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A study on Exploration of the Potential Application of Renewable Energy in Promoting Environmental Sustainability in India

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Abstract

Energy is the main topic of discussion worldwide, and one important way to differentiate different energy sources is by their effects on the environment. The main goals of renewable energy deployment in India are to reduce climate change, improve energy security, increase access to electricity, and promote economic growth. Utilizing renewable energy is essential to achieving sustainable development since it guarantees access to contemporary, economical, and dependable electricity. Renewable energy has garnered a lot of support as a climate change mitigation method since it is carbon and pollutant free, making it a competitive alternative to fossil fuels. It is gradually becoming a necessary component of the energy mix. Political pressures, governmental regulations, corporate sway, antiquated infrastructure, inadequate battery storage systems, and the state of the market are some of the obstacles that the renewable energy industry must overcome. Widespread use of renewable energy is still a ways off, with some obstacles coming from particular technologies and others from the infrastructure, laws, and market dynamics of today.

Keywords: *Renewable Energy, Renewable Energy Costs, Energy Efficiency, Sustainable Development, Climate Change*

Introduction

Despite the Earth's limited ability to adapt, the globe is rapidly becoming a multicultural society due to the rising demand for energy worldwide. Energy and related services are becoming more and more important for human wellbeing and health, as well as for social and economic growth. Every society depends on energy services to support a range of productive endeavours as well as basic necessities including communication, transportation, heating, cooking, healthcare, and power. Ensuring a reliable energy supply and reducing the energy sector's influence on climate change are two of the biggest problems it faces in the quest for a sustainable future. The fact that 1.4 billion people globally still do not have access to electricity is shocking, and that 85% of them live in rural regions. Accordingly, it is anticipated that by 2030, there will be 2.8 billion rural residents who rely on biomass for energy, up from the current 2.7 billion.[2]

Many nations' national policies, strategies, and development plans now place a strong emphasis on sustainable development. At the United Nations in New York, the Open Working Group unveiled the worldwide 2030 Agenda for Sustainable Development (SDGs), which consists of 169 targets and 17 goals. The SDGs have higher standards and a stronger focus on science than the Millennium Development Goals. Global monitoring and modeling of numerous social, economic, and environmental elements is crucial to addressing issues including climate change, renewable energy, food security, health, and water access.

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[2] Abbasi (ET.AL.), *Renewable and Sustainable Energy Reviews*, The return to renewables: Will it help in global warming control?, *15*, 891–894, 2011

Renewable Energy

According to Tester, sustainable energy is "a dynamic harmony between the preservation of the earth for future generations and the equitable availability of energy-intensive goods and services to all people."[3]

Bioenergy, hydropower, geothermal energy, solar energy, wind energy, and ocean (tide and wave) energy are examples of renewable energy sources that replenish themselves naturally without diminishing the earth's resources. The world's growing population and rising energy demands have led to the continued use of fossil fuel-based energy sources (coal, oil, and gas), which has led to a number of problems, including the depletion of fossil fuel reserves, greenhouse gas emissions and other environmental issues, military and geopolitical conflicts, and fluctuating fuel prices. These issues could permanently jeopardize human cultures and exacerbate unsustainable conditions.[4] Conversely, renewable energy sources are the only way to address the growing problems and the most amazing choice.[5] In 2012, 22% of the world's energy was generated from renewable sources[6], just ten years ago was unimaginable. Every economy needs a dependable energy source for transportation, industrial equipment, heating, lighting, and other uses (International Energy Agency, 2014When renewable energy sources are used in place of fossil fuels, greenhouse gas emissions are greatly reduced. Renewable energy sources should be sustainable because they are naturally generated by continuous energy flows in our environment. Renewable energy must have no boundaries and provide eco-friendly goods and services in order to be sustainable.

