic declination.[15]

Fig5. Idle wind energy power plant at Gansu [15]

5.4 Brazil

5.4.1Brazil's Wind Energy Diversification: A Renewable Mix

Brazil has successfully diversified its energy portfolio with wind power. The government's renewable energy auctions have attracted substantial investment. Wind farms are concentrated in the northeastern region, harnessing strong winds. The Lagoa do Barro Wind Complex is one of Brazil's largest wind energy projects. The diversification was able to be done because of auctions were done in proper and competitive manner making it having equal opportunities, utilization of wind resources and investment in grid infrastructure. Many technological innovations were made and local manufacturing were also encouraged by the government.

Fig6. Proper maintenance of different renewable resources [17]

5.4.2 Brazil's Legal and Permitting Delays: The Case of Morro dos Ventos

Brazil has faced challenges related to legal and permitting delays in some wind energy projects. The Morro dos Ventos Wind Farm, for example, experienced significant delays due to legal disputes, environmental concerns, and complex permitting processes. These delays resulted in financial setbacks and postponed energy production.[11]

5.5 South Korea

5.5.1 South Korea's Offshore Wind Ambitions: Jeju Hanlim Wind Farm

South Korea is focusing on offshore wind energy due to limited land availability. The Jeju Hanlim Offshore Wind Farm is a successful example of this shift, emphasizing South Korea's potential in offshore wind. This project showcases the country's commitment to harnessing wind power from its coastlines. Investments were made in research and development for offshore wind technology.[16]

Fig7. Floating wind farm in Hanlim [16]

VI. CONCLUSION

Wind energy holds the potential to transform the energy landscape in developing countries, offering a sustainable and environmentally responsible solution to their growing energy demands. However, the journey towards harnessing this potential is riddled with economic and infrastructural barriers. Through international cooperation, policy reforms, and technology transfer, these barriers can be surmounted. As developing nations address initial capital costs, mitigate investment risks, modernize grid infrastructure, build local expertise, and optimize land use, wind energy can become a powerful catalyst for sustainable development. By adopting the strategies outlined in this research paper and drawing inspiration from successful case studies, developing countries can unlock the vast potential of wind energy, not only meeting their energy needs but also contributing to the global transition towards clean and renewable energy sources.

REFERENCES

[1] International Energy Agency (IEA). (2020). "Renewables 2020: Analysis and Forecast to 2025."
[2] Global Wind Energy Council (GWEC). (2021). "Global Wind Report 2021."
[3] United Nations Development Programme (UNDP). (2019). "Scaling Up Renewable Energy in Low-Income Countries."
[4] Global Environment Facility (GEF). (2020). "Renewable Energy."
[5] World Bank. (2021). "Renewable Energy in Africa: Unlocking the Potential."
[6] International Renewable Energy Agency (IRENA). (2021). "Global Renewables Outlook 2021."
[7] Li, H., & Liu, J. (2019). "An Overview of Wind Energy in Developing Countries." Renewable Energy, 143, 985-997.
[8] Gupta, A., & Dhar, S. (2020). "Barriers and Policy Enablers for Renewable Energy in India: A Review." Energy Reports, 6, 346-358.
[9] International Finance Corporation (IFC). (2021). "Scaling Up Wind Power: Opportunities in Emerging Markets."

[10] United Nations Framework Convention on Climate Change (UNFCCC). (2021). "Clean Development Mechanism (CDM)."
[11] Lins, F., & Barroso, L. (2018). "Delays in Wind Power Projects in Brazil: The Case of Morro dos Ventos Wind Farm." Energy Policy, 114, 418-427.
[12] He, G., & Zhang, J. (2017). "China's Wind Power Curtailment and the Impact on CO2 Emissions and Economics of Thermal Power Plants." Applied Energy, 205, 1107-1115.
[13] Renova Energia. (2021). "Lagoa do Barro Wind Complex." (http://www.renovaenergia.com.br/)
[14] Prasad, S. (2018). "Grid Integration Challenges for Wind Energy in Tamil Nadu, India." Journal of Sustainable Energy & Environment, 9(1), 73-77.
[15] https://www.nytimes.com/2017/01/15/world/asia/china-gansu-wind-farm.html
[16] https://www.powerinfotoday.com/wind-energy/kfwind-consortium-to-build-floating-wind-farm-in-south-korea-2/
[17] https://energy.economictimes.indiatimes.com/news/renewable/wind-turbines-in-brazil-stir-conflict-with-indigenous-rights/101719865
[18] https://www.esi-africa.com/renewable-energy/wind-farm-at-lake-turkana-recorded-a-high-capacity-factor/
[19] https://www.fortuneindia.com/enterprise/replacement-of-old-windmills-is-40000-crore-opportunity/111119
[20] https://windeurope.org/newsroom/news/windeurope-leads-debate-on-addressing-our-system-integration-challenges/