An overview of renewable clean energy sources and India's technological prowess

Renewable energy comes from the steady and organic flow of energy that occurs in our immediate surroundings. These consist of ocean energy (wave and tide), geothermal energy, wind, hydropower, bioenergy, and direct solar energy.

Solar Energy

"Direct" solar energy is the term used to describe the energy source for renewable energy sources that directly capture solar radiation. Solar energy is used by some renewable technologies, such as wind and ocean thermal, after it has been absorbed on the ground and changed into various forms. Since ancient times, the Sun has been thought to be the origin of life on Earth. The Industrial Revolution taught humanity how to harness the power of sunlight. India's solar energy potential is immense. Over the past few years, solar energy has had a major impact on India's energy landscape. Millions of people in Indian communities have profited from solar energy-based decentralized and distributed applications that provide them with ecologically benign energy for cooking, lighting, and other uses. The social and economic benefits include lowering the risk of lung and eye diseases, creating jobs at the village level, reducing the drudgery of rural women and girls who must carry fuel wood long

[3] Hoogwijk, (ET.AL.), Potential of biomass energy out to 2100, for four IPCC SRES land-use scenarios. *Biomass and Bioenergy, 29*, 225–257, 2005

[4] Asumadu (ET.AL.), The potential and economic viability of wind farms in Ghana *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 2016

[5] Ajanovic, Biofuels versus food production: Does biofuels production increase food prices? *Energy, 36*, 2070–2076, 2016

[6] Ayoub, (ET.AL.), *Renewable and Sustainable Energy Reviews,* Critical review on the current scenario and significance of crude glycerol resulting from biodiesel industry towards more sustainable renewable energy industry. *16*, 2671–2686, 2012

distances and cook in smoky kitchens, and eventually improving living standards and creating economic opportunities at the village level.

Additionally, India's solar energy sector has grown over time to become a significant player in the grid-connected power generation capacity. It positions itself as a key participant in meeting the country's energy needs and ensuring energy security while also advancing the government's long-term prosperity agenda.

Approximately 5,000 trillion kWh of energy are received by India's geographical area each year, with most of its regions receiving 4–7 kWh per square meter every day. Solar photovoltaic power can be effectively utilized and greatly expanded in India. Furthermore, distributed power generation and rapid capacity additions with short lead times are made possible by solar. Apart from meeting other energy requirements for power and heating and cooling in both rural and urban areas, low-temperature, off-grid decentralized applications will be advantageous.[7]

Assuming that solar PV modules will cover 3% of the waste land area, the country has a 748 GW solar potential, according to the National Institute of Solar Energy. Solar energy has taken center stage in India's National Action Plan on Climate Change, with the National Solar Mission serving as one of the primary missions. The National Solar Mission (NSM) was launched on January 11, 2010. The Government of India initiated the NSM, a major program in which the States actively engaged, to solve India's energy security concerns and promote environmentally sustainable growth. Furthermore, India will be making a substantial contribution to the global effort to address the challenges presented by climate change. The Mission aims to make India a global leader in solar energy by creating the legal framework necessary for the quick adoption of solar technology across the country. The Mission aims to install 100 GW of grid-connected solar units by 2022. This is in line with India's Intended Nationally Determined Contributions (INDCs), which aim to achieve about 40% of its installed capacity for electricity from non-fossil fuel-based energy sources and reduce the emission intensity of its GDP by 33 to 35% from 2005 levels by 2030.[8]

As stated in the National Action Plan on Climate Change, "India is a tropical country, where sunshine is available for longer hours per day and in great intensity," Consequently, solar energy holds great potential as a future energy source. It also has the advantage of facilitating decentralized energy distribution, which gives local people more control.[9] The National Solar Mission was launched by the Indian government with the intention of making India a leader in solar energy worldwide by creating the legal framework required for its quick national adoption.

Wind Energy

Due to its growing significance as a global energy source, wind has surpassed all other renewable energy sources. Wind is present everywhere in the planet and has a high energy density in some locations.

India's wind energy sector, which has steadily advanced, is led by the indigenous wind power industry. The expansion of wind has resulted in a strong ecology, the ability to operate projects, and a manufacturing base of about 10,000 MW per year. As of March 31, 2021, the country's installed wind capacity is at 39.25 GW, its fourth-highest in the globe. It produced

[7] Government of India, Ministry of New and Renewable Energy of India. Renewable energy is green, clean and sustainable, 2013

[8] *Id*

[9] *Supra note 7*

about 60.149 billion units in 2020–21.[10] The government is promoting private sector investment in wind power projects around the country by providing various fiscal and financial benefits, such as the Accelerated Depreciation benefit and a concessional custom tax exemption on particular components of wind electric generators. Furthermore, the Generation Based Incentive (GBI) Scheme applied to wind projects that were put into operation before March 31, 2017.[11]

India is the world's fifth-largest producer of wind energy, behind the US, Germany, Spain, and China. Its installed capacity surpassed 21136.3MW as of March 3, 2014.[12] New technological advancements in wind energy design have led to significant advancements in wind energy penetration and optimizing the amount of power from available wind. India is a major market for the wind sector, with new installations growing by 2.1GW annually.[13]

Water (Hydro energy)

People have been using the force of flowing water, such as that created by a waterfall, to generate electricity for thousands of years. This sort of energy is known as hydroelectric energy, commonly called hydroelectric power or hydroelectricity.

Hydropower, or hydroelectric power, is one of the earliest and most impactful renewable energy sources, generating electricity by utilizing the natural movement of water. While iconic structures like the Hoover Dam exemplify large-scale hydropower by harnessing the energy of an entire river, these systems vary significantly in size and design. Hydropower plants can range from massive installations to smaller systems that utilize irrigation canals or municipal water flows. Some facilities, such as run-of-river systems or diversions, operate without traditional dams, redirecting a portion of a stream through a powerhouse before returning the water to its natural course. Hydropower is more widely accessible and utilized than many realize. It generates electricity by leveraging the elevation difference created by a dam or diversion structure, where water enters on one side and exits at a significantly lower level on the other.

Hydropower is considered a renewable energy source because it generates electricity by tapping into the Earth's natural water cycle. India, endowed with significant hydroelectric potential, ranks fifth globally in terms of exploitable capacity. The nation's total hydroelectric potential is estimated to be around 150,000 MW;[14] India possesses the capacity to develop over 100,000 MW of hydropower, leveraging its vast network of water resources. Mini- and micro-hydropower systems, ideal for small rivers and canals, can harness the energy of streams and reservoirs, offering sustainable electricity generation through renewable hydropower technology.[15]

Bioenergy

Alongside economic expansion, there is a growing amount of industry, urbanization, and changes in lifestyle, which results in the production of more trash and more environmental hazards.

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[10] GOVERNMENT OF INDIA, Ministry of New and Renewable Energy of India, Renewable energy is green, clean and sustainable

[11] *Id*

[12] *Id*

[13] Purohit (ET.AL.), *J Renew Sustain Energy*, Wind energy in India: status and future prospects. 2009

[14] Jain SV (ET.AL.), Investigations on pump running in turbine mode: are view of the state-of-the-art, *Renew Sustain Energy Rev* 2014;30:841–68.

[15] Reddy V S, (ET.AL.), Renew Sustain Energy Rev, Review on power generation scenario of India, 2013;18:43–8.

Waste Energy:

Technologies have been developed in recent years that not only help generate a significant amount of decentralized energy but also help reduce the amount of waste that needs to be disposed of safely. Waste that comes from our everyday or industrial activities includes organic waste, e-waste, hazardous waste, and inert waste. Organic waste is defined as waste that breaks down or degrades over time due to the action of microorganisms; it accounts for a significant portion of the total amount of waste generated in the industrial, urban, and agricultural sectors, and as such, it can be used to generate energy. The organic fraction of waste can be further classified as non-biodegradable and biodegradable organic waste.

The term "waste energy" in India refers to all of the technological options available for establishing projects that recover energy in the form of biogas, bioCNG, or electricity from renewable agricultural, industrial, and urban wastes, such as municipal solid wastes, vegetable and other market wastes, slaughterhouse waste, agricultural residues, and industrial/STP wastes & effluents. Waste-to-Energy (WTE) technologies include biomethanation, incineration, gasification, and pyrolysis.

Biomass:

The past ten years have seen an increase in interest in biomass as a sustainable energy source worldwide. Biofuel is any fuel that is produced from biomass and can be solid, liquid, or gaseous. The main motivations for biomass conversion to energy in India is lower costs and improved conversion efficiency. Because of the advantages it provides, biomass has always been a significant energy source for the country. It's renewable, widely available, carbon-neutral, and has the potential to produce a lot of jobs in rural communities. Biomass has the ability to offer stable energy. Biomass still accounts for over 32% of the country's overall primary energy use, and more than 70% of the country's population relies on it for their energy needs.[16]
Developing methods that maximize the utilization of the country's biomass resources for grid-based energy generation is the main objective of the biomass power and cogeneration initiative. Bagasse, rice husks, straw, cotton stalks, coconut shells, soy husks, de-oiled cakes, coffee trash, jute waste, groundnut shells, and sawdust are among the biomass materials used in this process. Large-scale biomass fuel production, however, is frequently criticized for raising food costs, endangering native habitats, displacing crops, and providing very modest reductions in greenhouse gas emissions.[17] Technologies of biofuels are Combustion, cogeneration in Sugar and Mills etc.

Biofuel:

With its sustainable feedstock that can be replenished more readily than fossil fuels like coal, petroleum, or natural gas, biofuel, which is made from biomass like plant materials, algae, or animal waste is a renewable energy source that has gained popularity in the wake of rising petroleum prices and growing awareness of the negative environmental effects of fossil fuels, especially their role in global warming.[18] Many environmentalists express concern about the widespread adoption

[16] *Supra 5*
[17] Patil V, (ET.AL.), Towards sustainable production of biofuels from microalgae. IntJMolSci, 2008;9(7):1188–95.
[18] Ratha S K, (ET.AL.), Bioprospecting microalgaeas potential sources of Green Energy – challenges and perspectivesm Appl Biochem Microbiol 2012;48(2):109–25.

of certain biofuels due to the economic and environmental costs associated with their refining processes. Additionally, the potential diversion of vast areas of arable land from food production raises significant sustainability and food security challenges.
Wood and other biofuels that have been in use for a long time can be burned directly as a source of heat. A power plant's generators can then be powered by the heat. A number of power plants now in operation produce electricity using biomass, such as wood, grass, or other materials. The large infrastructure already in place to facilitate the use of liquid biofuels, especially in transportation, makes them especially attractive. Ethanol (ethyl alcohol), which is made by fermenting sugar or starch, is the most widely used liquid biofuel.

- First-Generation Biofuels: Created using traditional processes from food-based materials like sugar, starch, vegetable oil, and animal fats. Examples include bioalcohols, biodiesel, vegetable oil, bioethers, and biogas.
- Second-Generation Biofuels: Produced from non-food sources such as agricultural residues (e.g., wheat and corn stalks), wood, and waste biomass. Notable examples include cellulosic biofuels, biohydrogen, and biomethanol.
- Third-Generation Biofuels: Derived from microorganisms like algae, these biofuels provide a sustainable and innovative alternative to conventional biomass-based energy sources.
- Fourth-Generation Biofuels: Built upon third-generation technologies, these biofuels leverage genetically modified feedstock and engineered microorganisms, such as cyanobacteria, to maximize efficiency. They are developed on non-arable land, preserving cropland for food production**.**

The Maintenance of Sustainable Renewable Resources

India may increase energy security, lessen adverse environmental effects, reduce carbon intensity, contribute to more balanced regional development, and become a leader in high-tech sectors by developing renewable energy.[19]

Resources that can sustain our needs indefinitely must be the foundation of sustainable energy plans. To avoid depleting, exhausting, or otherwise rendering these resources useless, they must be used carefully. Renewable resources may eventually run out of steam. Even if a resource is renewable, it will eventually be depleted if it is used up faster than it can refill. For most persons, sustainable energy use means that the environment is not severely harmed as a result of an energy practice's cumulative implications. There are very different opinions on this highly politicized aspect of the idea of sustainable energy. Fossil fuel proponents frequently claim that because of the size of their reserves, coal, oil, and natural gas are sustainable, ignoring the effects of climate change.

Fossil fuels are non-renewable due to their limited availability. Their consumption has a detrimental environmental impact, releasing carbon dioxide into the atmosphere, which contributes to global warming and intensifies climate change. Burning wood rather than coal has several advantages, but the procedure is difficult. On the one hand, if wood comes from responsibly managed forests, it is a renewable resource. Compressed briquettes and wood pellets can be seen as products of waste recycling, as they are created from byproducts of the wood processing industry. Energy security and the mitigation of greenhouse gas emissions could both benefit greatly from the deployment of renewable energy. The adoption of renewable energy can help reduce the reliance on fossil fuels, which are the primary source of

[19] Khan S A, (Et.AL.), RENEW SUSTAIN ENERGY REV, Prospects of biodiesel production from microalgae in India. 2009;13(9):2361–72.

carbon dioxide emissions. The use of renewable energy will keep growing until 2050. Additionally, the energy content of compressed biomass fuels is higher than that of logs. However, burning wood releases particles into the air, whether it's raw wood or garbage that has been treated.

Problems and Obstacles with Renewable Energy

Since most renewable energy resources are climate-dependent and need complex design, management, and operational optimization techniques, the following disadvantages still exist despite the many advantages of renewable energy sources: generation discontinuity susceptible to weather variations.

a) **Cost:**
The primary challenge to adopting renewable energy is the high cost of constructing and deploying infrastructure, such as wind and solar farms. However, like most renewable energy sources, both solar and wind have minimal maintenance requirements and do not rely on fuel to function. Therefore, the installation of renewable energy accounts for the majority of its cost.[20]

b) **Transmission:**
Using renewable energy sources to their full potential requires a substantial amount of extra transmission infrastructure. Large fossil fuel and nuclear reactors were considered for building power transmission infrastructure during the 20th century.[21] For renewable energy sources that are far from the infrastructure that is currently in place, this presents a challenge. For example, because offshore wind farms have little to no infrastructure, they are one of the best opportunities for renewable energy sources.

c) **Oversupply**
In recent years, governments and private businesses worldwide have increased their manufacture of solar panels. An oversupply issue resulted from the significant increase in panel output, even while the industry was expanding. Due to supply presently exceeding demand, businesses are reducing long-term expenditures and perhaps going out of business.[22]

d) **Barriers to Entry**
Renewable energy faces significant obstacles because of the strong presence of established non-renewable energy sources and the considerable market influence of utilities that oversee these traditional systems. Renewable energy sources like solar, wind, and others have to contend with decades of experience, established infrastructure, and significant financial resources. Start-ups encounter even more obstacles to entry when they contend with established market rivals. Startups must show that they have the capacity to expand in order to prove their value because investors frequently want massive energy output, which can be challenging to achieve.[23]

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[20] Hirmer S, (Et.AL.), RENEW SUSTAIN ENERGY REV, Making the deployment of pico-PV more sustainable along the value chain. 2014;30:401–11.

[21] Bhattacharya S, (Et.AL.), SOCIAL SCIENCE RESEARCH NETWORK, Options for energy efficiency in India and barriers to their adoption: as coping study.;2010

[22] Kennedy M, (Et.AL.), RENEW SUSTAIN ENERGY REV, Overcoming barriers to low carbon technology transfer and deployment: an exploration of the impact of projects in developing and emerging economies. 2013;26:685–93.

[23] Suzuki M., What are the roles of national and international in situations to overcome barriers in diffusing clean energy technologies in Asia? Matching barriers InTechnology diffusion with the roles of institutions, 2013

e) Regional Suitability:

This one concerns the little, multicolored maps that are located on the rear of seed packets. The rough lines that go from east to west represent growing zones, which are places where sunlight, temperature, and water availability produce favorable conditions for particular plant species.[24]

In certain regions, some crops will flourish while others may not. Although there is a broad range of oil-producing crops suitable for biofuel production, the most productive ones cannot grow everywhere, as they are not adaptable to all growing zones.

f) Food Security

Access to reasonably priced food could be significantly changed by the generation of bioenergy from food crops including corn, soybeans, and sorghum. Biofuels' basic supply-and-demand economics, such as raising demand for maize and making it more costly, can jeopardize food security in particular areas or the availability of reasonably priced, nutrient-dense food for the local population.

g) Deforestation

It looked like a huge plus: Regulations intended to lower greenhouse gas emissions were expected to boost demand for bioenergy. Industry scientists had found a solution in palm oil, a biofuel source that is very simple to generate. Environmental turmoil resulted from plantation owners preparing their enterprises to meet demand. Some estimates place the majority of Indonesia's deforestation in the late 1980s and early 1990s attributable to the growth of the country's palm oil plantations. Additionally, Southeast Asia is one of the world's top emitters of greenhouse gases due to high-consumption production methods including burning and draining peat bogs to make way for farms and delivering palm oil in trucks driven by petroleum.

h) Monoculture:

Growing a single, highly concentrated crop instead of gradually rotating different crops over a farmer's fields is known as monoculture. Although this is a profitable practice that takes use of economies of scale to boost the farmer's crop profits, it can have detrimental effects on the environment. Plant pests find hundreds, if not thousands, of acres of intact crop to be an enticing prey; in such a setting, insect populations can grow uncontrollably. In a similar vein, intense monocultural farming causes the nutrients that are restored to the soil through crop rotation and field fallow to vanish. Compared to their more sustainable equivalents, traditional monoculture farms must use a lot more artificial fertilizer, which increases water pollution. Furthermore, the distinct characteristics of a monoculture crop raise the possibility of complete loss for the farmer; just think of the destruction that would result from a virulent strain of corn blight striking a corn field that produces ethanol.[25]

i) Technical Challenges:

A notable drawback of bioenergy is its different behavior in engines designed for petroleum-based fuels. For example, ethanol-only engines require larger fuel injectors to accommodate the higher density of corn-based ethanol, ensuring the fuel flow matches that of a comparable gasoline engine. Additionally, some of the metal and rubber components used in gasoline engines may corrode or sustain damage as a result of alcohol fuels, including ethanol. Installing new injectors, gaskets, and fuel lines may be necessary in some situations when changing fuels. Furthermore, once the engine is running, the ignition timing of the ethanol-converted engine must be

[24] Cherni JA, (ET.AL.), Renewable energy policy and electricity market reforms, 2021

[25] Bhattacharya S, (ET.AL.), Options for energy efficiency in India and barriers t their adoption: as coping study. SocialScienceResearchNetwork;2010 Available at: SSRN1590510.

adjusted to account for the differences in combustion characteristics between gasoline and ethanol.[26]

j) Lack of financing mechanism

The development of many of India's innovative energy technologies is still in its infancy. Like in other emerging nations, India's economic and budgetary problems have become crucial to the advancement of sustainable and renewable energy solutions. Government incentives and funding sources are insufficient to promote companies' and industries' adoption of sustainable and renewable energy technologies.[27] Although they may get in touch with bigger technology producers and official communication channels, small and medium-sized businesses (SMEs) generally face a "financial barrier" to using greener technologies.

Conclusion:

While we are not yet ready to fully power all of our factories, homes, workplaces, and hospitals with solar or wind energy, promoting these energy sources through renewable energy certificates is a positive step forward. Additionally, further advancements in the clean energy sector are likely to emerge in the future. However, the renewable energy sector faces several challenges, some of which stem from a skewed market and regulatory framework, while others are inherent to renewable technologies themselves.

A significant barrier to the widespread adoption of renewable technologies is the lack of comprehensive regulations and regulatory frameworks. The government should allocate more funding to support research and innovation in this field. As the global shift toward renewable energy accelerates, it is essential that both governmental and educational institutions take proactive steps to prepare a skilled workforce. Currently, there is a shortage of trained individuals capable of teaching, maintaining, and operating renewable energy systems. This gap in expertise poses a major obstacle to the implementation and expansion of renewable energy projects. To address this, institutions must prioritize the development of training programs that equip individuals with the necessary skills, focusing not only on technical knowledge but also on effective maintenance and troubleshooting methods as renewable technologies continue to evolve.

In addition to workforce training, the high cost of imported equipment is another critical challenge hindering the growth of renewable energy. Systems such as solar panels, wind turbines, and batteries are often sourced from international markets, which drives up costs. This reliance on imported goods presents a significant barrier, particularly in developing nations where economic constraints are a major concern. Importing equipment can inflate energy costs, making renewable energy projects less feasible or even unachievable for some communities. Therefore, it is essential for nations to invest in local production of renewable energy equipment. By fostering domestic manufacturing capabilities, countries can lower the costs of renewable technologies, making them more accessible and sustainable in the long term. This approach not only reduces dependence on foreign markets but also stimulates economic growth by creating jobs and driving innovation in the renewable energy sector.

Another key challenge is the instability of grid connectivity. A reliable and robust grid infrastructure is crucial for effectively distributing renewable energy. However, many regions have outdated or underdeveloped grids that are ill-equipped to handle the

[26] K,Soar (ET.AL.), Examination of emerging issues for successful information technology transfer in North Africa a case of Libya.AfrJ Bus Manag 2009;3(3):107–14.

[27] Suzuki M, (ET.AL.), ECONOMICS AND MANAGEMENT, International University of Japan, Identifying Barriers for the implementation and the operation of biogas power generation projects in Southeast Asia: an analysis of clean development projects in Thailand. 2010; 20.

decentralized nature of renewable energy sources. For instance, solar and wind power are intermittent, meaning energy production fluctuates based on weather conditions, which can strain an unstable grid. This variability makes it difficult to balance supply and demand, leading to delays or even the unsustainability of renewable energy projects. To address this, governments must prioritize modernizing grid infrastructure by implementing smart grid technologies, energy storage solutions, and expanding grid capacity to ensure reliable energy delivery.

Investor confidence in renewable energy has also been undermined by concerns about failure risks. Despite the long-term advantages, the high upfront costs and perceived technological uncertainties deter many investors. To overcome this, governments should create clear, attractive policies and financial incentives, such as tax breaks, subsidies, or guaranteed power purchase agreements, to reduce perceived risks and encourage investment in renewable energy projects. These measures can help foster a more robust and stable renewable energy market.

Finally, India and other countries must focus on developing comprehensive plans for the evacuation and transmission of renewable energy. Effective planning ensures that energy produced in remote areas, such as solar farms in deserts or wind farms along coastlines, can be efficiently transmitted to population centers. Without proper transmission strategies, renewable energy generation may become stranded, unable to reach consumers. By improving transmission infrastructure, India can enhance the reach and reliability of its renewable energy systems, ensuring a steady and dependable energy supply to its growing population.